Agenda

08:30 – 09:00		*Arrival / Registration / Coffee*
09:00 – 09:50		SMPS Topologies, tips and tricks (Analog Devices)
09:50 – 10:45		Filtering Considerations for DC/DC Converters (Wurth Electronics)
10:45 – 11:10		*Coffee Break & Networking Opportunity*
11:10 – 12:00		The Art of Loop Compensation (Wurth Electronics)
12:00 – 13:00		*Lunch*
13:00 – 13:50		LTspice Examples (Analog Devices)
13:50 – 14:45		Smart Selection of Inductors and Capacitors (Wurth Electronics)
14:45 – 15:10		*Coffee Break & Networking Opportunity*
15:10 – 16:00		PCB Board Layout Optimisation (Analog Devices)

ANALOG DEVICES

WÜRTH ELEKTRONIK
MORE THAN YOU EXPECT

SMPS Topologies and Tipps and Tricks

Frederik Dostal
Power Management Expert

Agenda

Buck (Step Down)

Boost (Step Up)

Buck-Boost (Step Up and Step Down)

SEPIC (Step Up and Step Down)

Zeta (Inverse SEPIC)

Inverting (Buck-Boost)

CUK (Inverting)

Charge Pump (High Power)

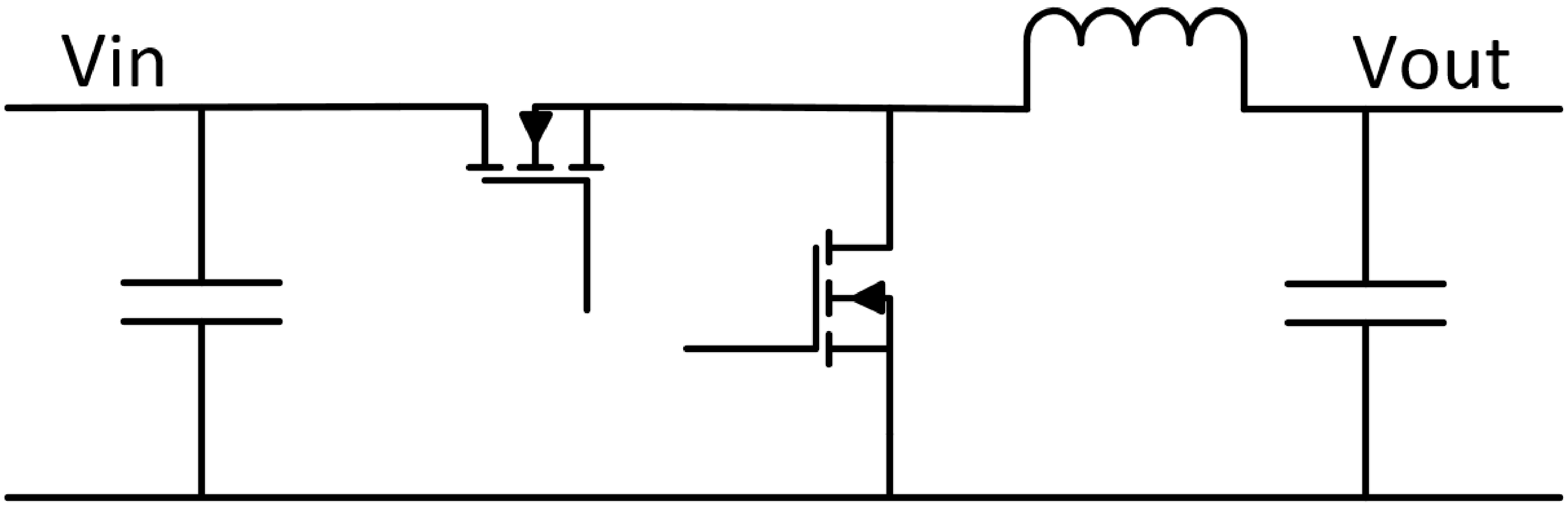
Hybrid Converter

Other combined Topologies (Cascaded)

Isolateded

- Flyback (Isolated)
- Forward (Isolated)
- Push-Pull (Isolated)

Buck (Step Down)



Synchronous / Non Synchronous / Synchronizable

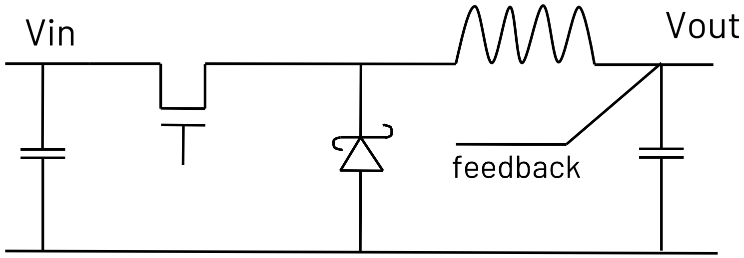
Monolythic

Pulsed Energy Flow on the input side

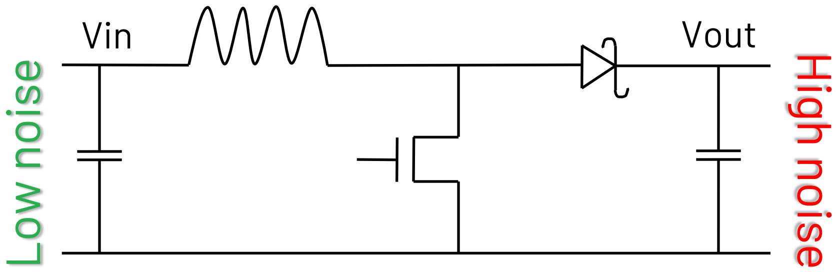
Additional filtering

Often input and / or output traces radiate the most

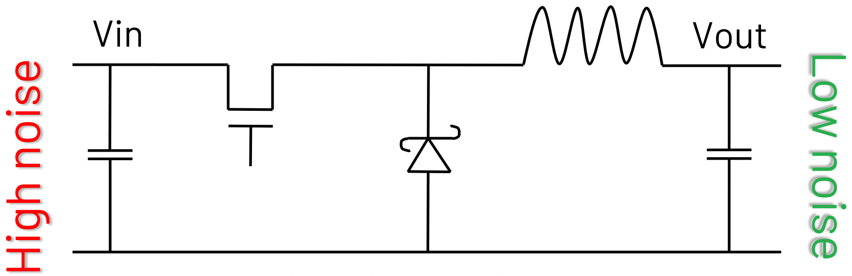
Additional LC filter



Generally trace with inductance in series is less noisy



boost topology



buck topology

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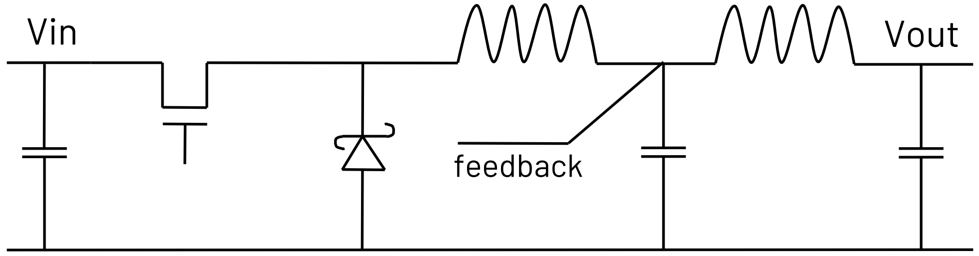

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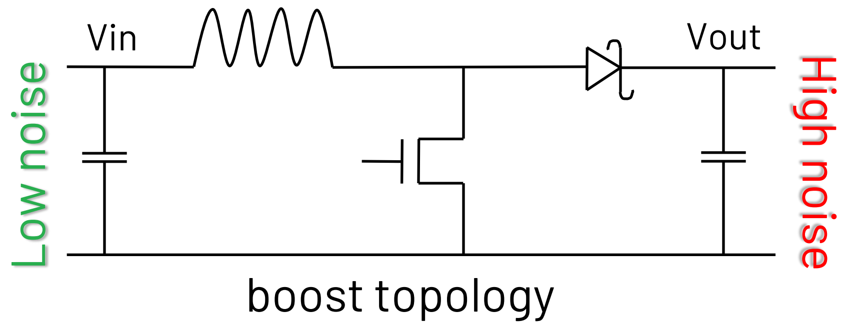

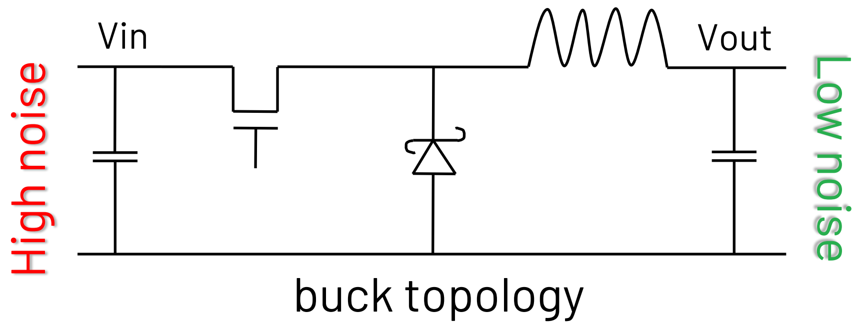

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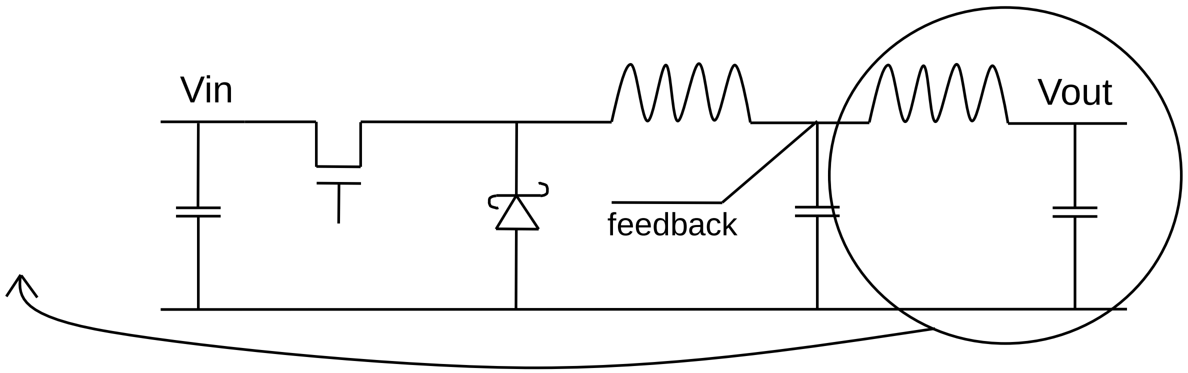

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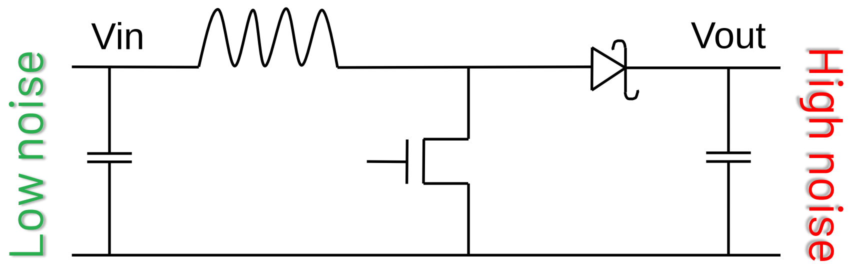
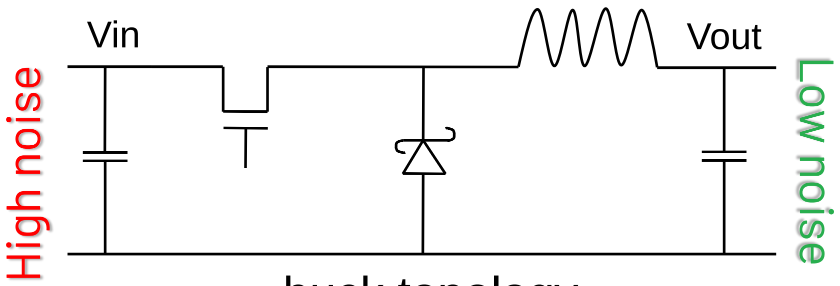
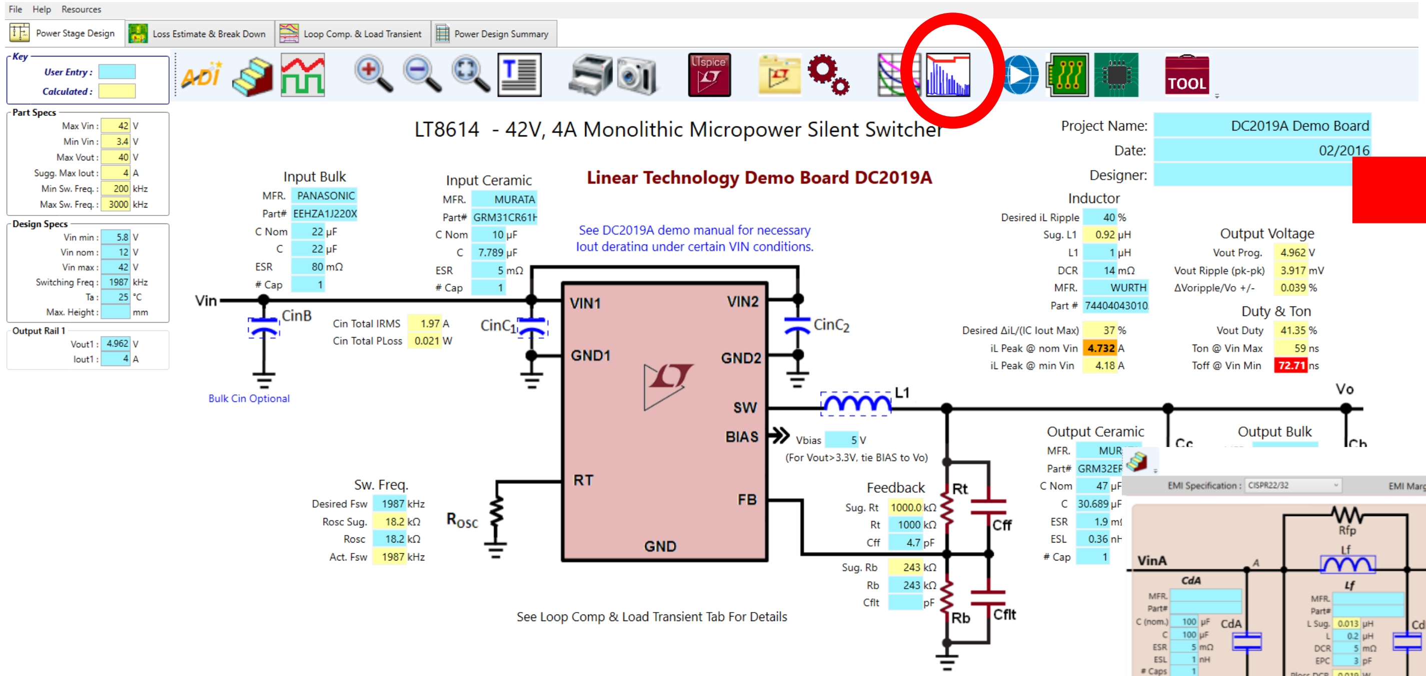


