Automotive Lighting Design and EMI Best Practices

Ralf Ohmberger, Applications Engineer, MPS

Francesc Estragués, Applications Engineer, MPS

June 2020

MPS

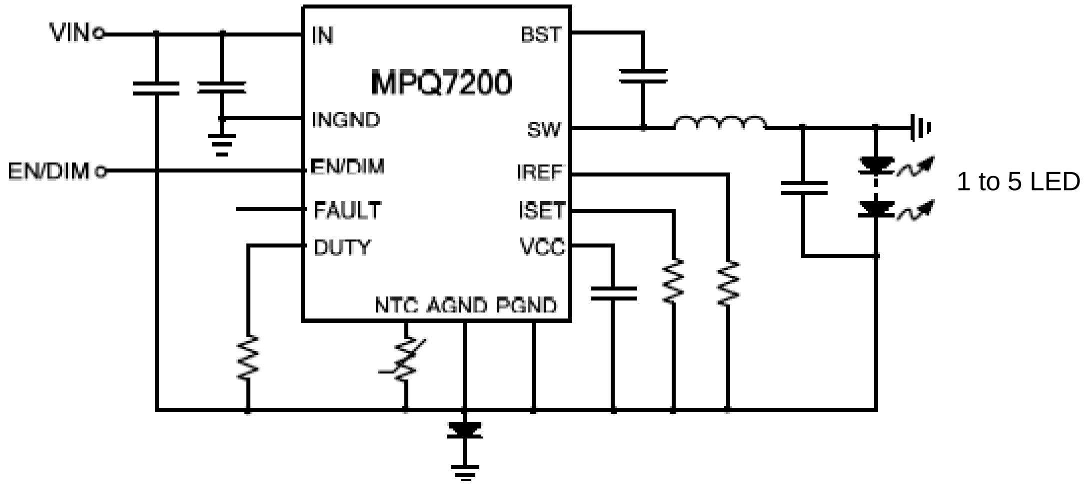
Agenda

- Introduction
- What Is So Tricky about Lighting Power Supplies?
- Improving the Design at the Schematic Level
- Component Selection
- Tips to Solve EMC Issues with Good Layout
- Layer Stack
- Open Q&A

