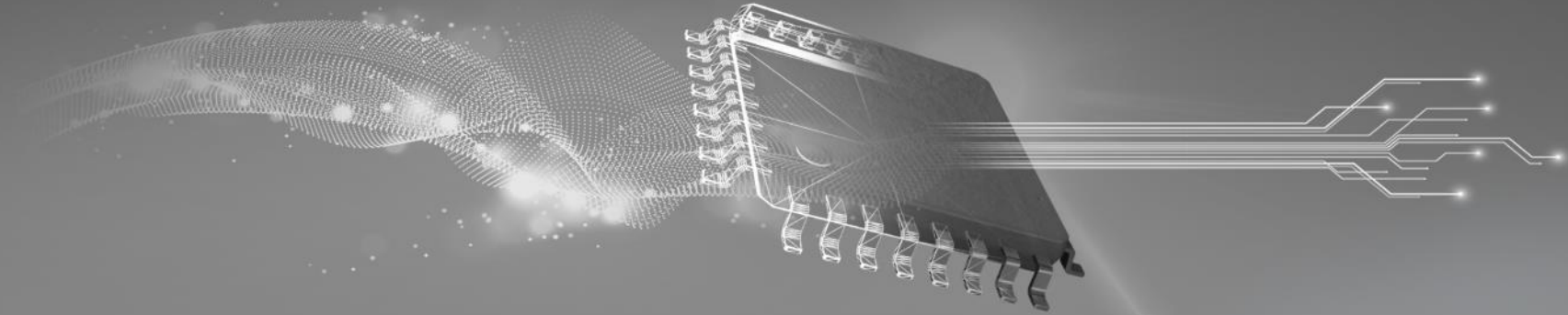


# TI TECH DAYS



## **Influence of Layout on EMI performance of Buck-Boost Converters**

Brigitte Hauke, APP, BMC-BCS

# Agenda

- EMI Basics
  - Basic Operation of a 4-Switch Buck-boost Converter
  - Difference between Schematic and Real World Components
  - Board Layout Rules and How to Review It
- 
- Real world example with TPS63070

# EMI BASICS

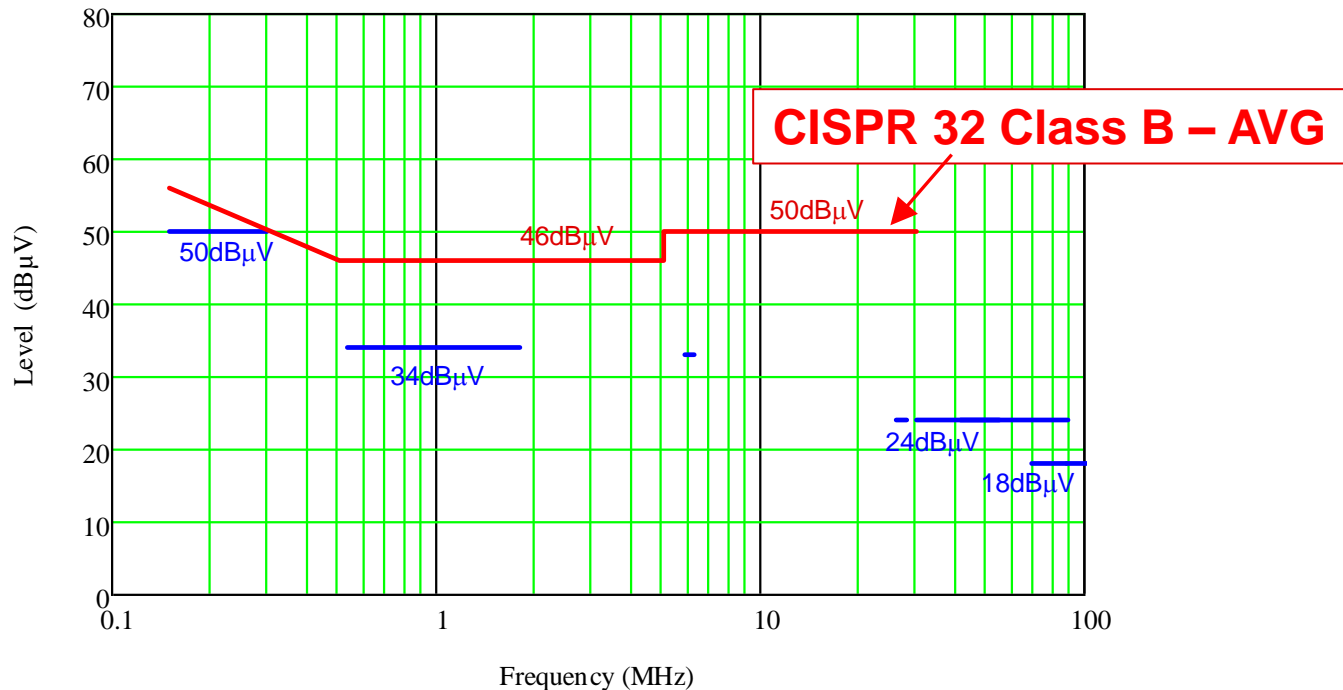
# EMI Model

- EMI needs
  - Aggressor
  - Path
  - Susceptor
- Measured on Systems not components
  - All components can comply but system still does not comply
- DC/DC converter
  - Hot loops
  - Important nodes

# Conducted and Radiated EMI

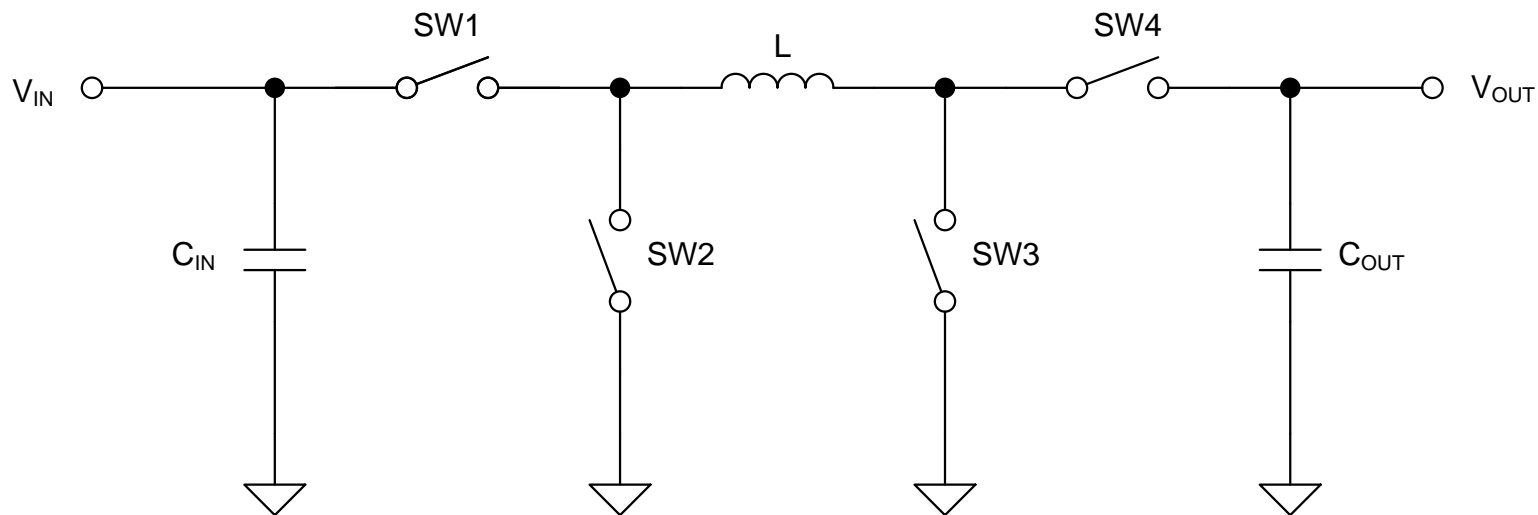
- Conducted EMI
  - Differential mode vs. common mode
  - Reference GND necessary (drives setup specification for compliance measurements)
  - Termination
  - Layout and Component selection important
  - 10kHz to 30MHz (automotive 108MHz)
- Radiated EMI
  - Primarily Layout Dependent
  - Shielding
  - Filtering
  - 30MHz to 1GHz
- Peak, Average or quasi-peak measurements