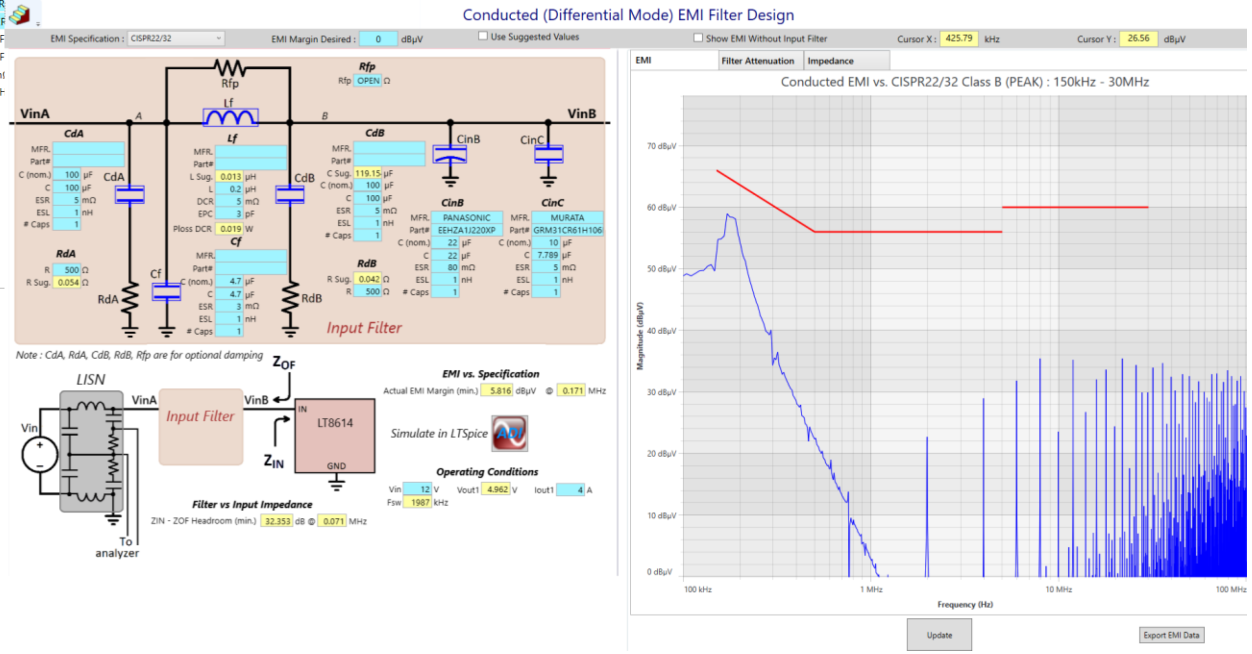
boost topology



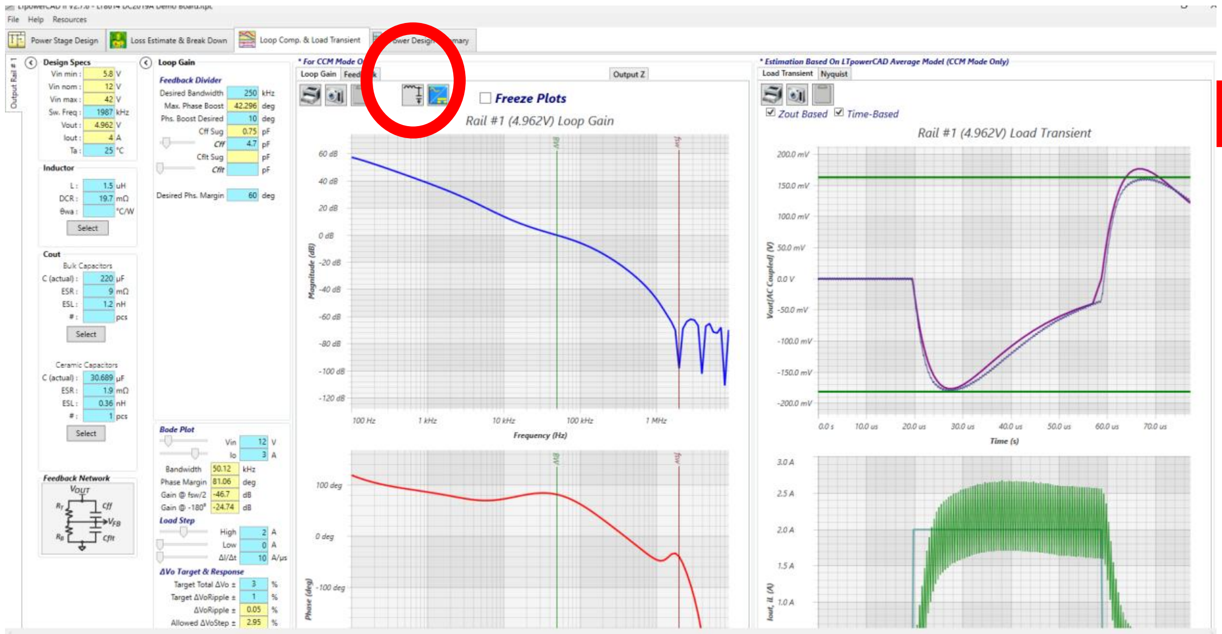
buck topology

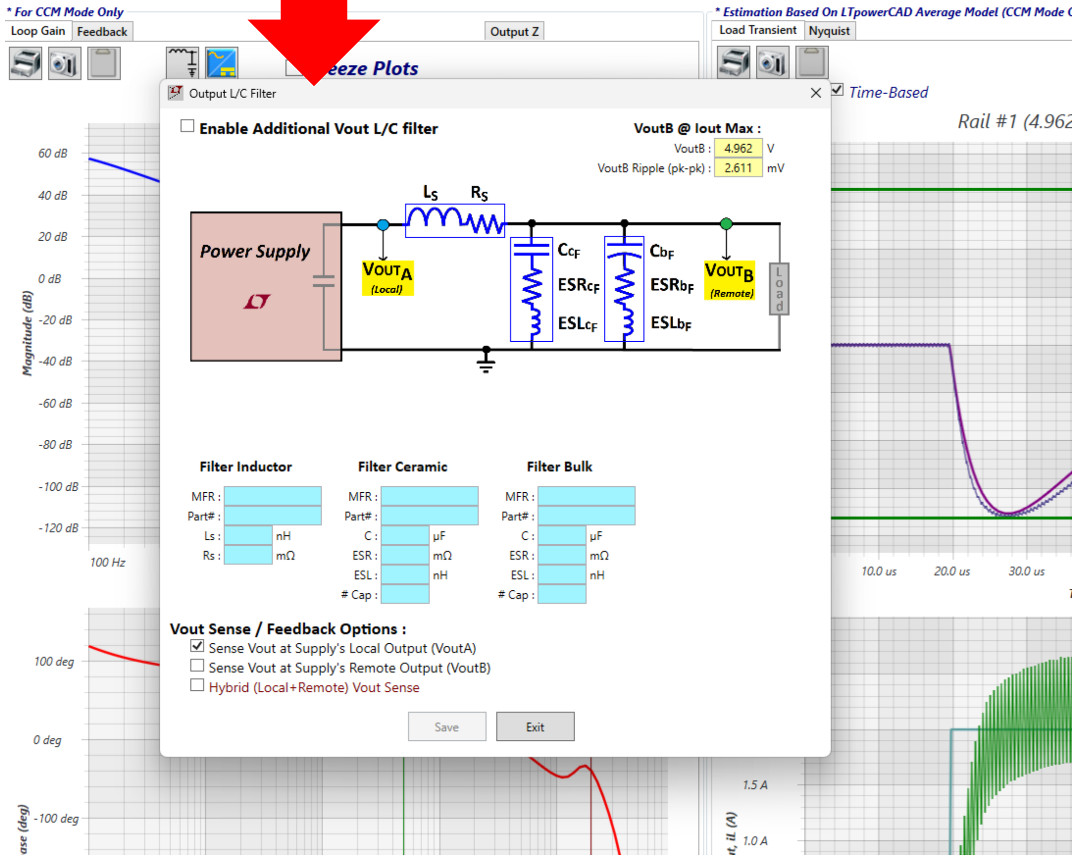
Additional filtering – Input - LTPowerCAD



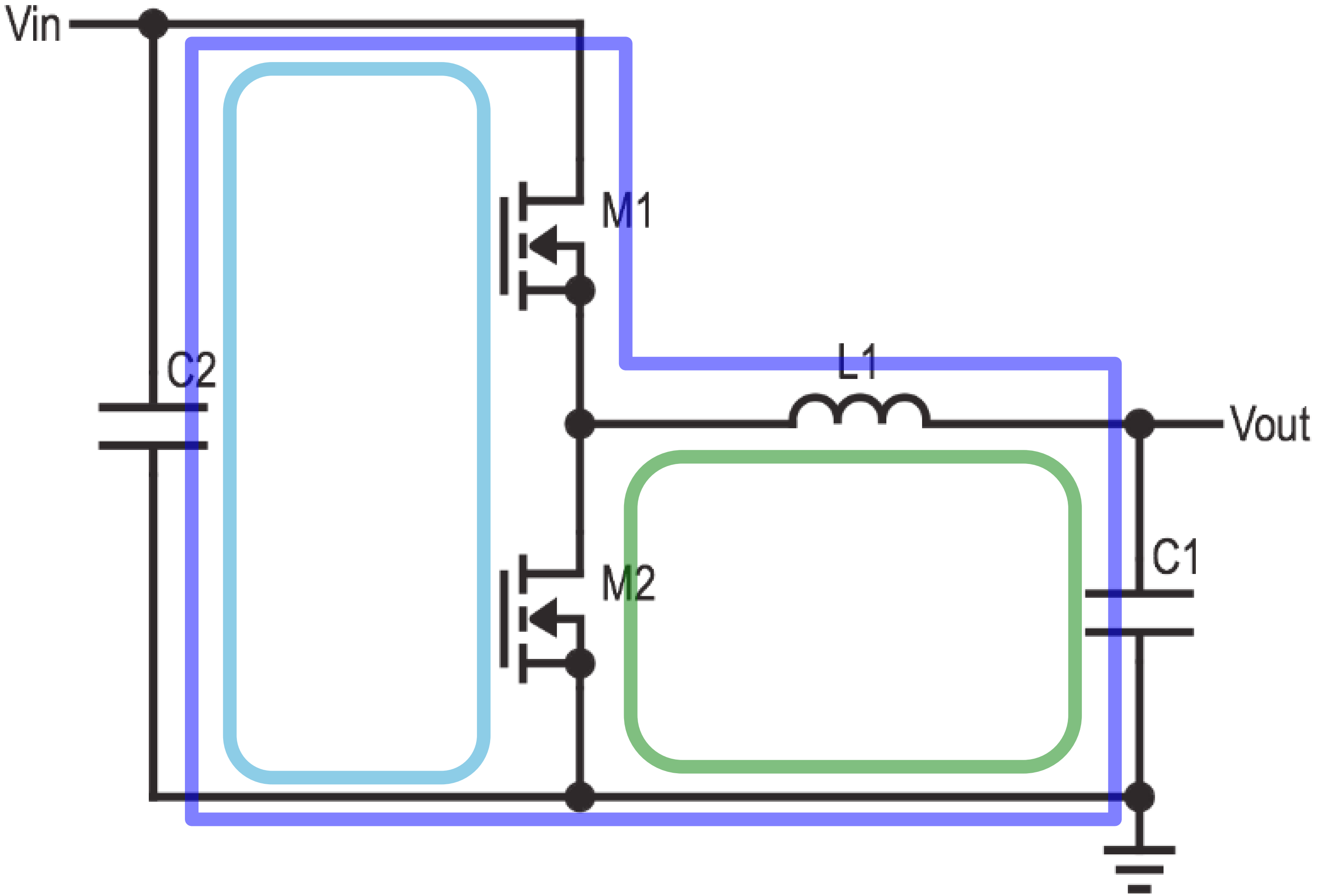


Additional filtering – Output - LTPowerCAD

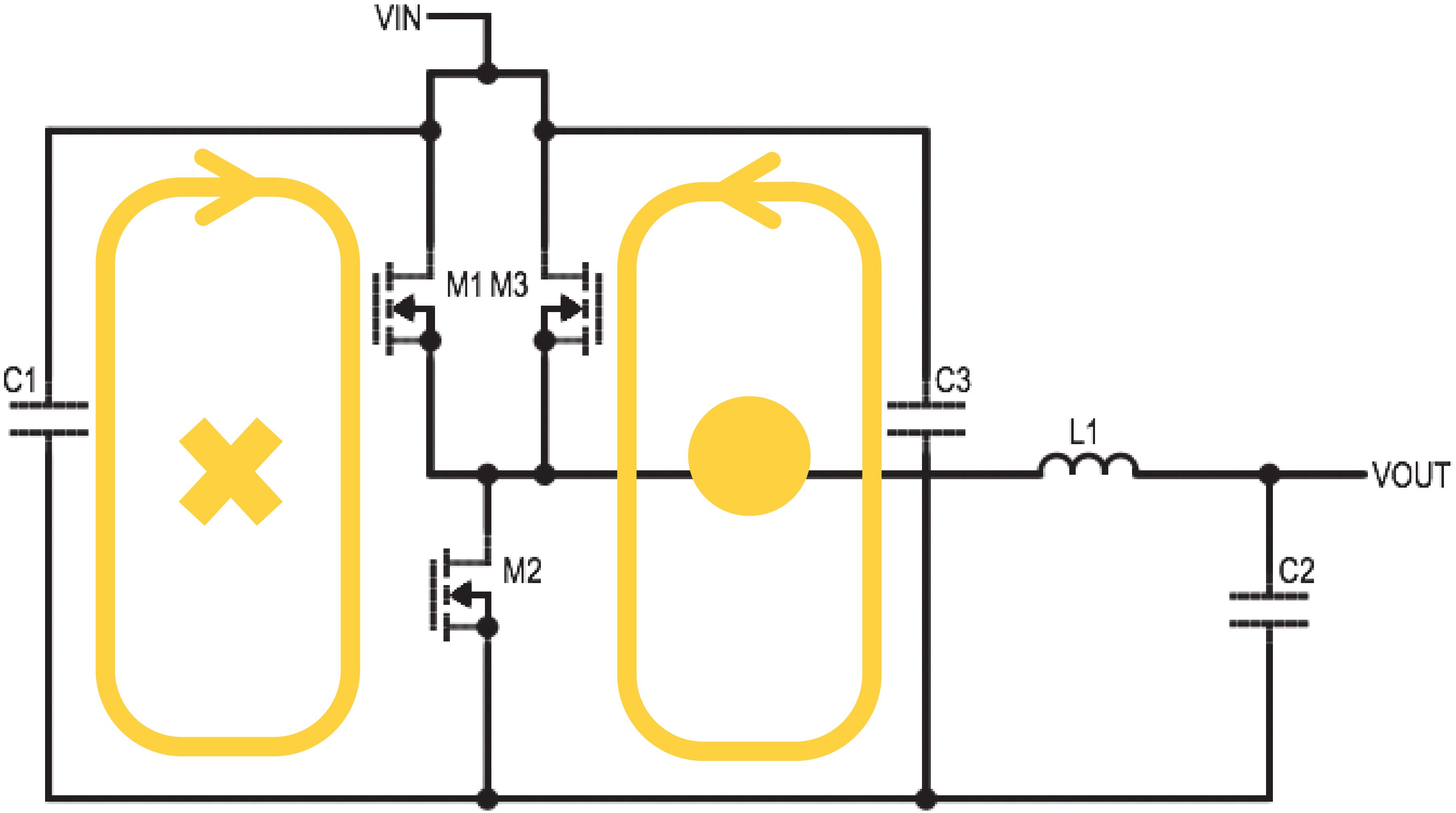




Buck Hot Loops



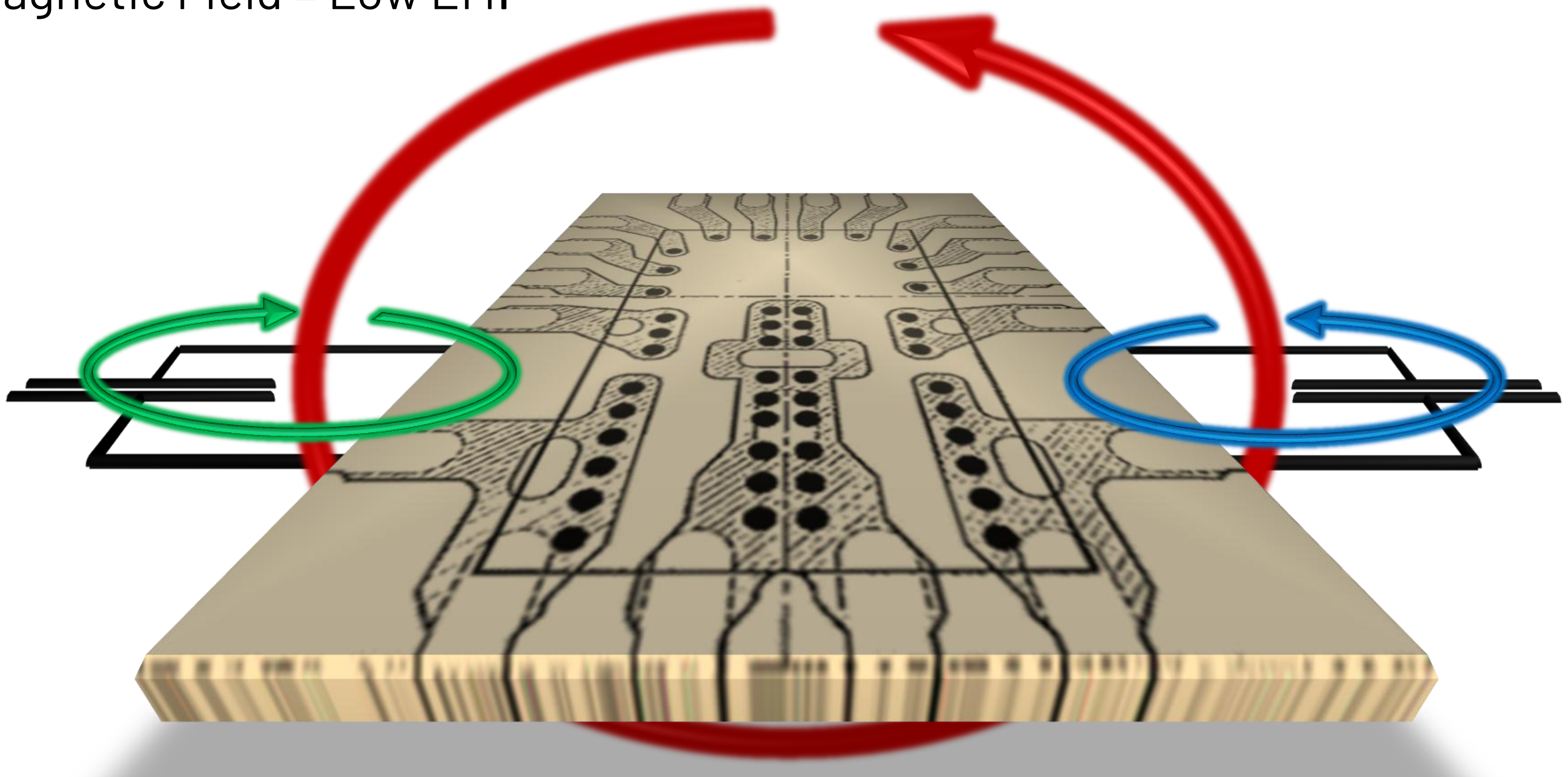
Silent switcher – magnetic field cancellation