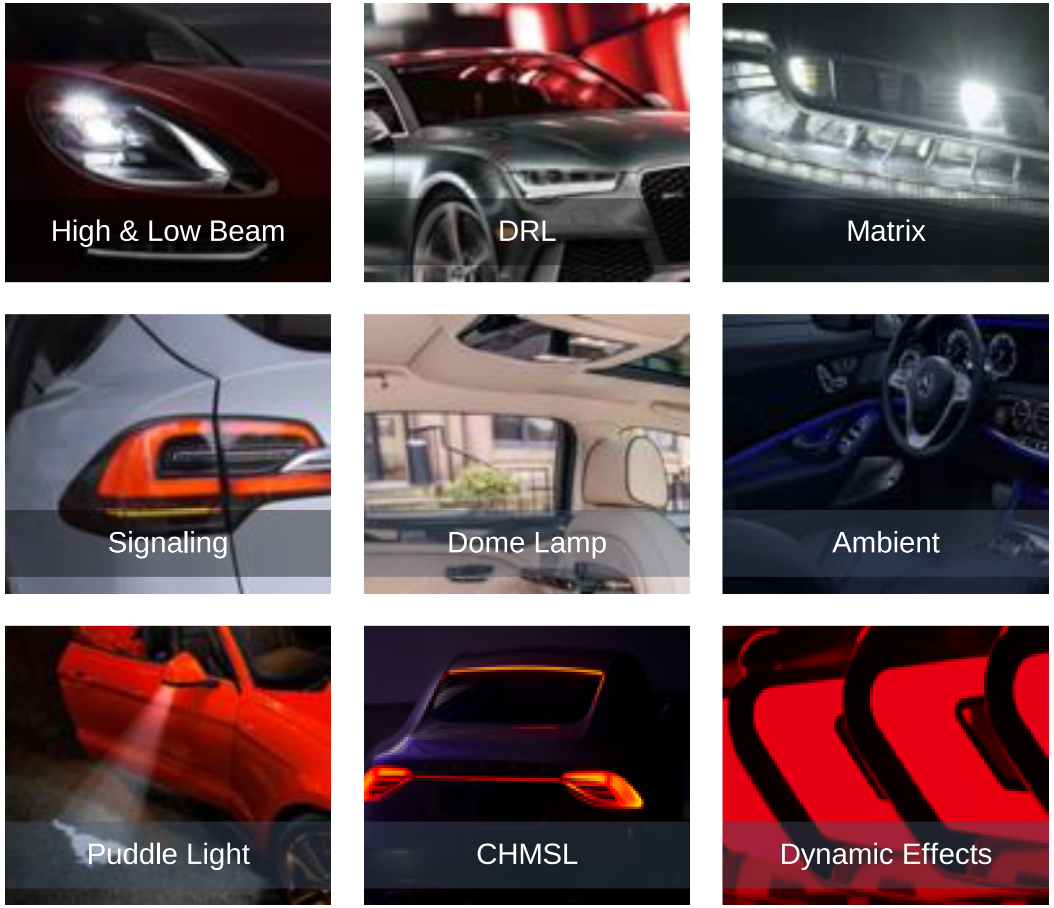
Introduction to Automotive LED Lighting

LED lighting is gaining popularity in the automotive market because it offers:

- High efficiency
- Flexibility of design
- Dimming and dynamic signalling
- More control