# CISPR 32 (class B) vs. CISPR 25 (class 5) conducted EMI average limits



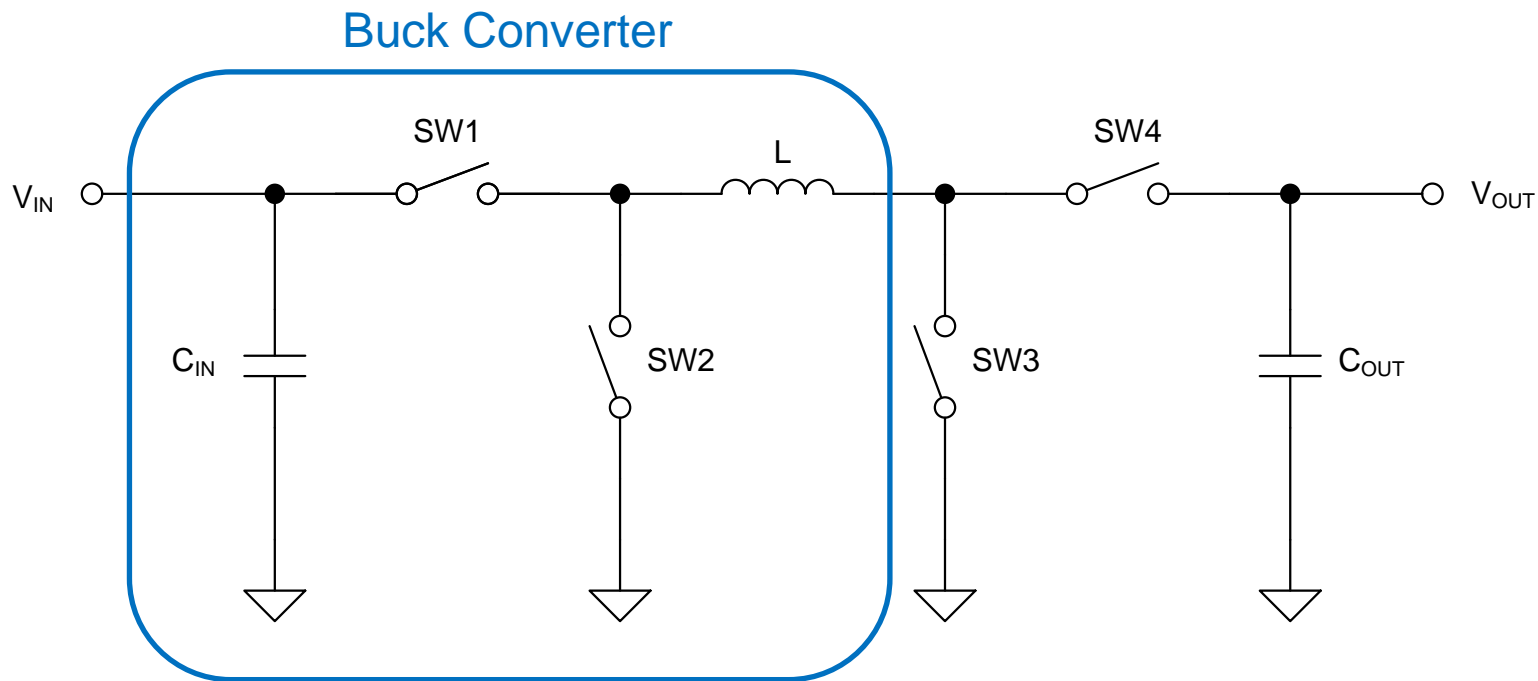
# BASIC OPERATION OF A 4-SWITCH BUCK-BOOST CONVERTER

# 4-Switch Buck-boost Converter

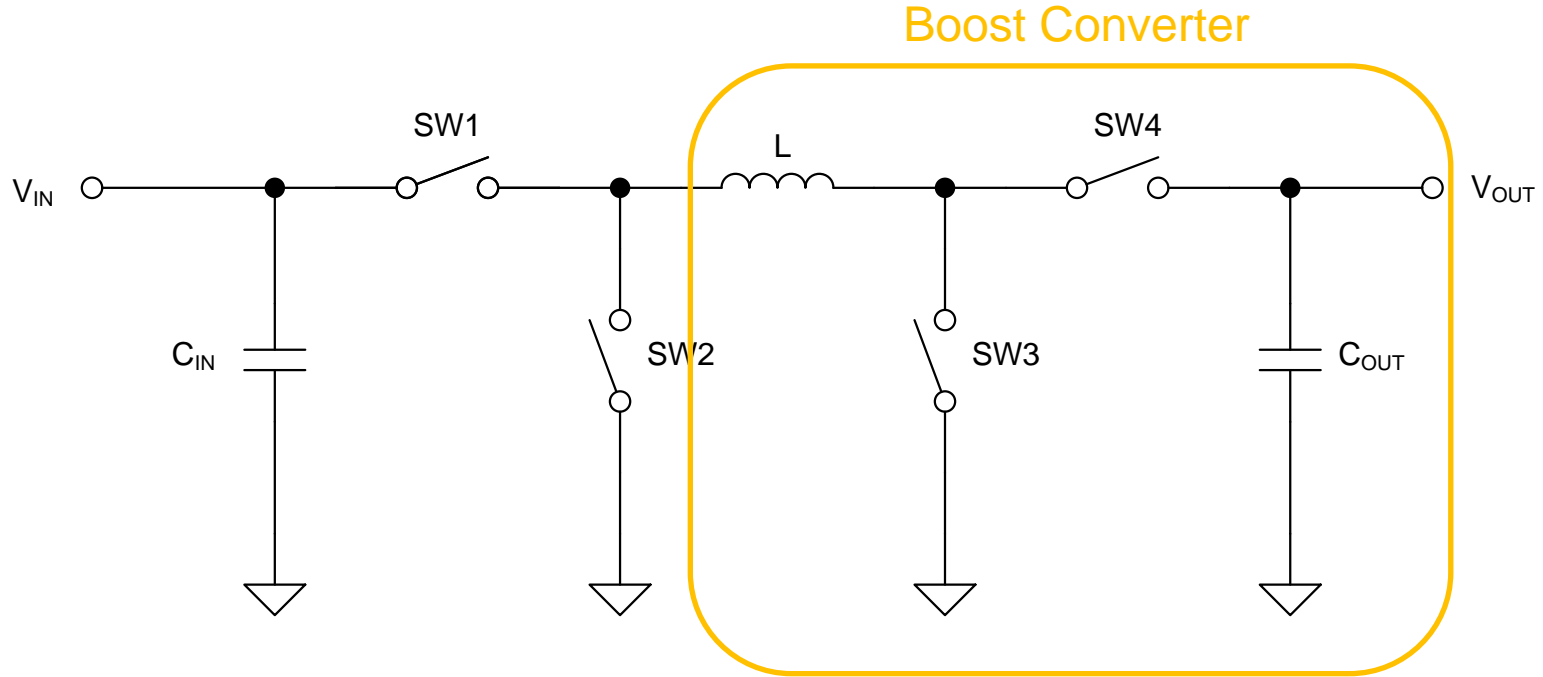




# 4-Switch Buck-boost Converter

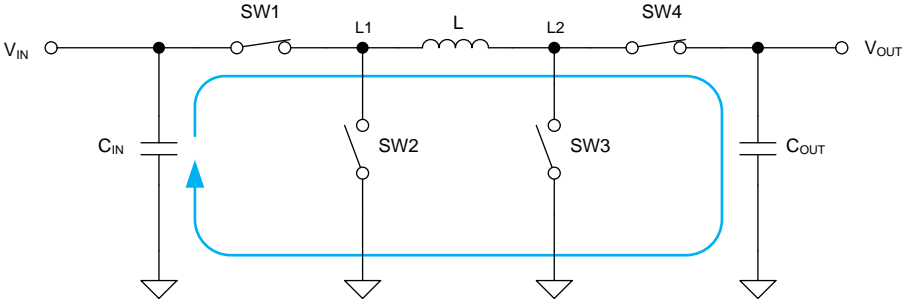