Cancelling Hot Loops

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

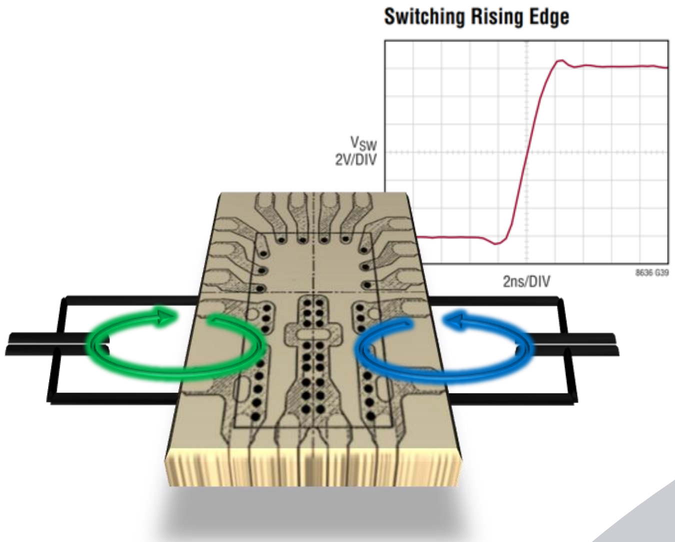
Confined Magnetic Field = Low EMI

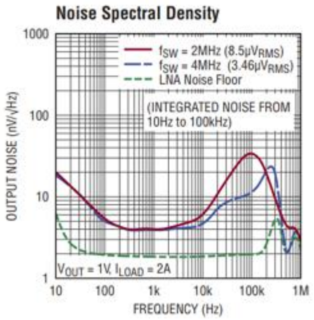


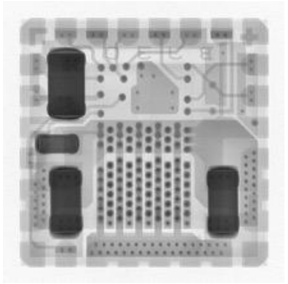
–LT8614–

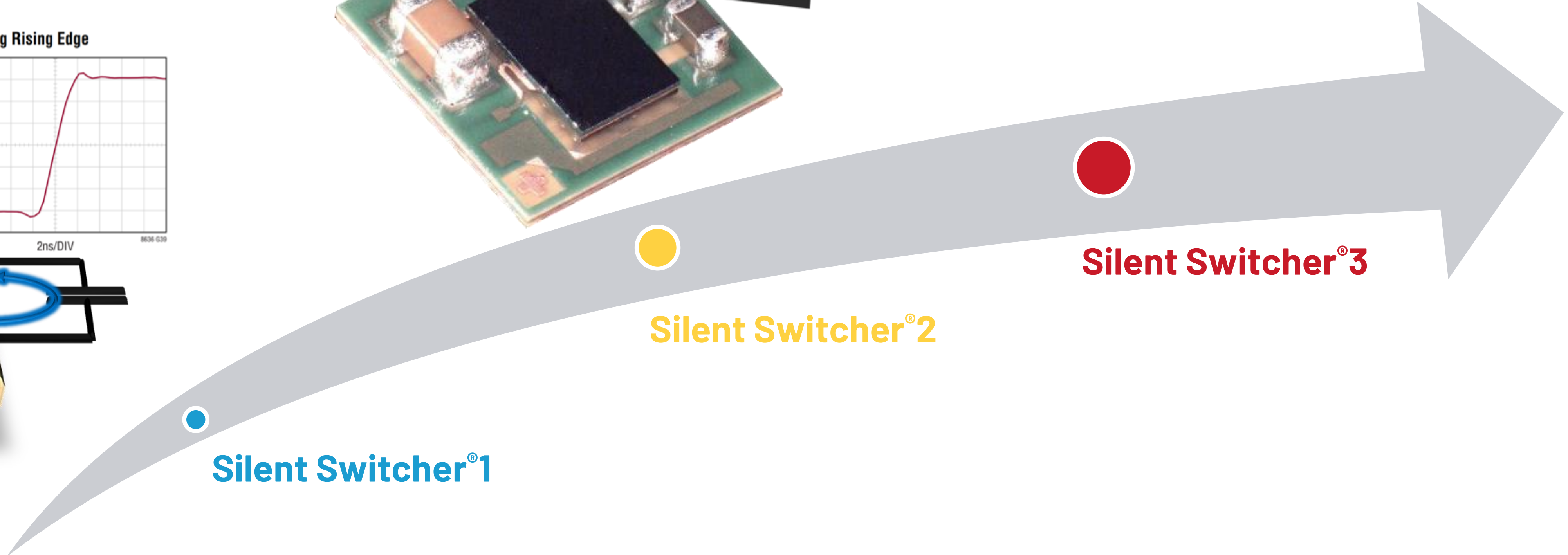
New Silent Switcher 3

- Ultralow EMI Emissions
- High Efficiency at High Switching Frequency
- Integrated Bypass Capacitors
- Eliminates PCB layout sensitivity
- **Ultralow LF Noise (0.1Hz to 100kHz)**
- **Ultrafast Transient Response**









Demo setup Silent Switcher 3

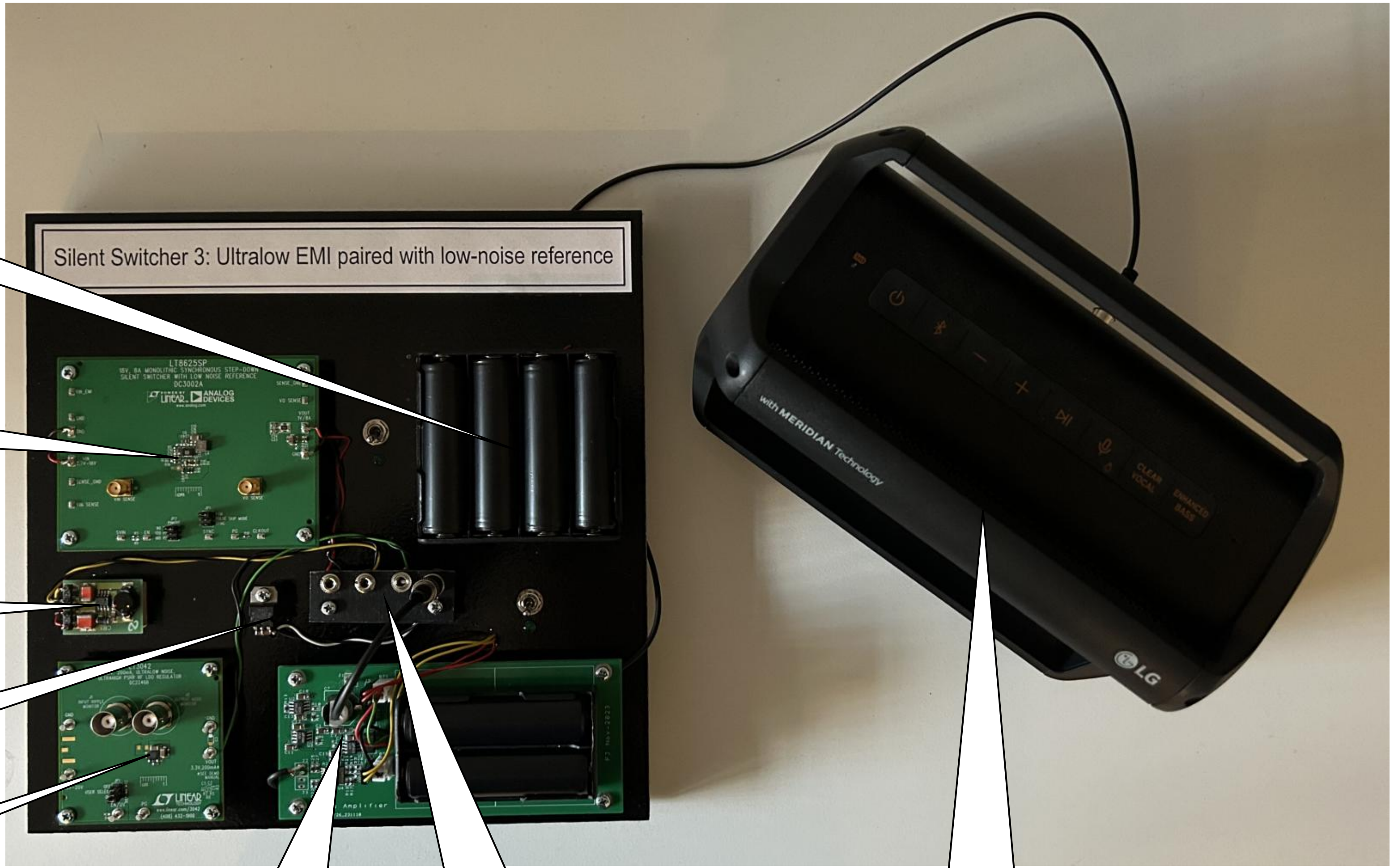
Batteries

Silent Switcher 3

Heritage Switcher

Simple Linear Regulator

Ultra Low-noise LDO

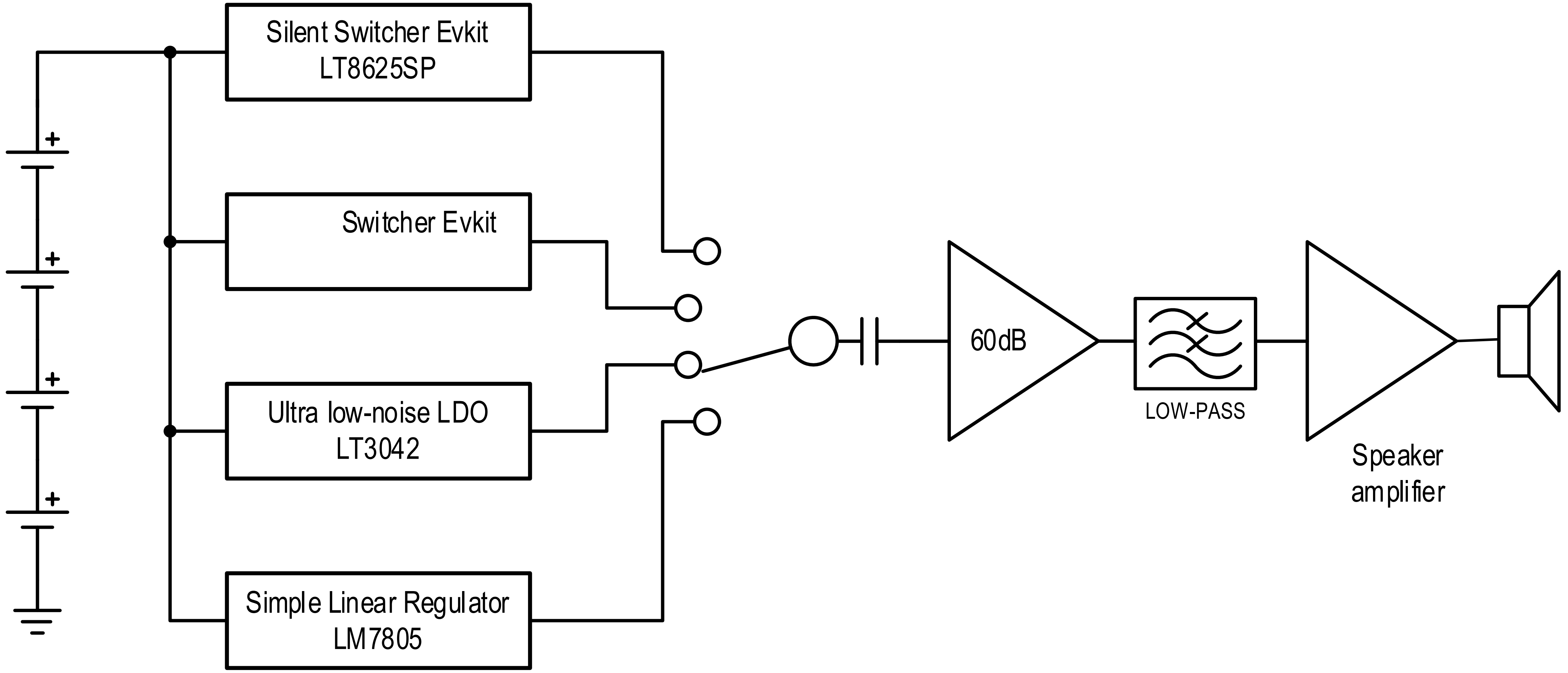


60 dB noise amplifier

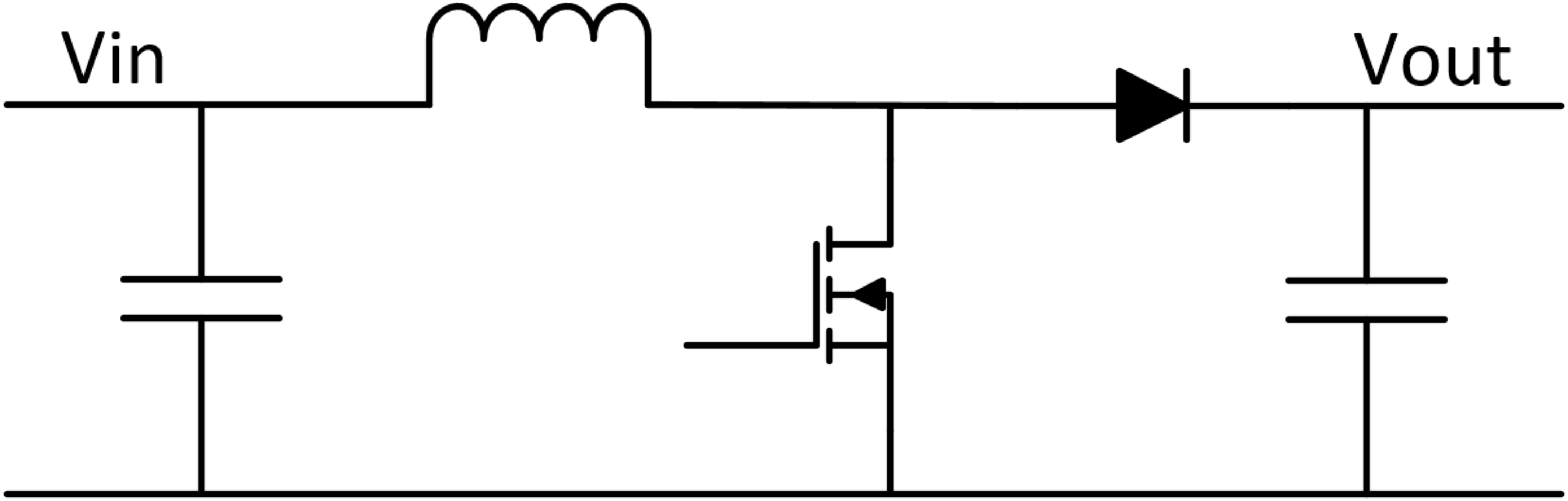
Selector

Speaker 20Hz to 20kHz

Block diagram



Boost (Step Up)



Pulsed Energy Flow on the output side

Usually Non Synchronous / Synchronous adds true shutdown

Max boost factor dependent on DCR of inductor and load resistance

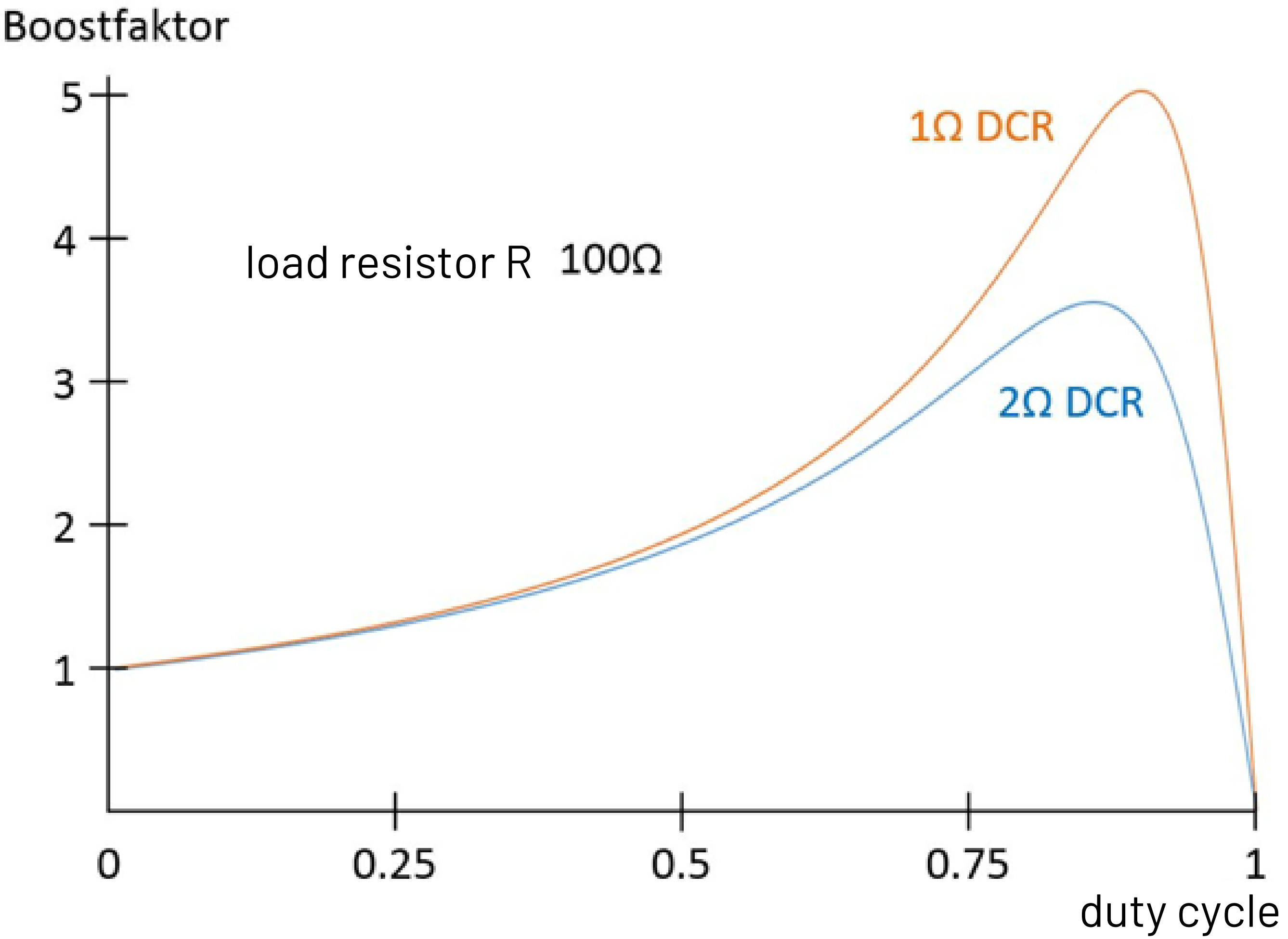
Boost-Factor

Duty cycle for a boost:

$$V_{out} = \frac{V_{in}}{(1-D)}$$

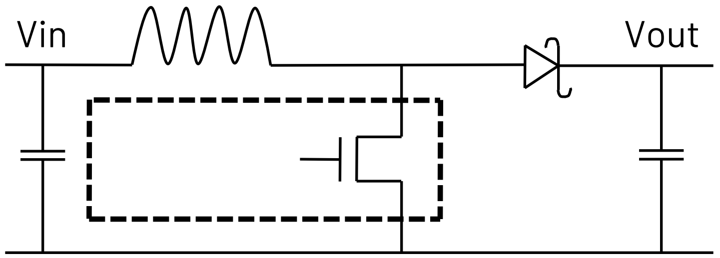
But, There is a limit to how much a boost can boost:

$$BF = \frac{1}{(1-D)} \frac{1}{(1+\frac{DCR}{(1-D)^2 * R})}$$

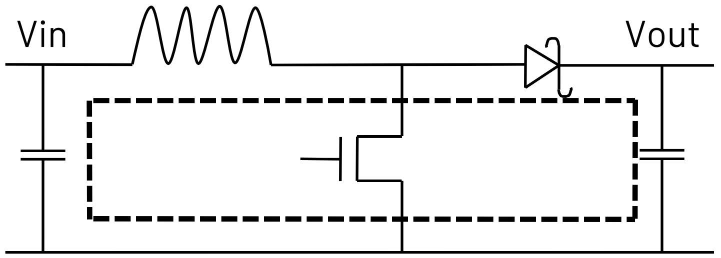


Hot Loop Boost Regulator

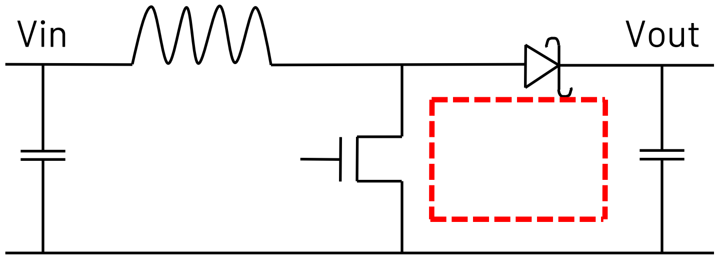
Current flow during on-time:



Current flow during off-time:

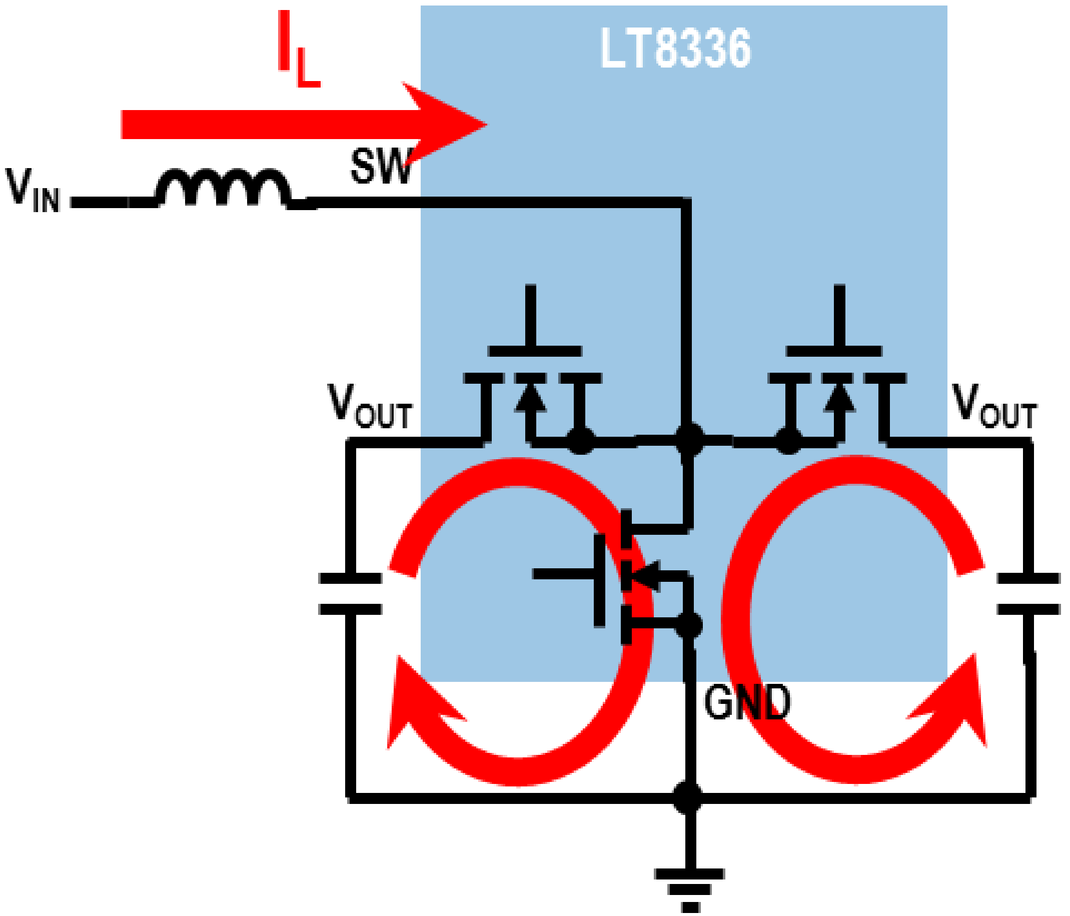


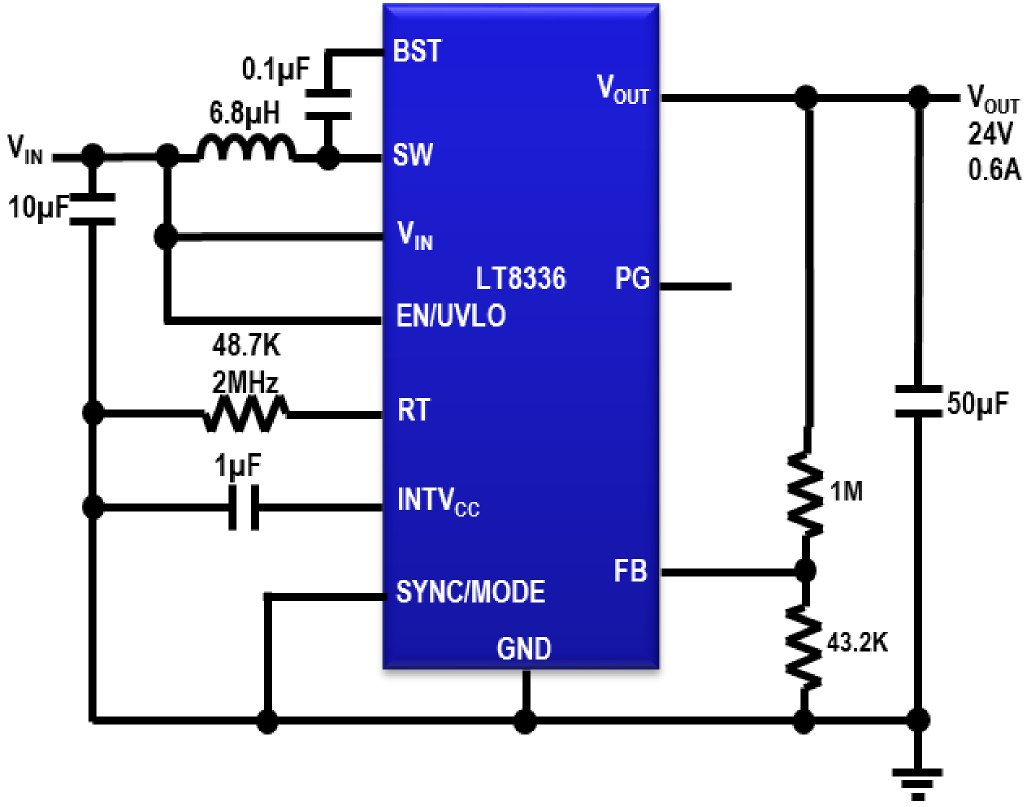
AC traces:



Keep AC traces as short as possible...(ASAP)

Silent Switcher Boost Converters





Silent Switcher Boost Converters

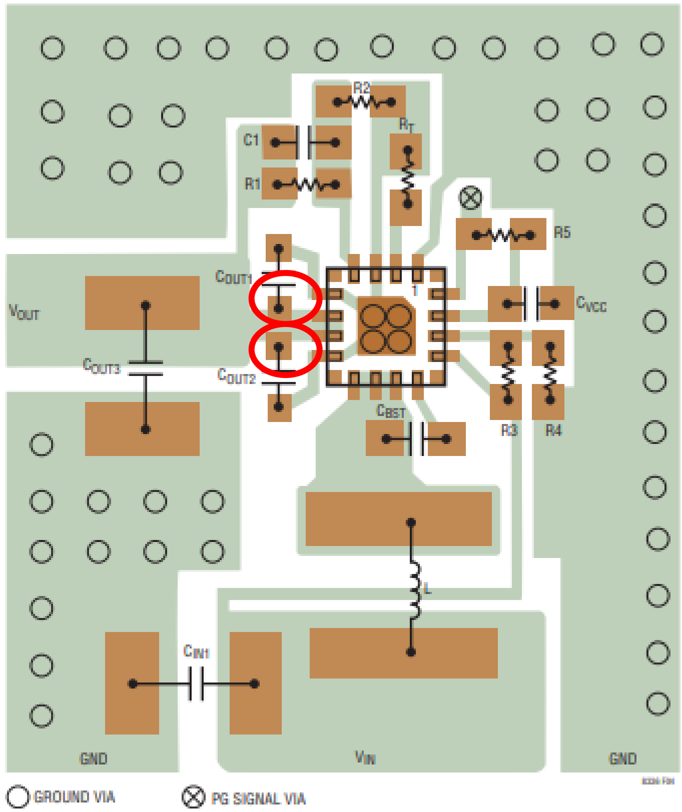
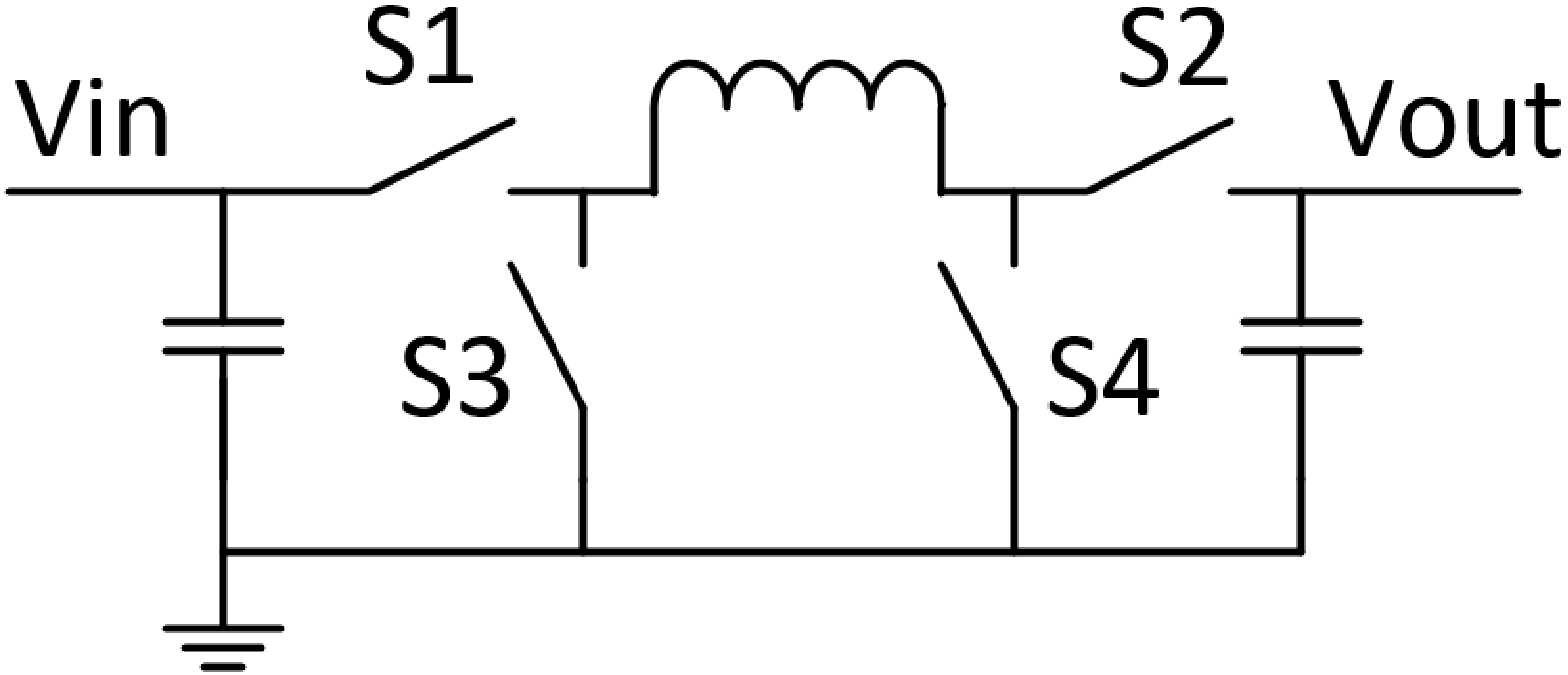


Figure 4. A Recommended PCB Layout for the LT8336

Buck-Boost (Step Up and Step Down)



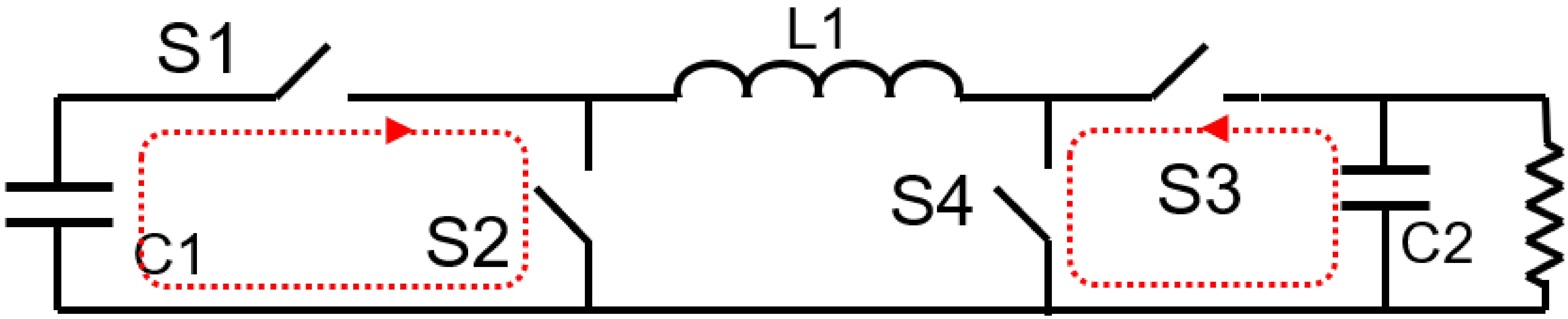
Very efficient

More silicon / fewer passives

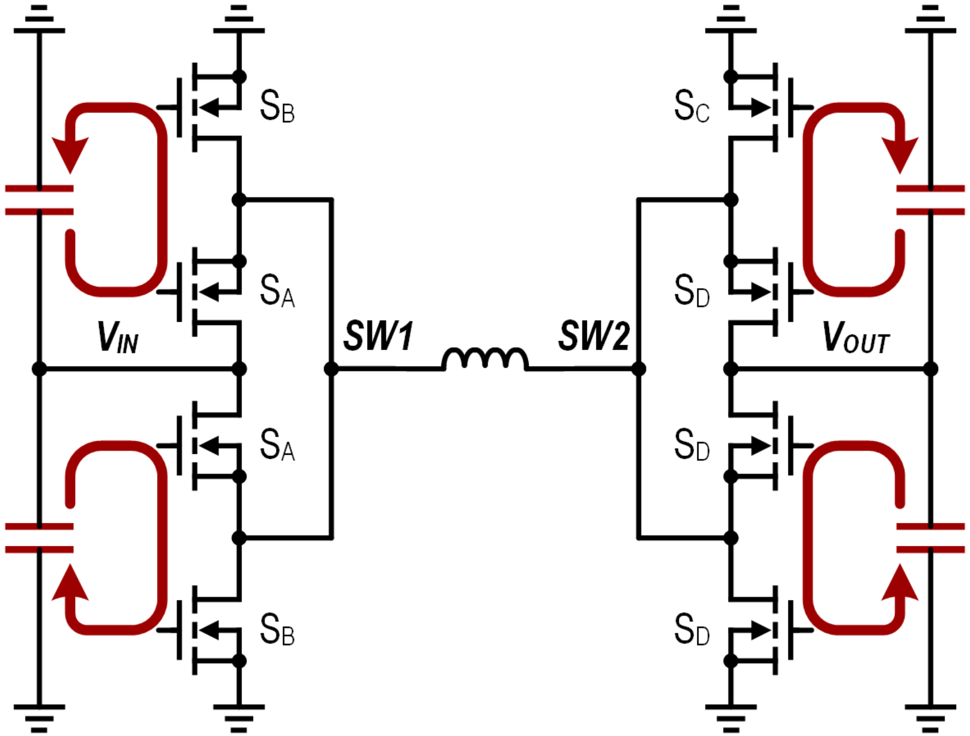
Challenge is switch over

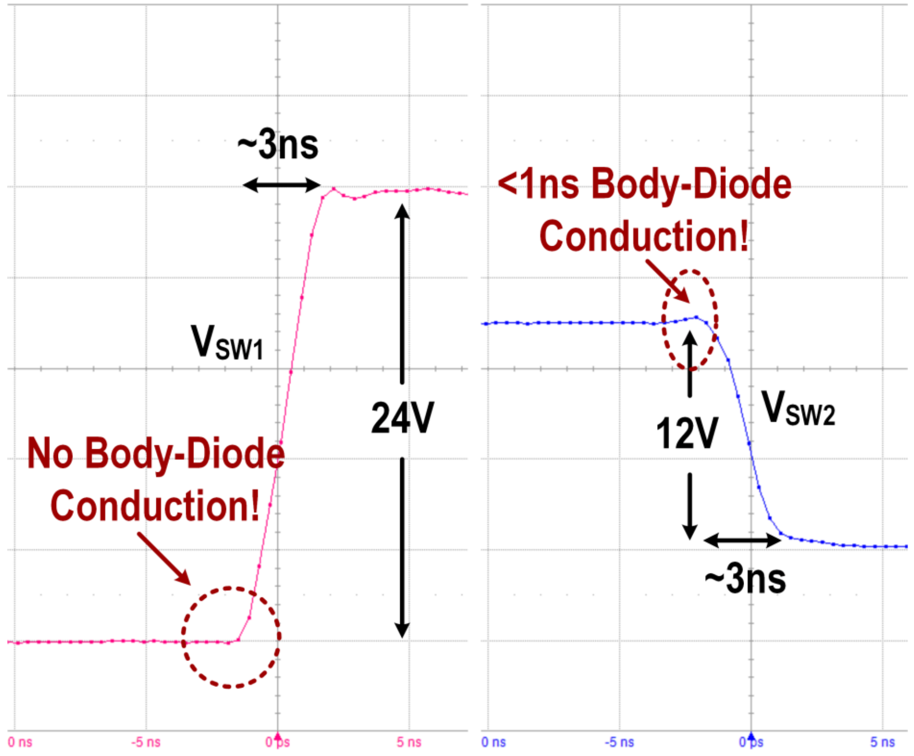
Synchronous Buck-Boost Topology Hot Loops