# 4-Switch Buck-boost Converter

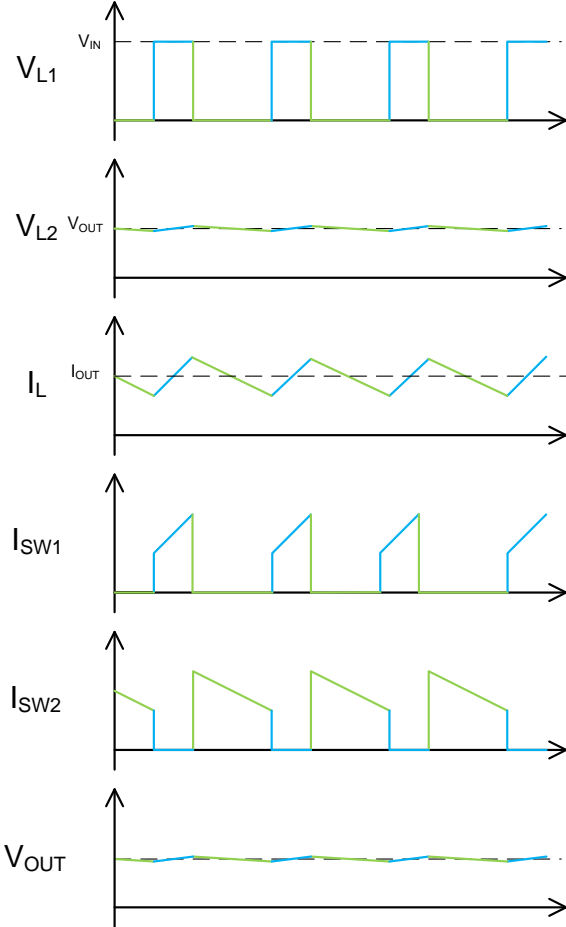
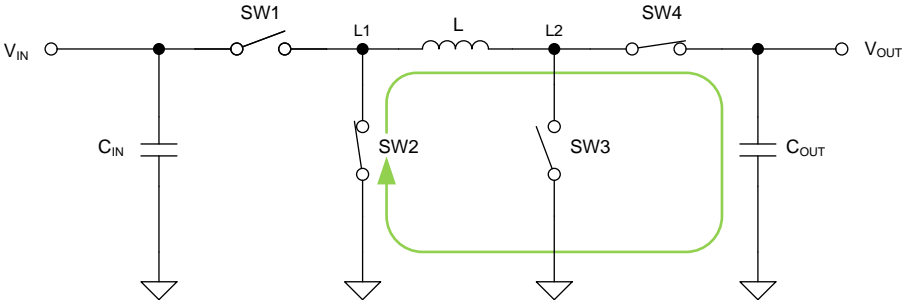


# Buck Operation

Power Switch SW1 on

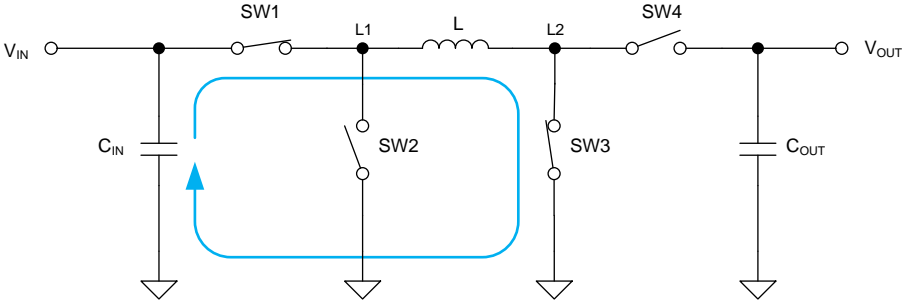


Power Switch SW1 off

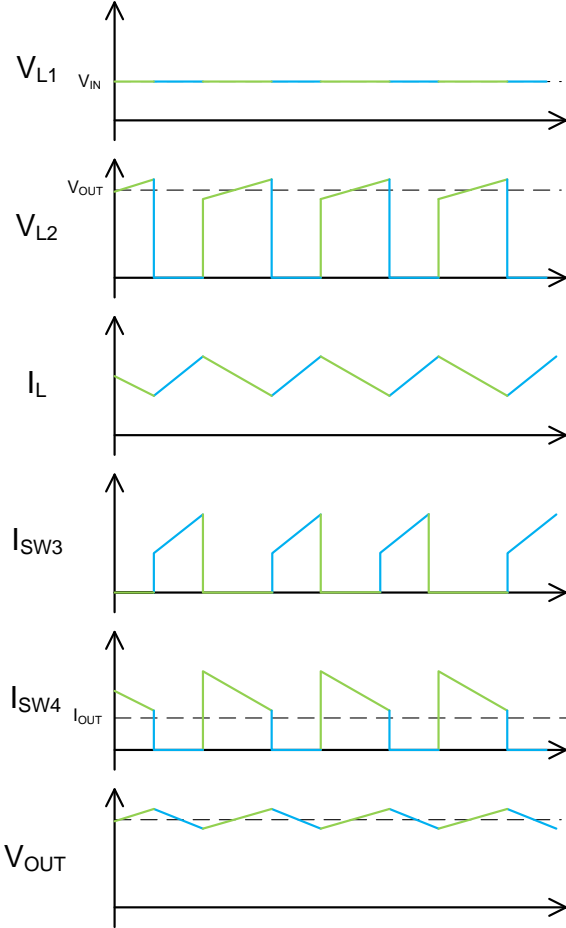
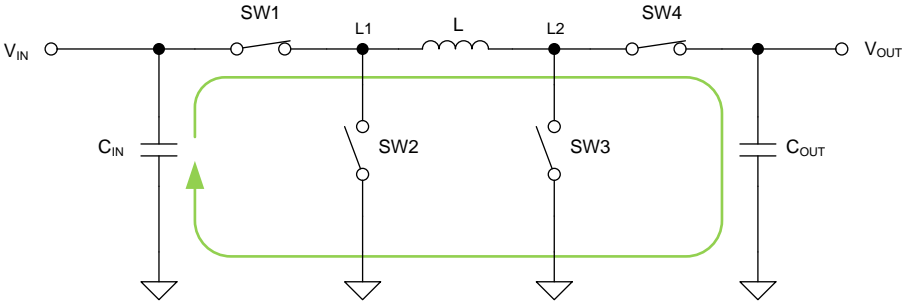