Input **and** Output capacitor has to deliver, depending on operation mode



LT8350S – New Generation Silent Switcher 2

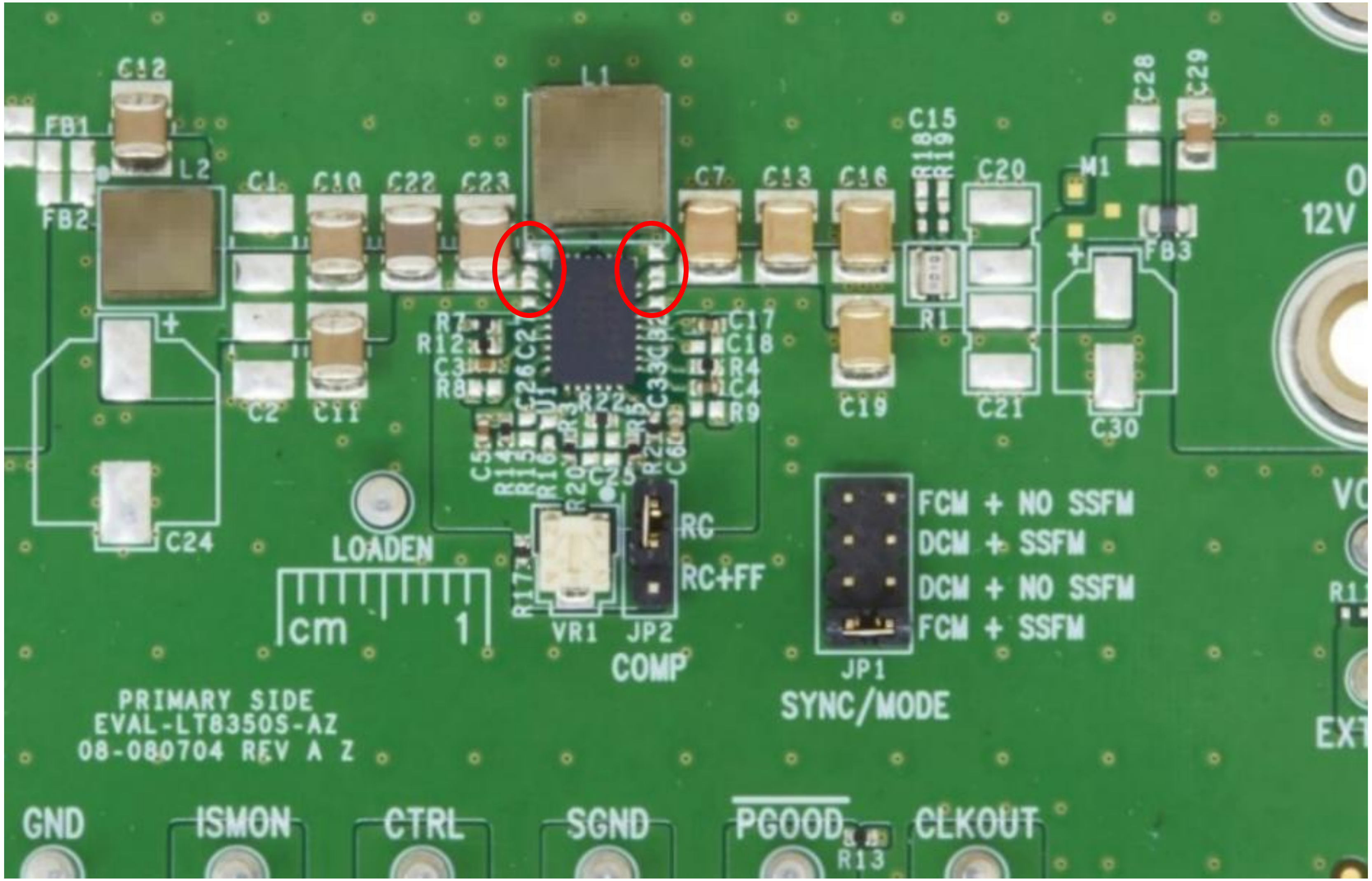




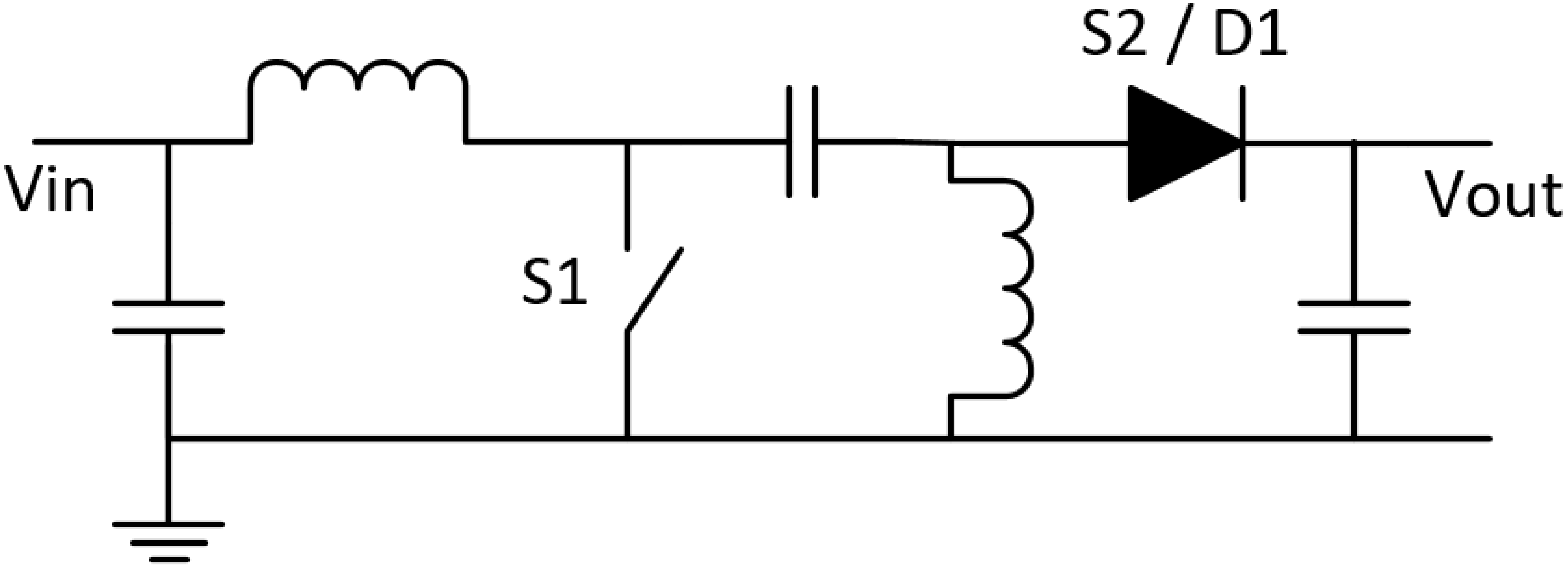
- Silent Switcher 2 Architecture
  - Symmetrical hot loops
  - Internal hot loop caps
  - Cu pillars instead of bond wire
- Safe zero-deadtime

For Good EMI, Good Efficiency, Simple PCB

LT8350S – New Generation Silent Switcher 2



SEPIC (Step Up and Step Down)



Coupled inductors / coupling capacitor

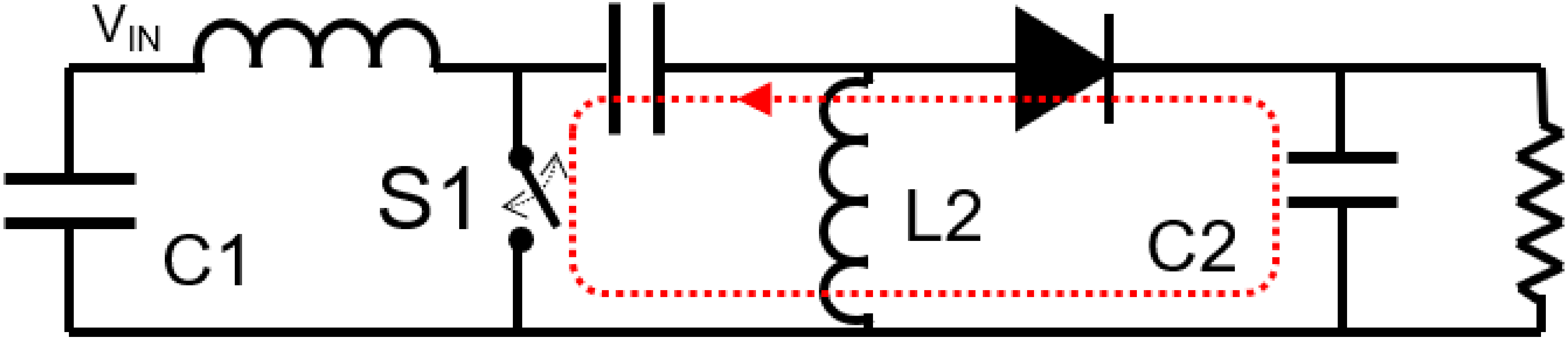
RHP Zero

Lower efficiency compared to buck-boost

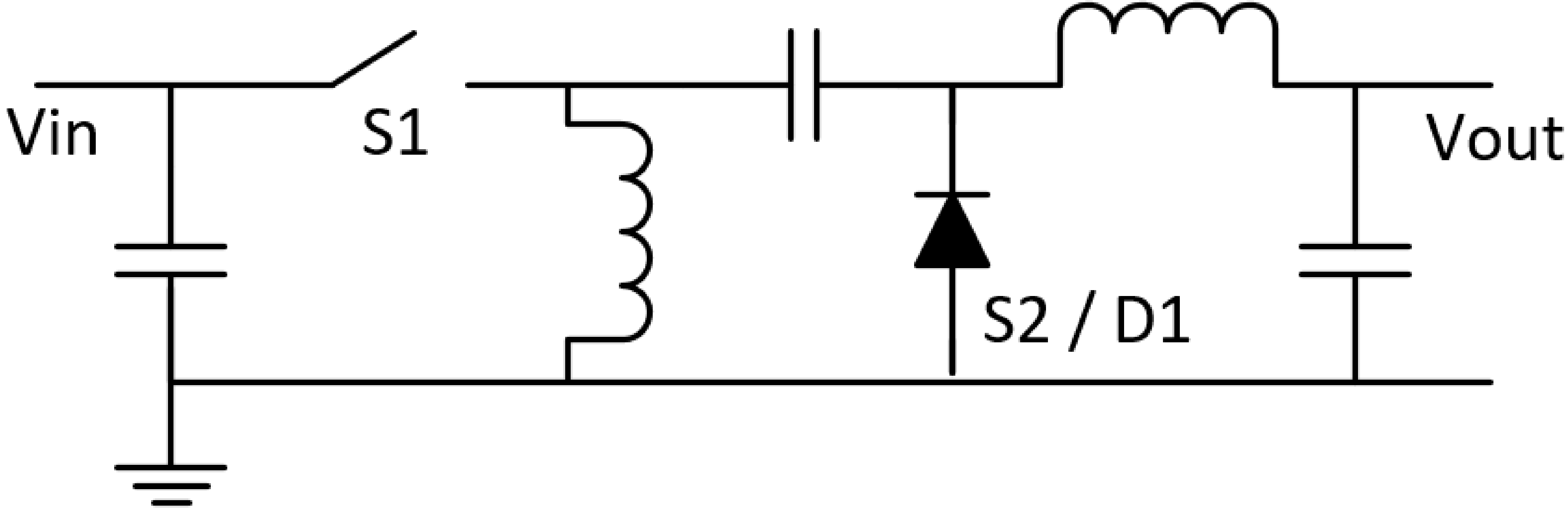
Single FET/Switch (Pro & Con)

L on input

SEPIC Topology Hot Loop



Zeta (Inverse SEPIC)

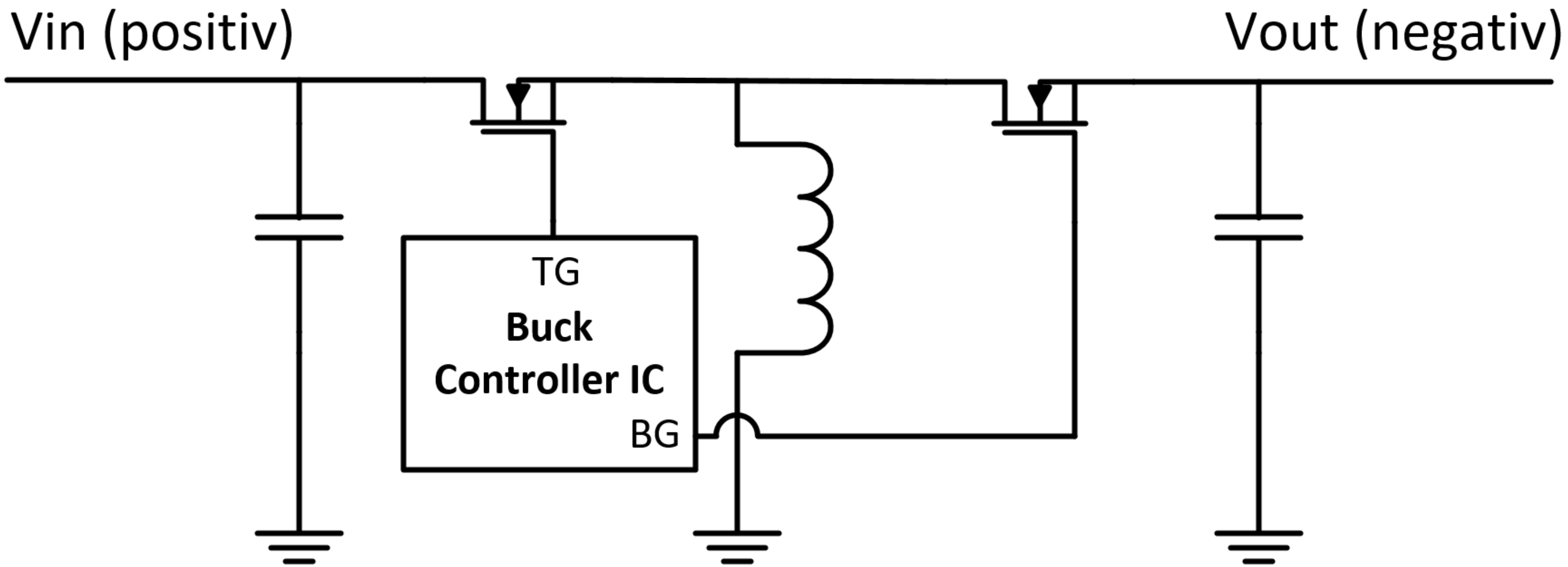


No right half plane zero

Active high side switch needed (buck converter type)

L on outpjut

Inverting (Buck-Boost)