# Boost Operation

Power Switch SW3 on

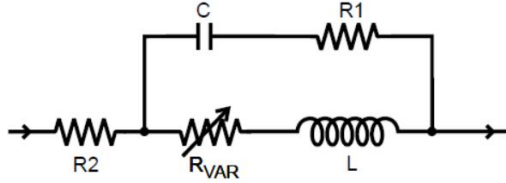


Power Switch SW3 off



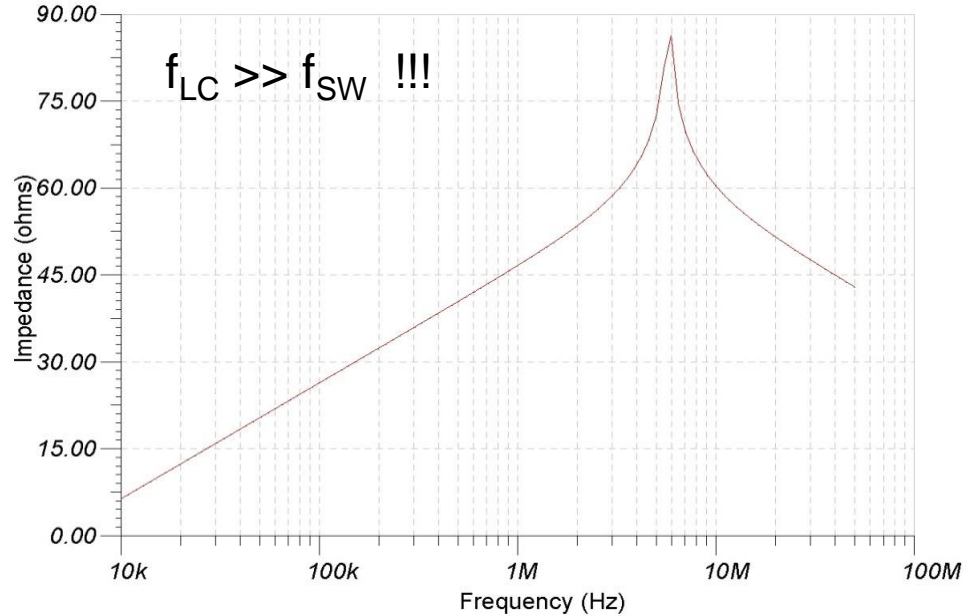
# **DIFFERENCE BETWEEN SCHEMATIC AND REAL WORLD COMPONENTS**

# Inductors – Parasitic Components



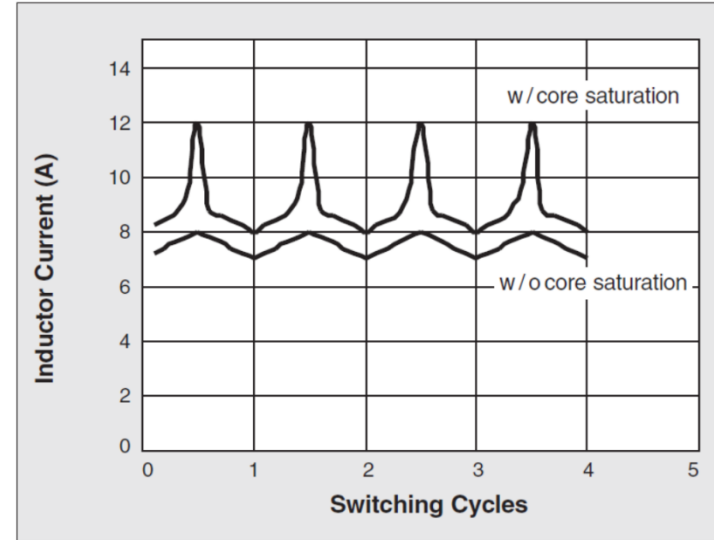
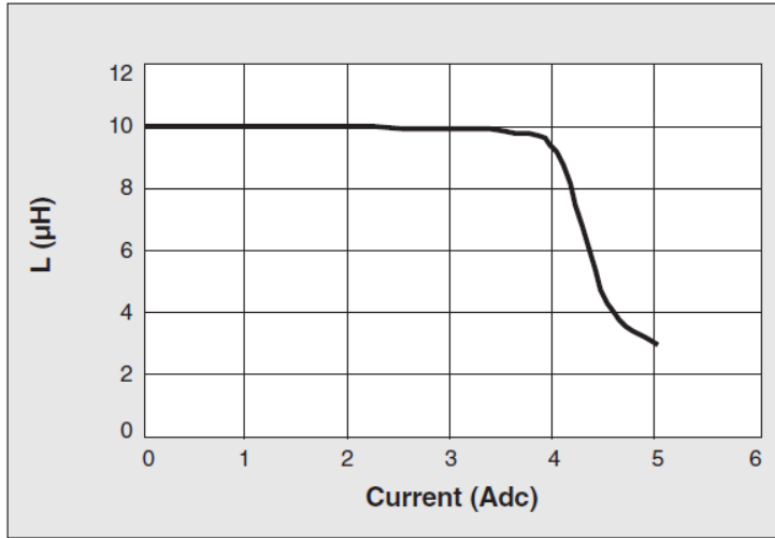
Real-world inductors

- parasitic capacitance causes ringing

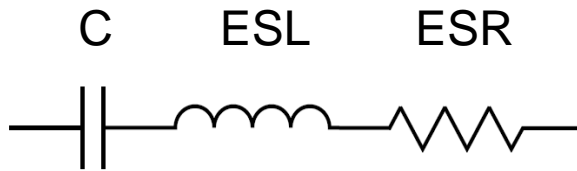


# Inductors – Saturation Current

- Inductor current includes a DC component
- DC current biases core and can cause it to be saturated with magnetic flux
- **Saturated inductor** is not an inductor – it's a **piece of wire**

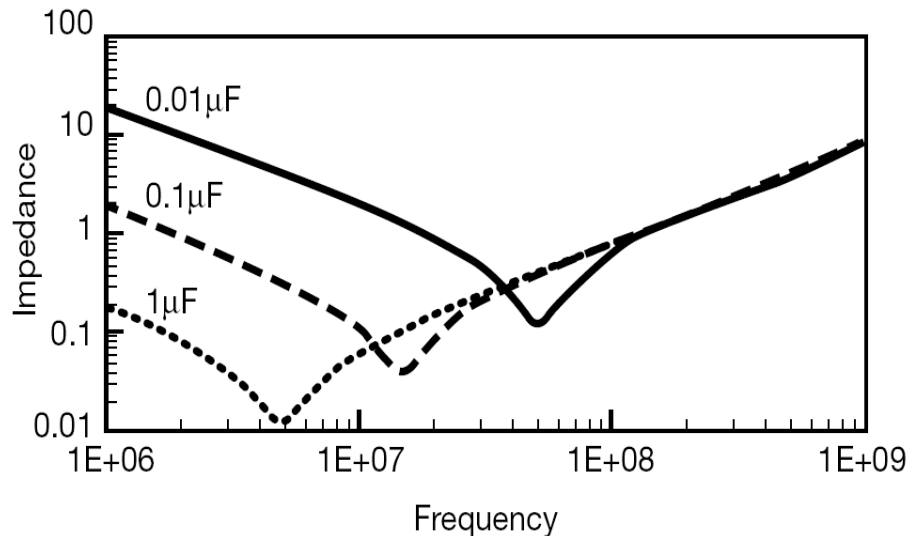


# Frequency Behavior of Ceramic Capacitors



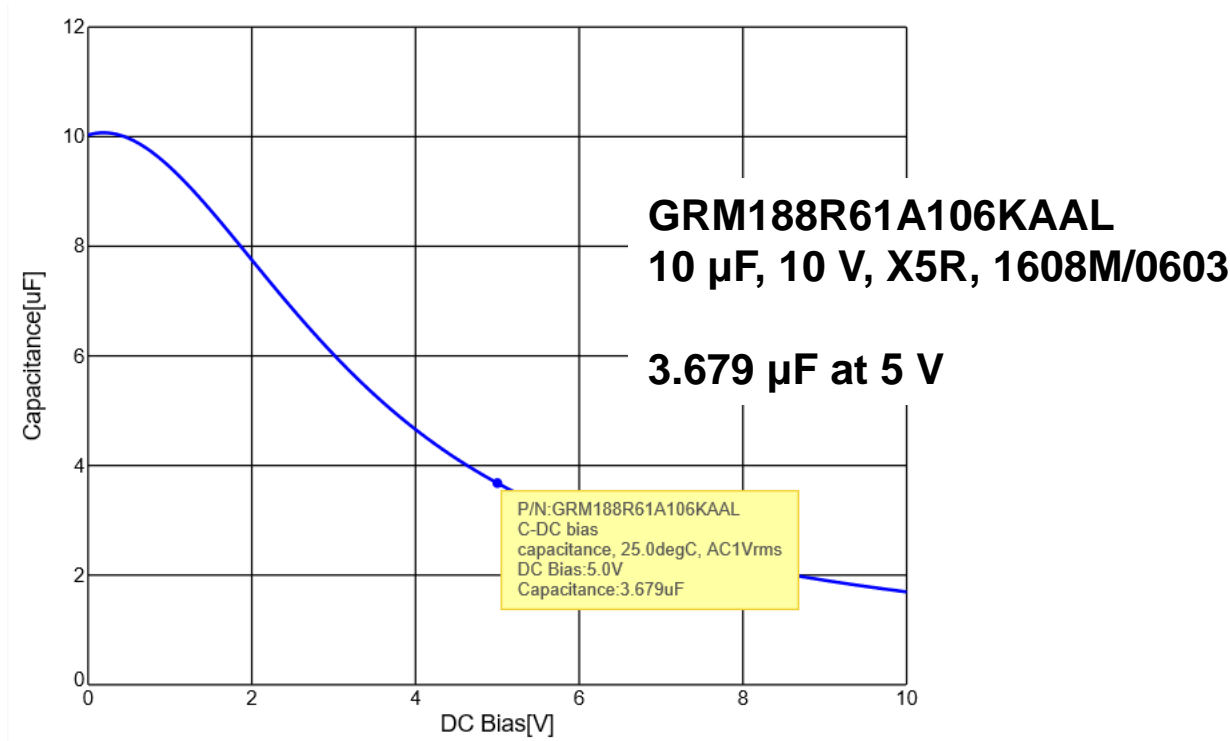
**Resonance Frequency**

$$f_{LC} = \frac{1}{2 \cdot \pi \cdot \sqrt{ESL \cdot C}}$$





# DC Bias Behavior of Ceramic Capacitors

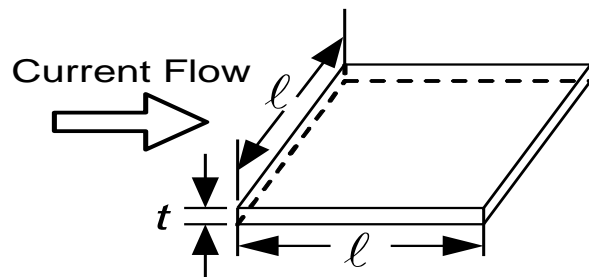


# Design for low EMI

- Starts with schematic
- Difference between schematic symbol and real world components
- **Line in schematic is impedance in real world**
- Current flows in loops!
- Help the layout person with good schematic drawings and hints for the important nodes and loops
- Additional hints for DC/DC converter design
  - High f caps
  - Input and output cap network instead of several times same cap
  - Shielded inductors

# BOARD LAYOUT RULES AND HOW TO REVIEW IT

# Count Squares to Estimate Trace Resistance



$$R = \frac{\rho \times \ell}{t \times \ell}$$

$$R = \frac{\rho}{t}$$

Copper resistivity is 0.264mΩ/cm at 25°C and doubles for 254°C rise

Thickness (mm)	mΩ per Square (25°C)	mΩ per Square (100°C)
0.0175	1.0	1.3
0.035	0.5	0.65
0.07	0.2	0.26

# Stray Inductance and Stray Capacitance

- Most problems are caused by stray inductance and capacitance between:
  - Components and the ground plane
  - Tracks and the ground plane
  - Tracks and other tracks

# Stray Inductance and Stray Capacitance

- Equations describing basic behavior of inductors and capacitors:

$$I = C \frac{dV}{dt}$$

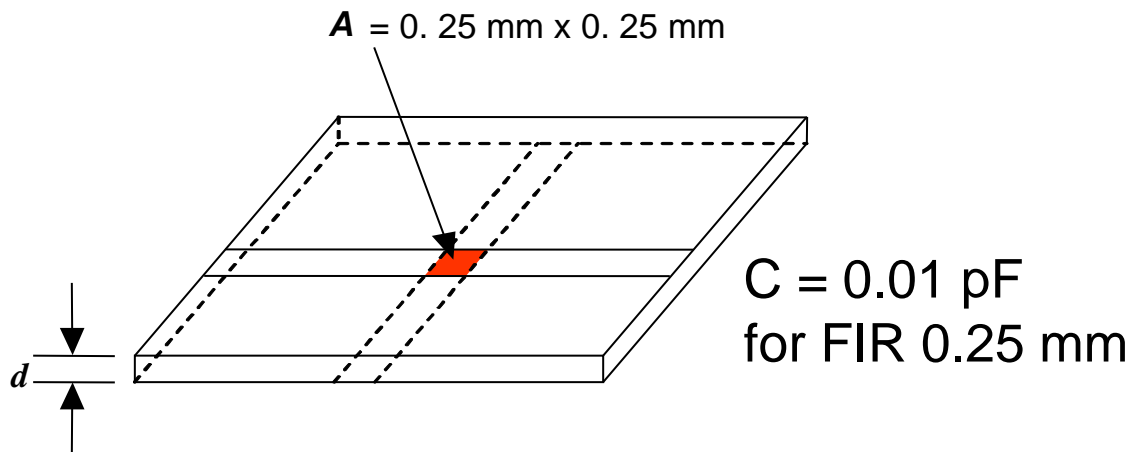
$$V = L \frac{dI}{dt}$$

- High slew-rate voltages across stray capacitance  
=> **unwanted *currents***
- High slew-rate currents through stray inductance  
=> **unwanted *voltages***
- Higher signal slew-rate  
=> **greater impact of stray capacitance/inductance**
- Higher switching frequency  
=> **higher signal slew-rate**