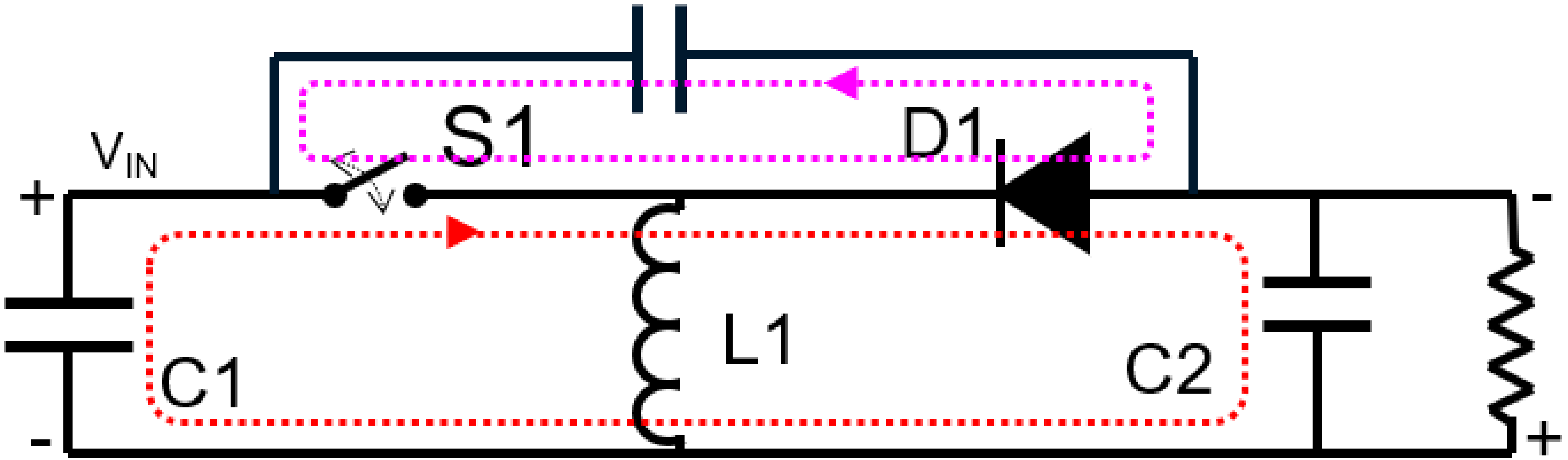


RHP zero

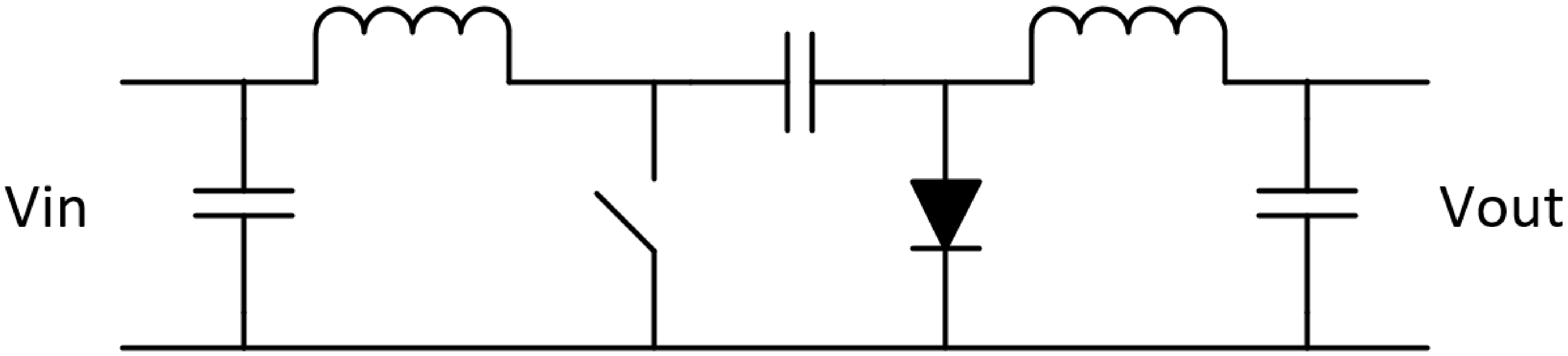
Lower eff vs Buck, Vin Req higher, Less current

Level Shift possibly needed

Inverting (Buck-Boost) Topology Hot Loop



CUK (Inverting)(Ćuk)



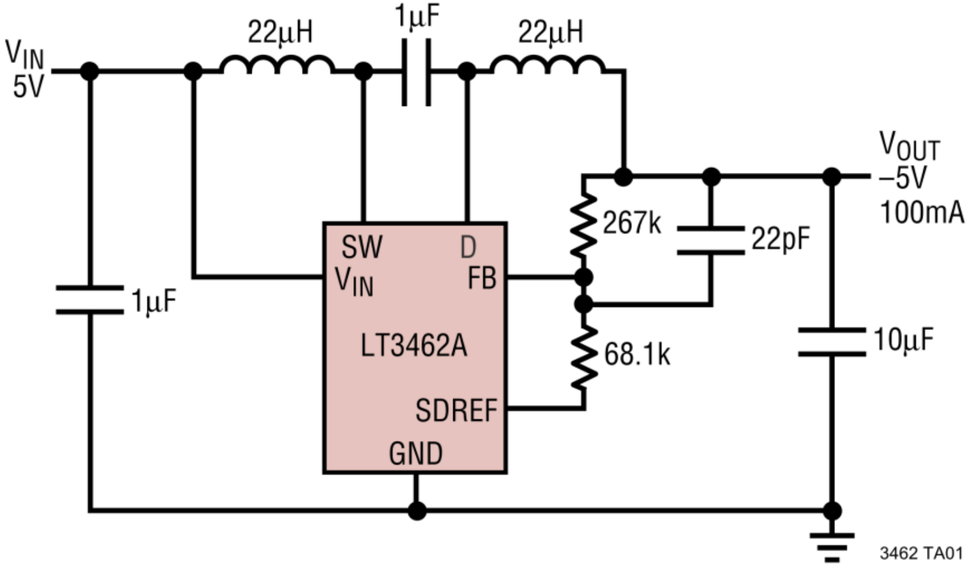
Continuous power flow on Vin and Vout

Low noise

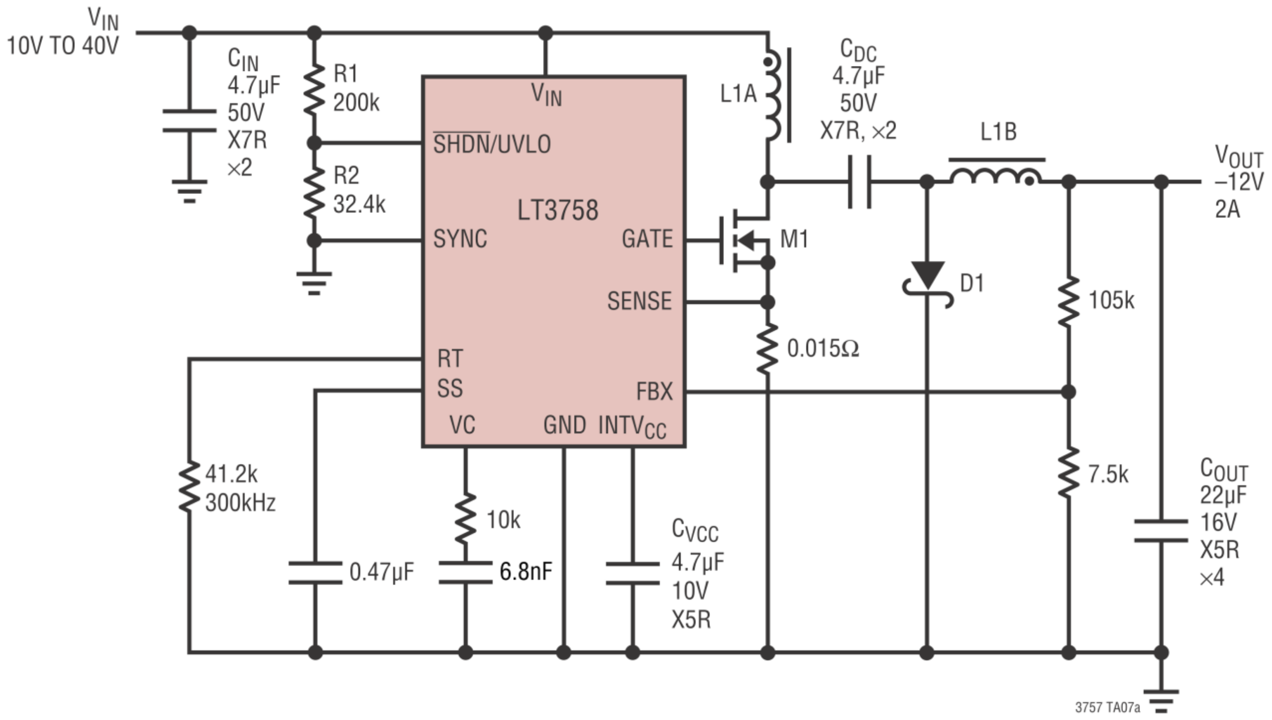
Special converter needed (neg FB)

Ćuk Converter Examples

5V to –5V, 100mA Inverting DC/DC Converter

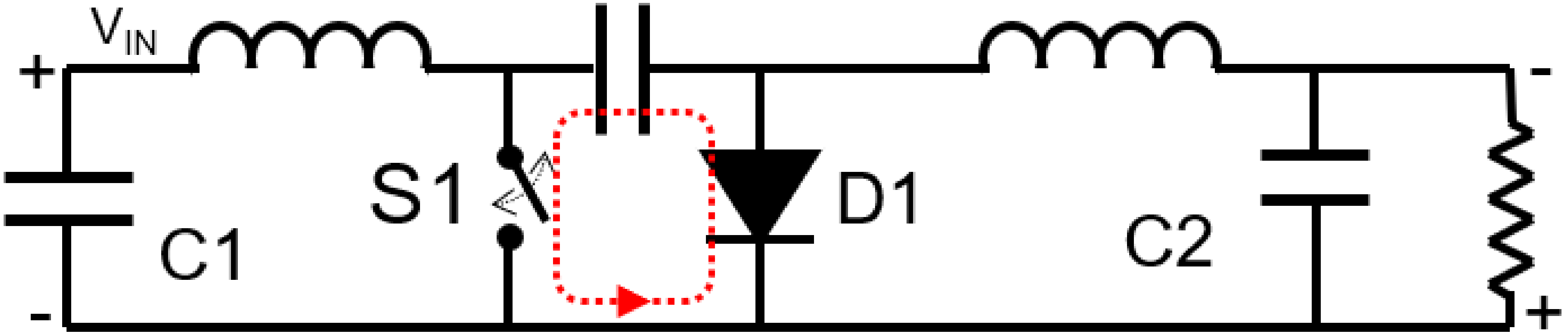


10V to 40V Input, –12V Output Inverting Converter

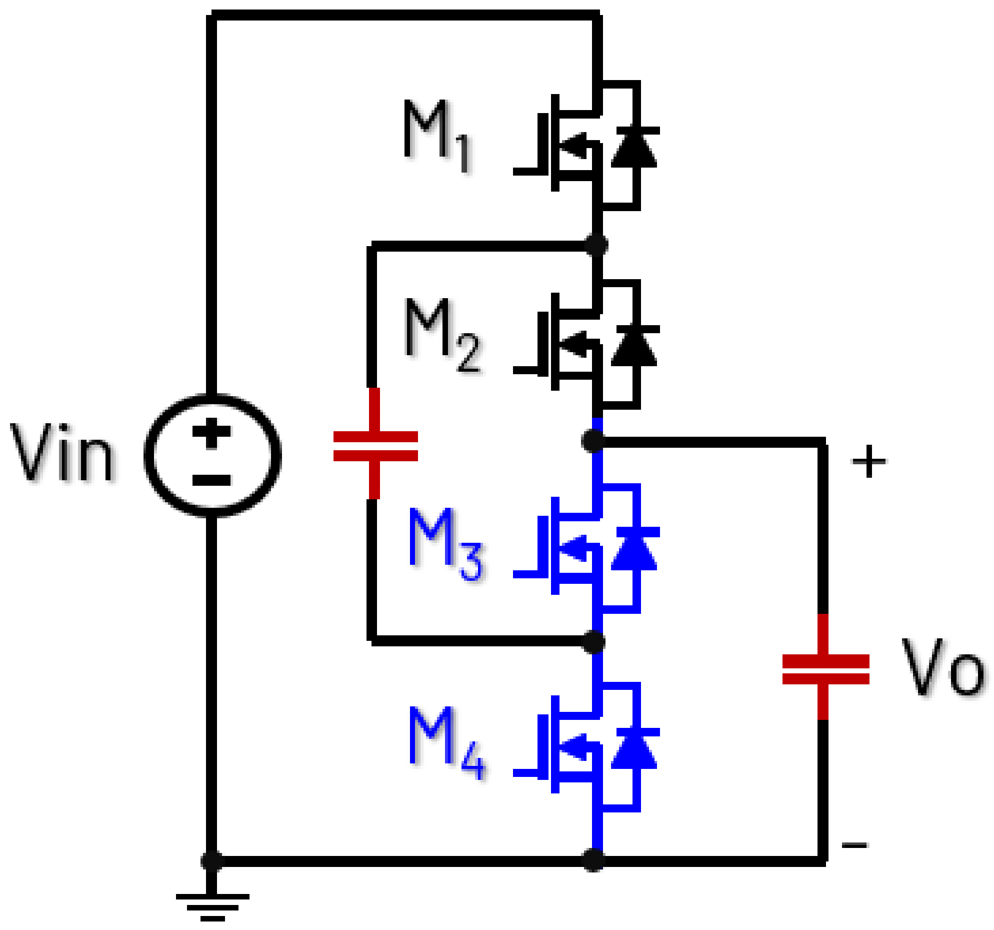


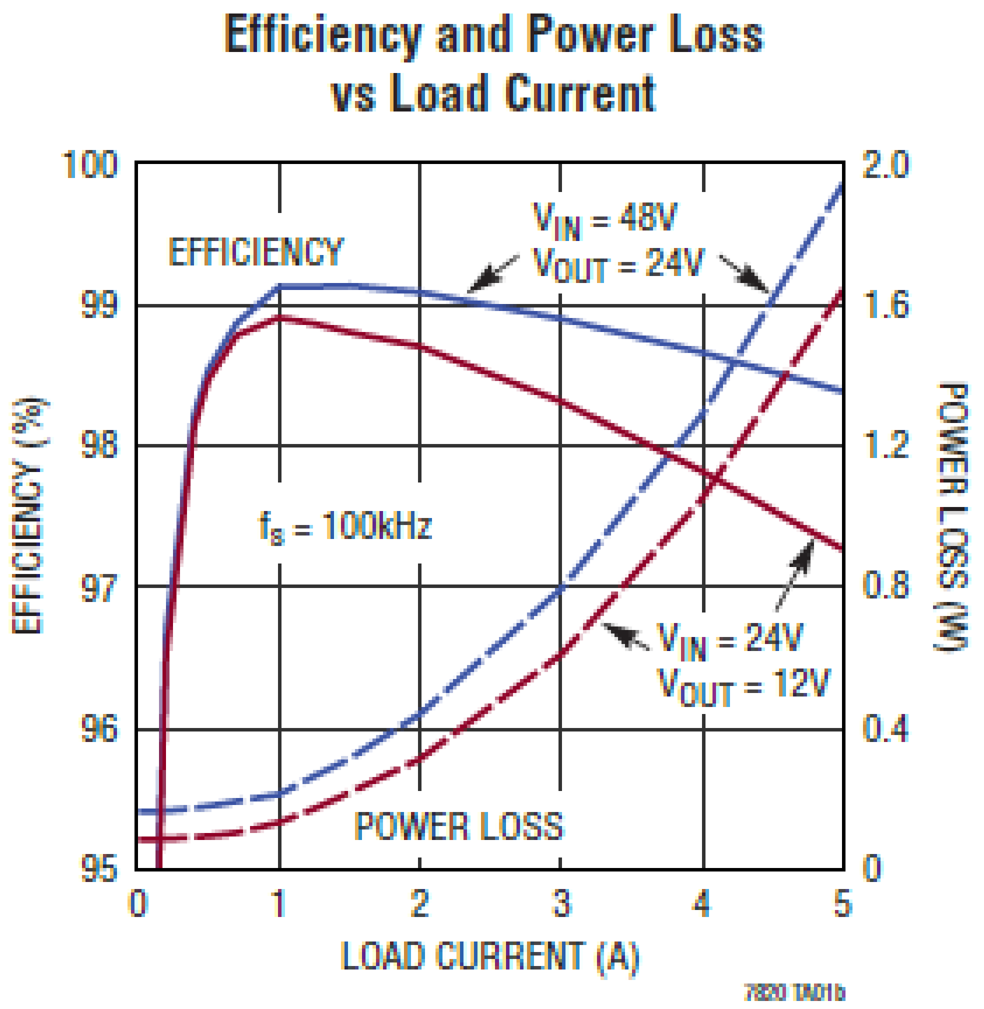
Ćuk Topology Hot Loop

This topology produces the smallest interferences in comparison to all other DC/DC topologies



Charge Pump (High Power)





Hybrid Converter

Low FET voltage stress (Vin/2)