# Calculating Stray Capacitance

The capacitance in  $pF$  between two parallel plates:

$$C = \frac{\epsilon_0 \epsilon_r A}{d}$$



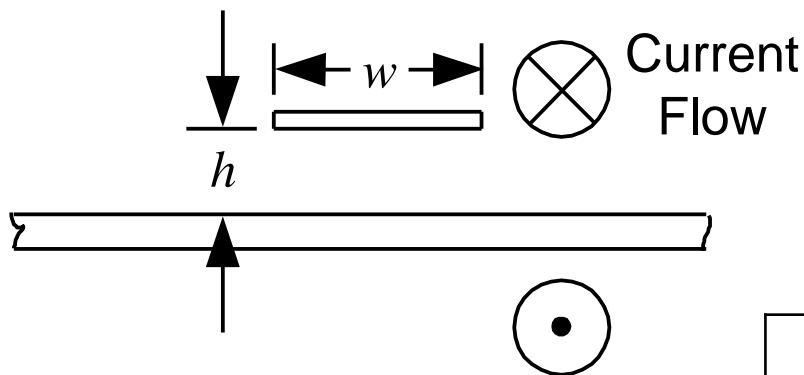
$\epsilon_r$  = *relative* dielectric constant of the PCB material

d = PCB thickness in millimeters

A = area of parallel plates in square millimeters

# PWB Traces Over Ground Planes

Inductance inversely proportional to width



$$L = \frac{2 \cdot \ell \cdot h}{w} \text{ nH/cm}$$

h (cm)	w (cm)	Inductance (nH/cm)
0.25	2.5	0.2
1.5	2.5	1.2



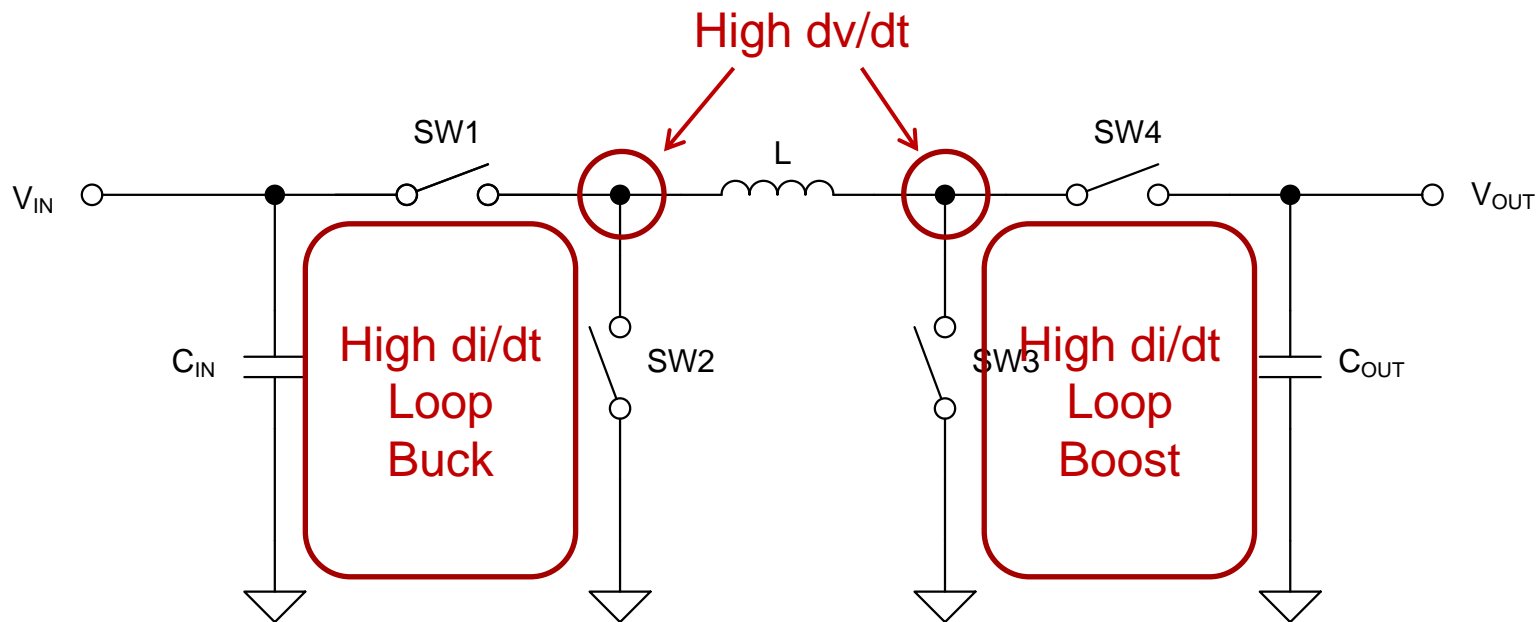
# PCB Stack-up

- PCB Stack-up is essential for low EMI board designs
- Place GND layer next to power layer for noise suppression
- Use at least 4 layers and keep the outer layers together for maximum flux cancellation

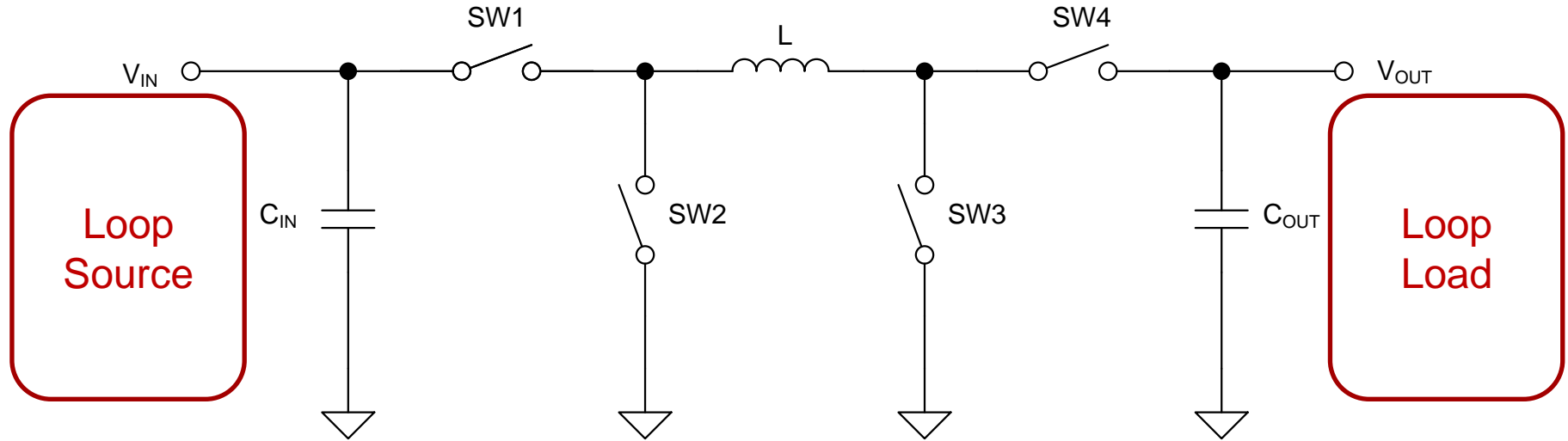


- Make sure there is no cut in the GND layer below the high  $di/dt$  paths

# 4-Switch Buck-boost Converter



# 4-Switch Buck-boost Converter

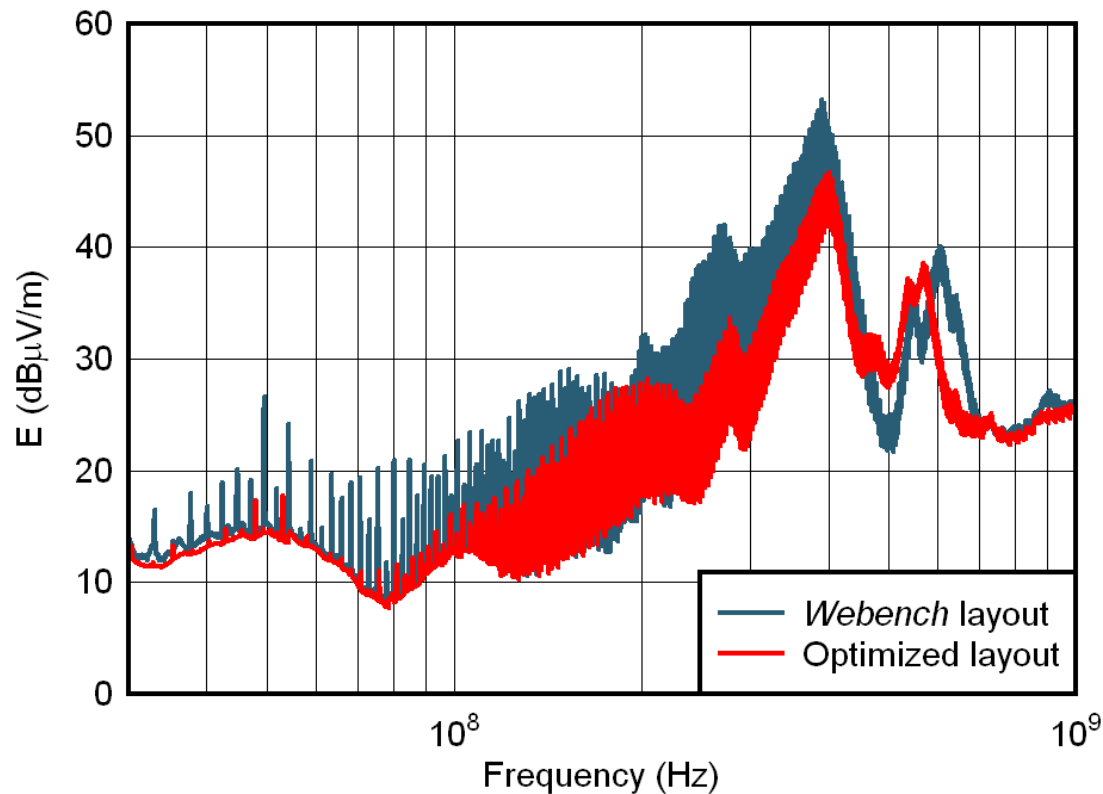
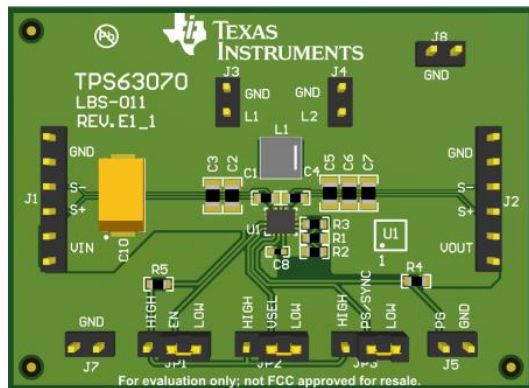
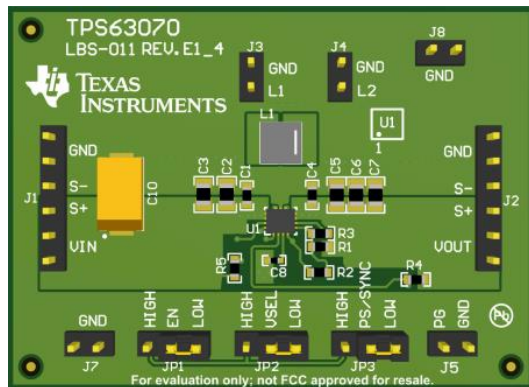


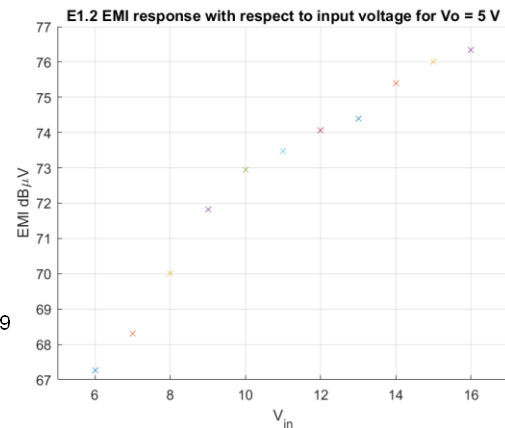
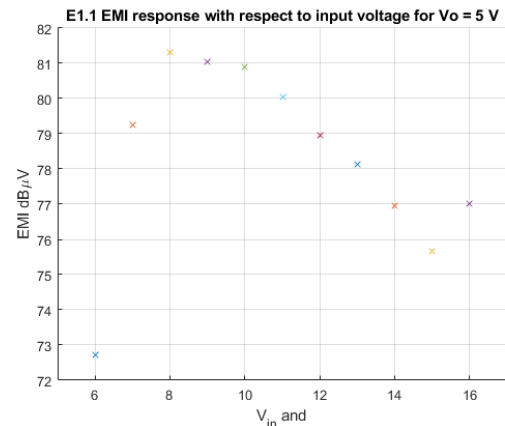
# Layout for low EMI

- Start with hot loops
- Use shielding effects
- Use 4 layer board with specific layer stackup
  - Thick center core material
  - Outer layers shield hot loops/important nodes
- Placing small high-frequency caps close to input and output pins might be helpful