Low switching loss

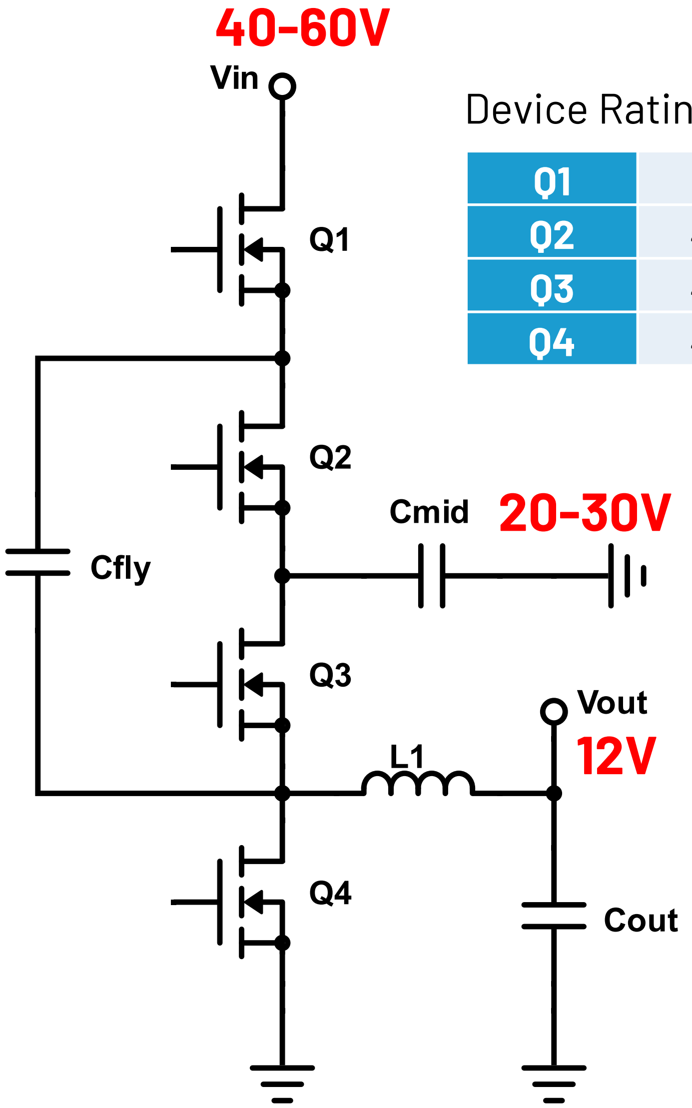
High switching frequency

Small inductor

Vo = ½Vin*D, tightly regulated

Current Mode control

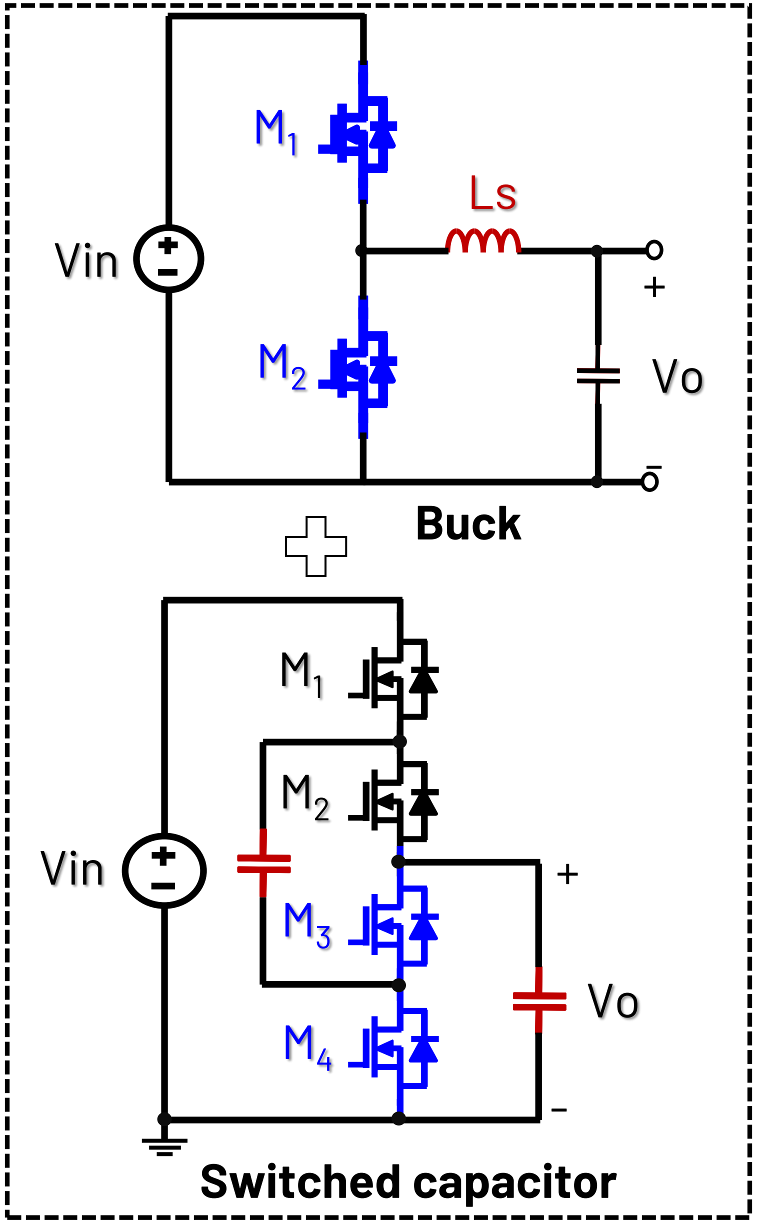
Current Sharing (Scalable)

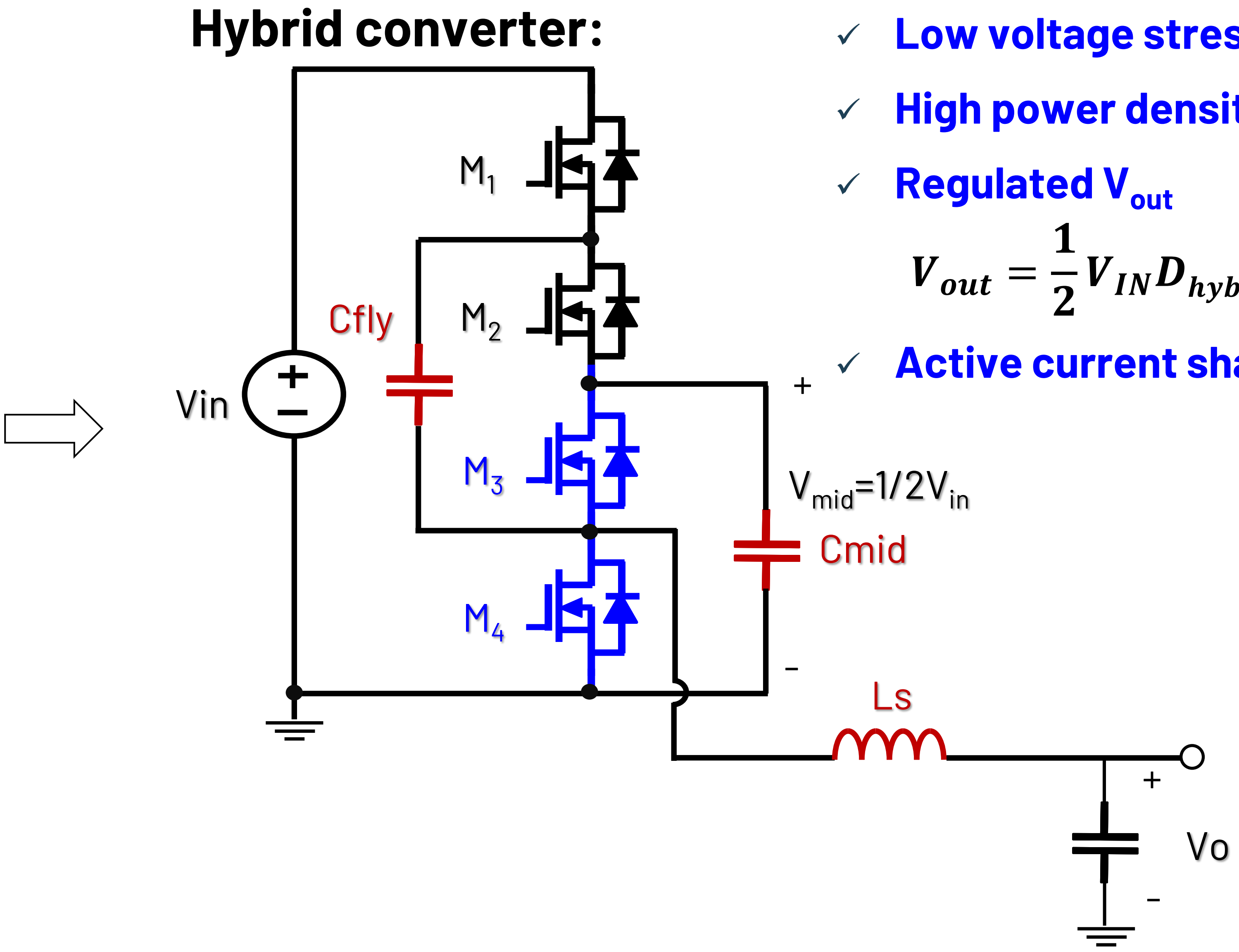


Device Rating:

Q1	80V
Q2	40V
Q3	40V
Q4	40V

Step-down Regulators: Hybrid Converter





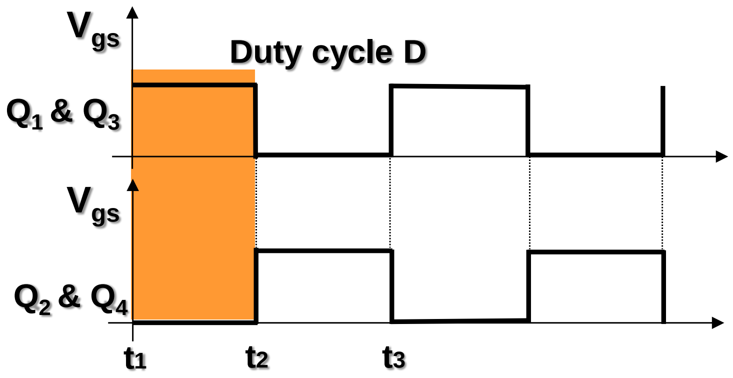
- ✓ **Low voltage stress**
- ✓ **High power density**
- ✓ **Regulated V_{out}**

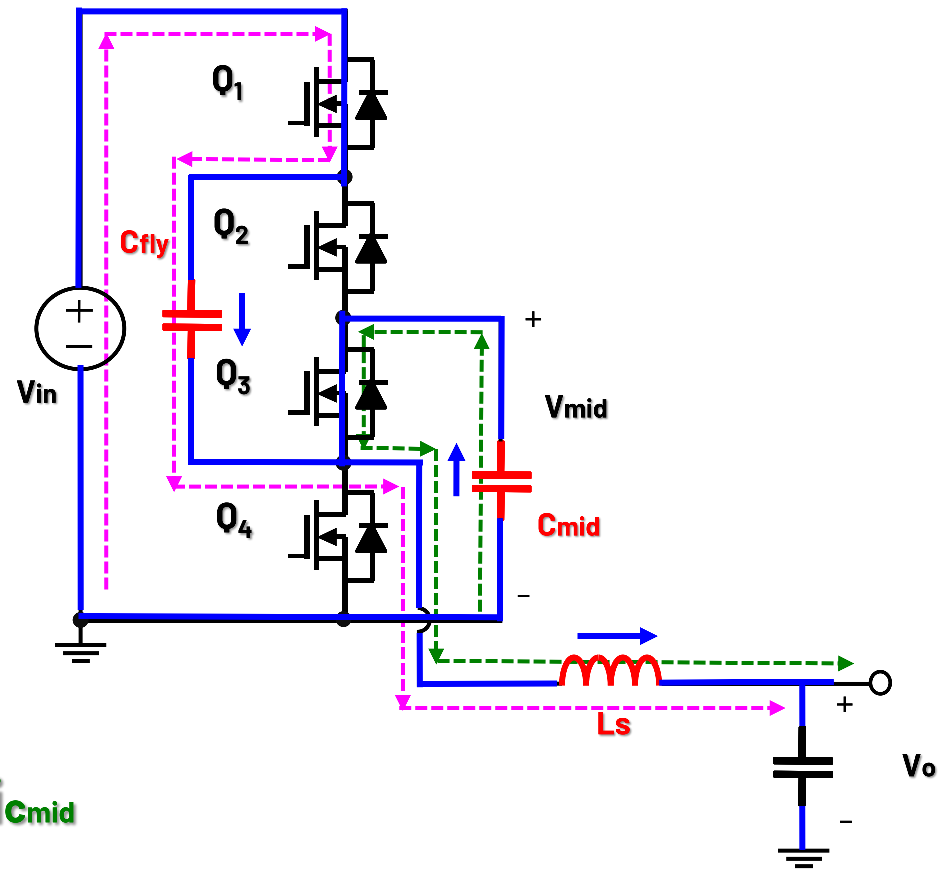
$$V_{out} = \frac{1}{2} V_{IN} D_{hybrid}$$

- ✓ **Active current sharing**

Hybrid Converter Operation Mode I

➢ t1 ~ t2, Mode I:



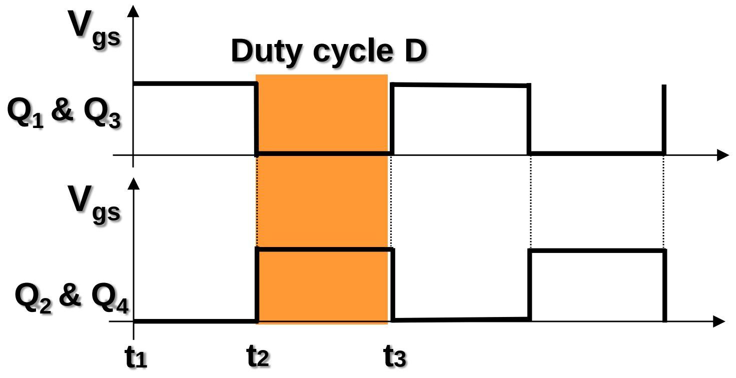


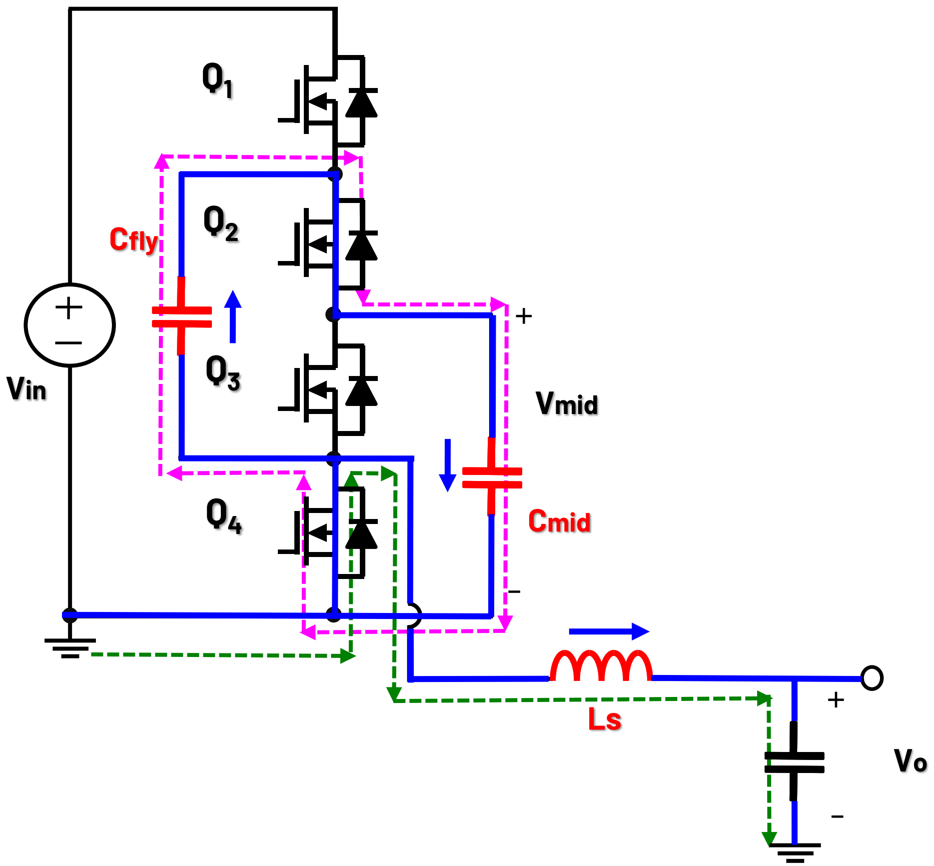
- $i_{Ls} = i_{Cfly} + i_{Cmid}$
- $i_{Q3} = i_{Cmid}$

Q3: reduced conduction loss, reduced switching loss

Hybrid Converter Operation Mode II

- **t2 ~ t3,   Mode II:**



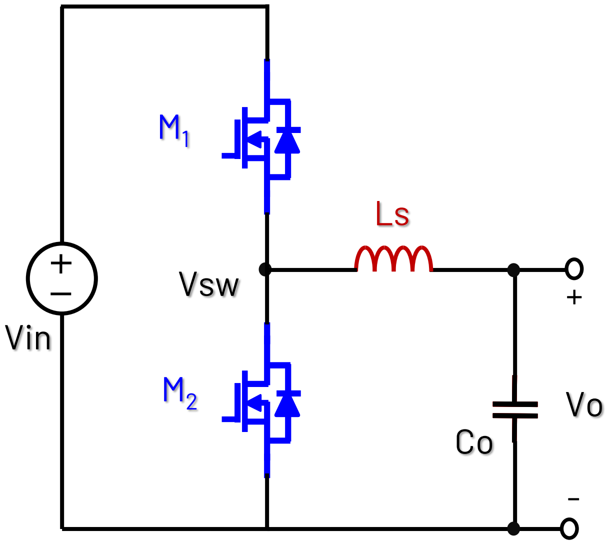


- $i_{Cfly} = i_{Cmid}$
- $i_{Q4} = i_{Ls} + i_{cfly}$

Q4: increased conduction loss

Step-down Regulators: Buck vs. Hybrid

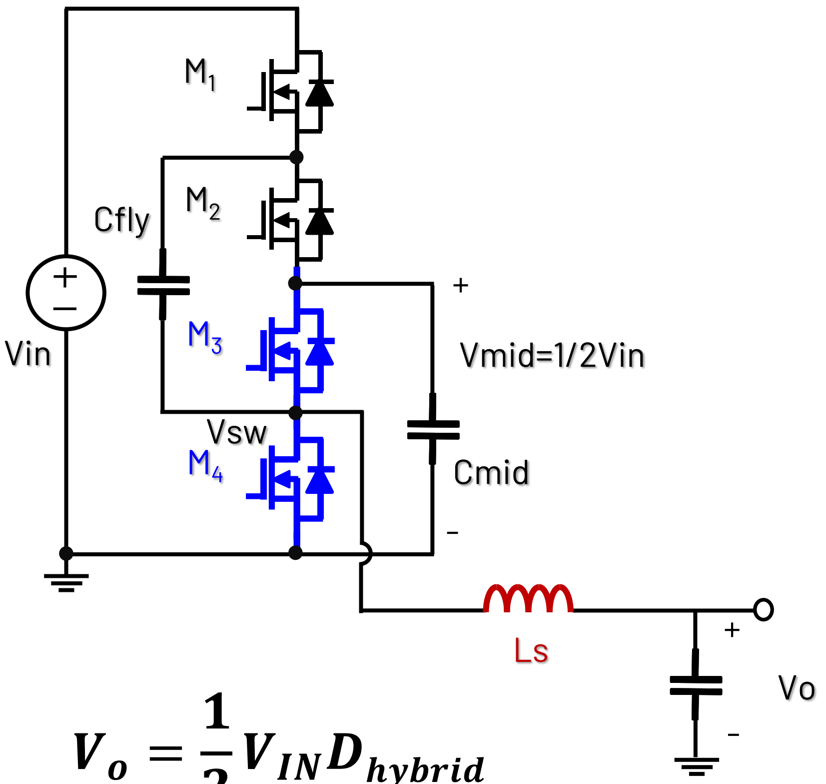
❖ Buck converter



$$V_o = V_{IN} D_{buck}$$

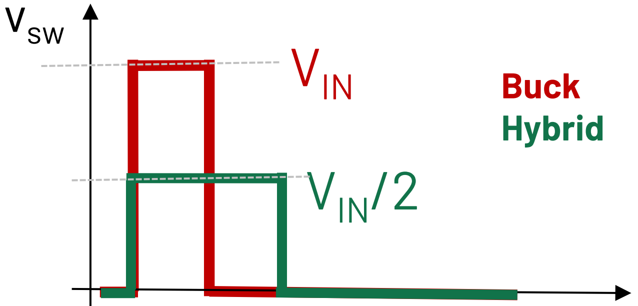
D_{buck}=0.25 (48Vin to 12Vo)