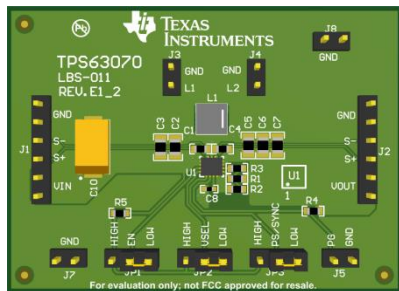
# REAL WORLD EXAMPLE WITH TPS63070

# Fast Created Layout compared to Good Layout

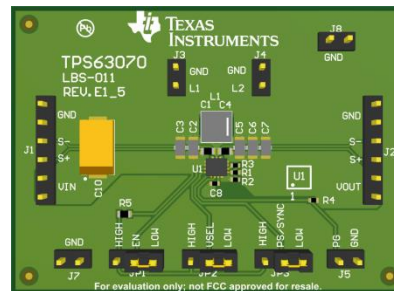
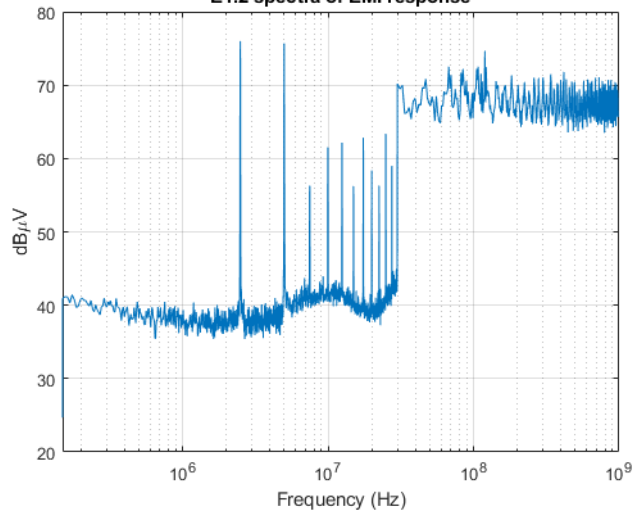




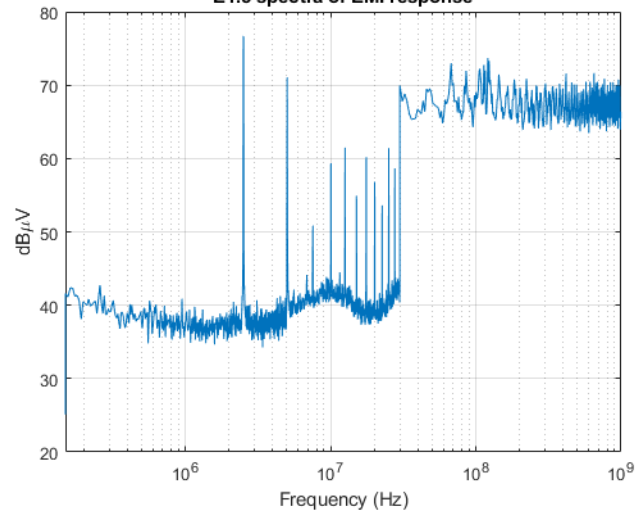
# Good Layout compared to Minimum Size



E1.2 spectra of EMI response

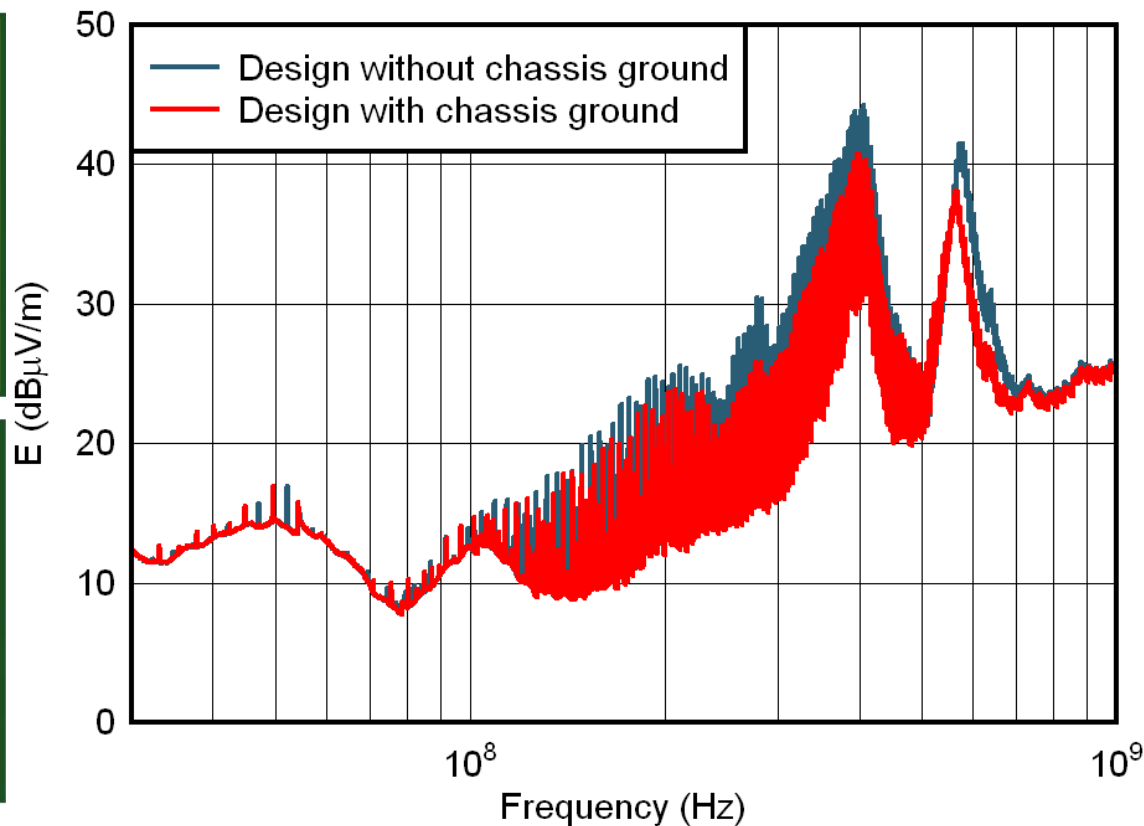
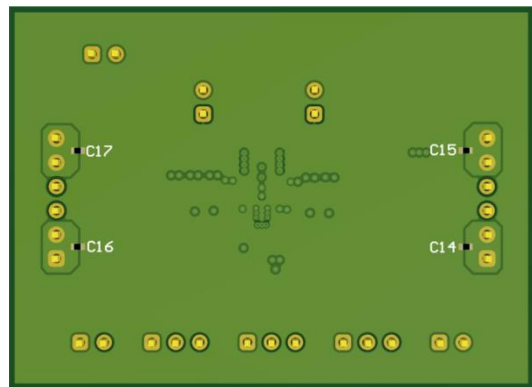
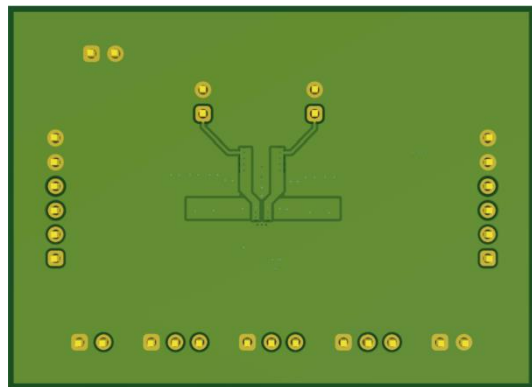


E1.5 spectra of EMI response





# Good layout without and with Chassis GND



# Buck-Boost Tools and Links

- EMI
  - [Layer Design for Reducing Radiated EMI of DC to DC Buck-Boost Converters](#)
  - [Layout Tips for EMI Reduction in DC/ DC Converters](#)
- Buck-boost Converter Technical Content Summary
  - [A Topical Index of TI Low-Power Buck-Boost Converter Application Notes](#)

- Hardware Development Kit
  - [TPS63802HDKEVM](#)



- Standard operation
- Backup power supply
- High-side LED driver
- High-side LED driver with dimming option
- Input current limit
- Extended soft start or limit inrush current limitation
- Digital voltage scaling
- Output voltage tracking
- Bypass mode
- Precise enable and start-up delay



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