❖ Hybrid converter



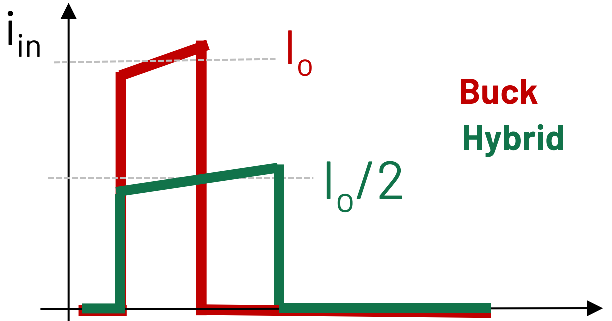
$$V_o = \frac{1}{2} V_{IN} D_{hybrid}$$

D_{hybrid}=0.5 (48Vin to 12Vo)



Switching node waveform

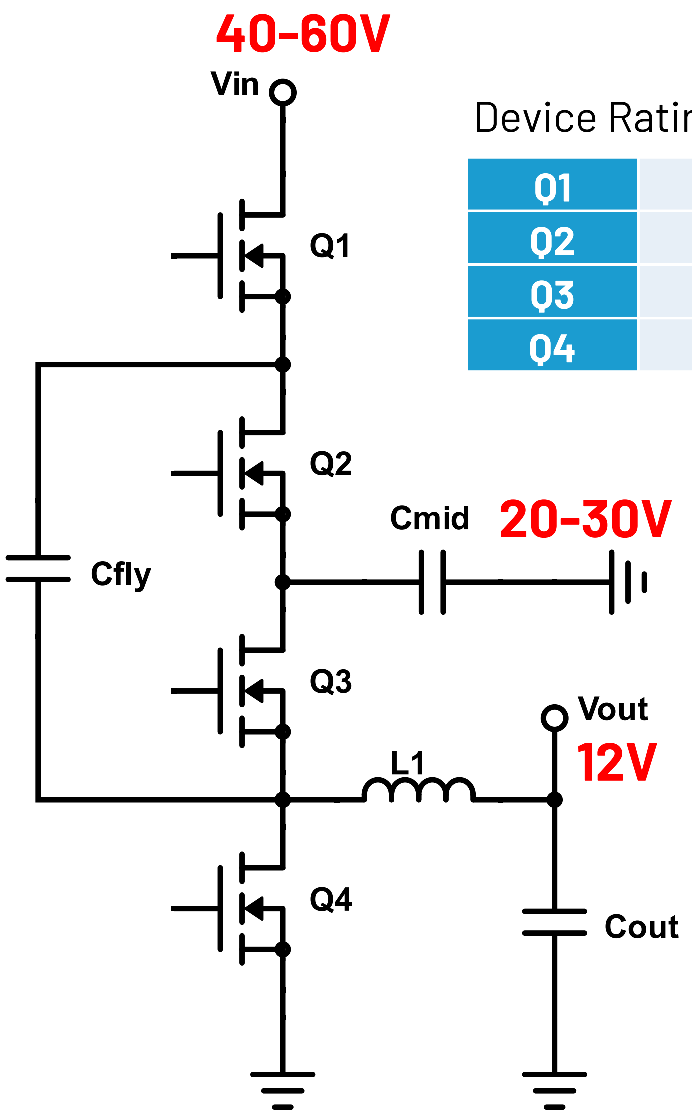
48Vin to 12Vo



Input current waveform

48Vin to 12Vo

Benefits of Hybrid Converter

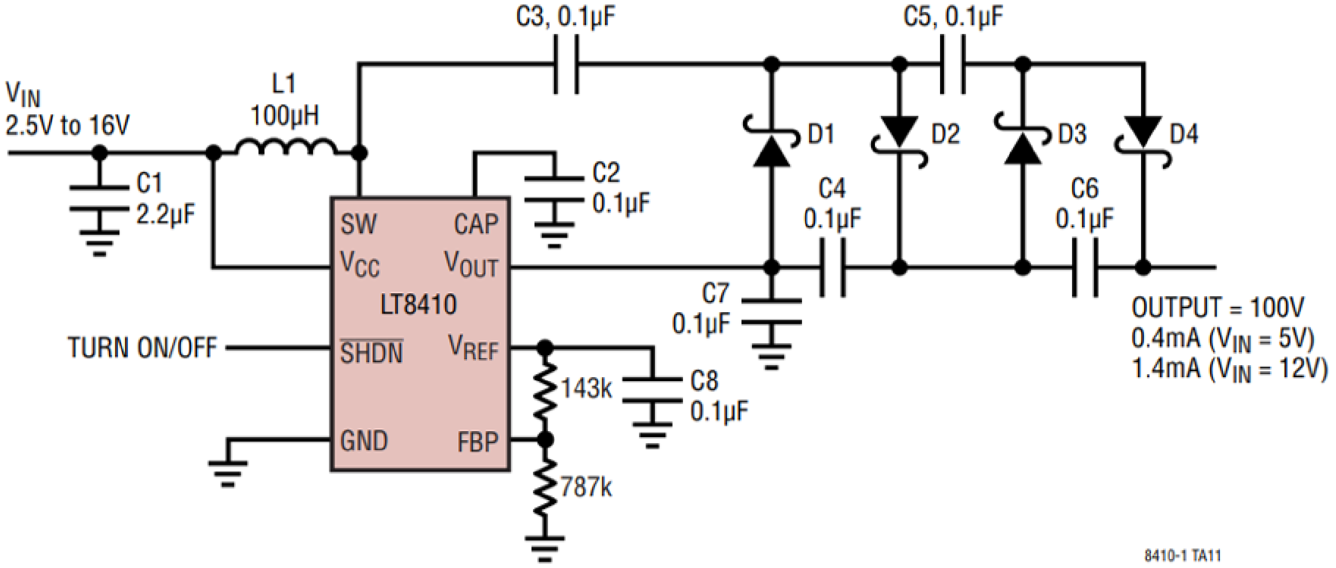


Device Rating:

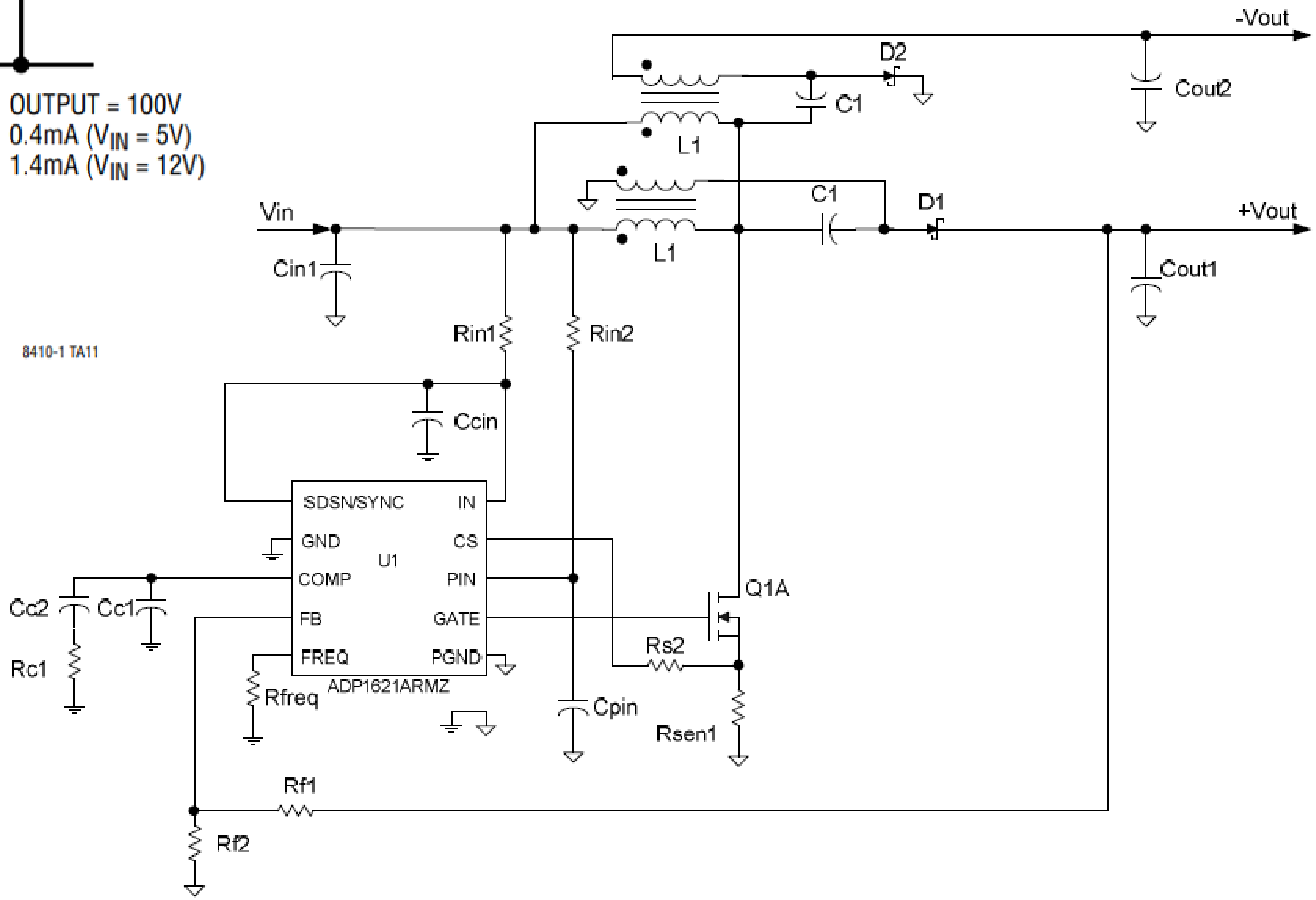
Q1	80V
Q2	40V
Q3	40V
Q4	40V

- **Low FET voltage stress (Vin/2)**
- **Low switching loss**
- **High switching frequency**
- **Small inductor**
- **$V_o = \frac{1}{2}V_{in}*D$, tightly regulated**
- **Current Mode control**
- **Current Sharing (Scalable)**

Other combined Topologies (Cascaded)

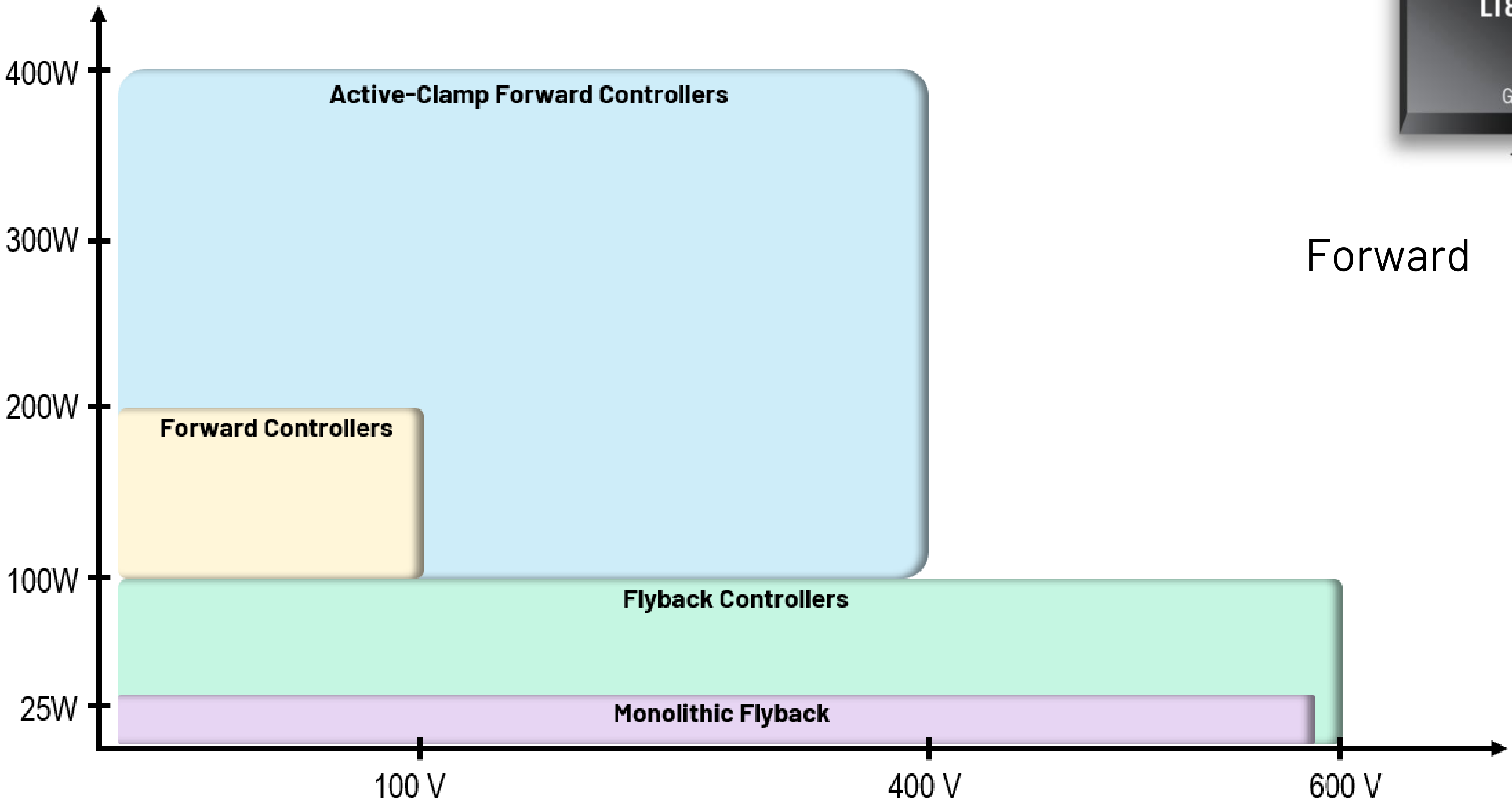


Boost and Charge Pump (voltage doublers)

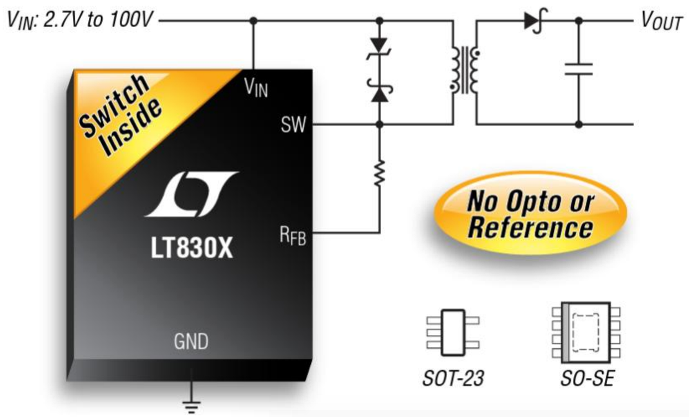


Coupled SEPIC - CUK

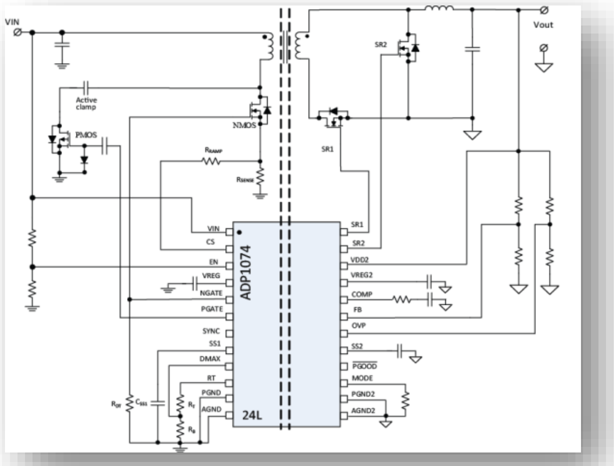
Isolated Topologies



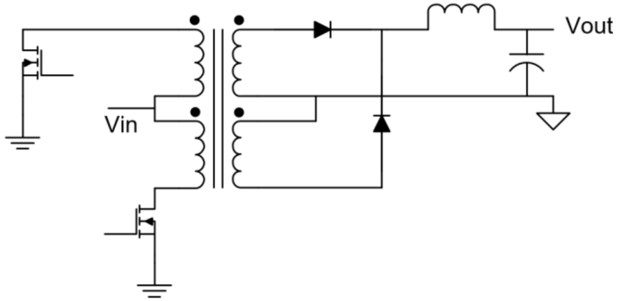
Flyback



Forward



Push-Pull



AHEAD OF WHAT'S POSSIBLE

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