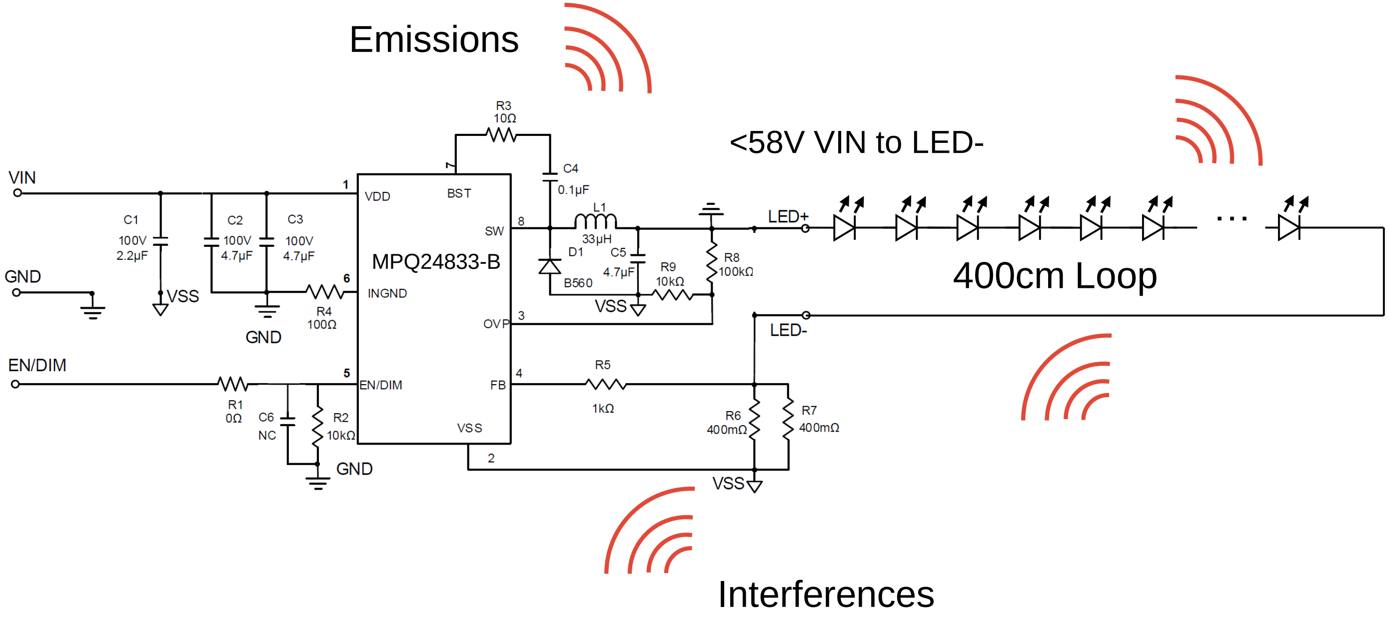
Example of an SMPS for LEDs



LED Lighting Applications

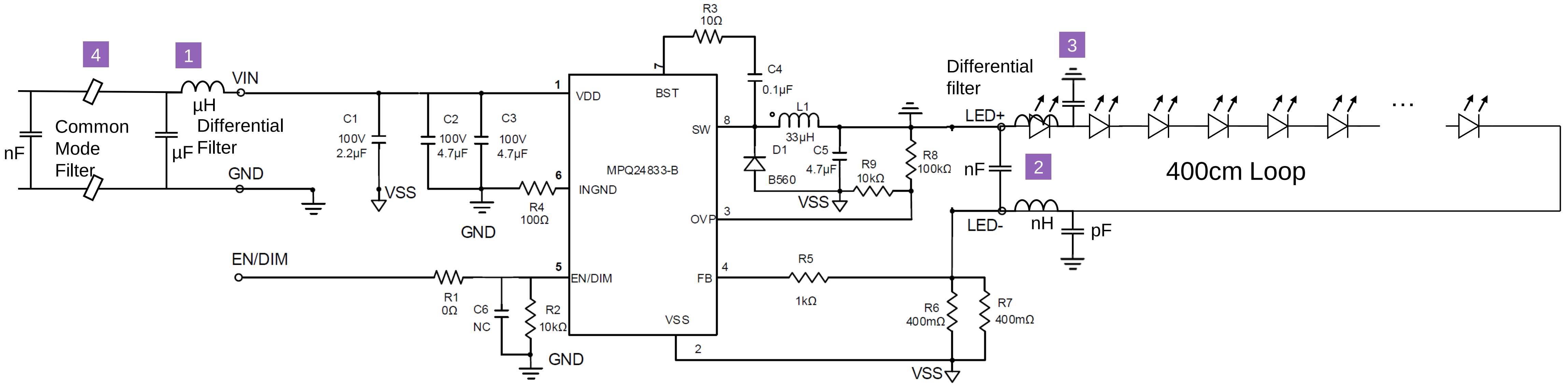
What Is So Tricky about Lighting Power Supplies?

Great design brings interesting challenges.



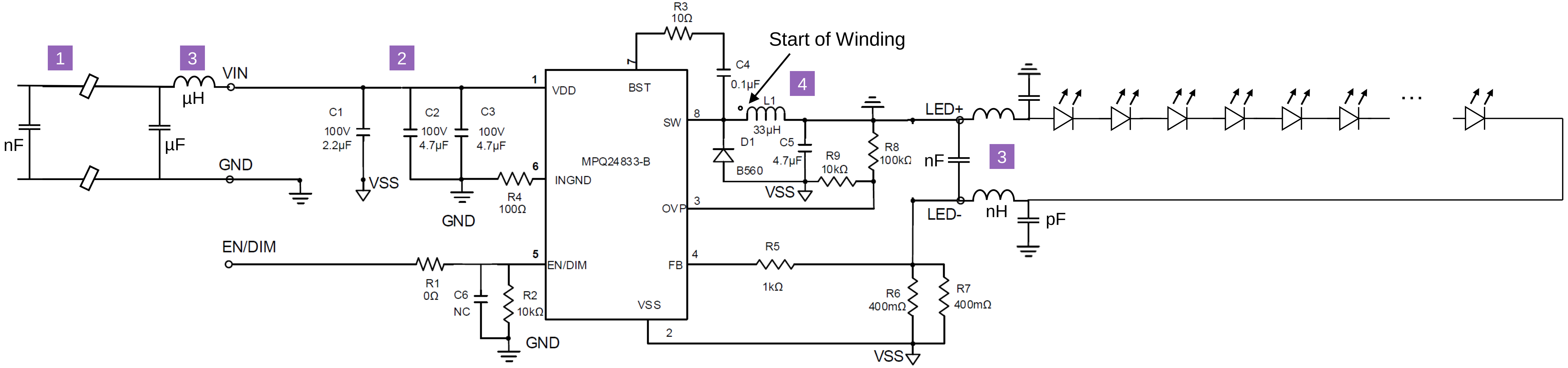
MPS

Improving the Design at the Schematic Level



1. A differential mode input filter attenuates the fundamental frequency and low-frequency harmonics.
2. The output filter provides two-fold benefit in preventing that noise from the converter from radiating through the LED harness, and that the noise picked up in the LED harness is transferred to the system.
3. These capacitors help reduce common-mode noise.
4. If common-mode noise is a problem, two ferrites in the input PWR and GND lines can help supress it, and are more convenient than a common-mode choke.

Component Selection



1. Ferrite beads suffer greatly from DC current saturation. Apply a 66% or greater derating when choosing the part (e.g. 2A max on a 6A rated ferrite bead).
2. Capacitors are also affected by DC bias. In a typical car battery supply, 50V rated capacitors are used. When inverting power supplies, the voltage across VDD and VSS can be very high, so 100V capacitors are recommended.
3. Filter inductors should be between 220nH and 4.7µH as a trade-off between performance, size, and R_{DC}.
4. The power inductor is a major source of E-field radiation, an small, flat coil is recommended. The coil's start of winding can be a 6dB difference from changing orientation 180°. Usually marked with a dot.

SimSurfing Tool by muRata which shows real capacitance value with DC bias over temperature

Tips to Solve EMC Issues with Good Layout

Important concepts:

$$\lambda = \frac{c}{f}$$

- The user only needs to be concerned with structures that are larger than λ/10 of the signals being worked with (signal tracks, enclosure openings, antenna structures, etc).

- Radiated immunity test injects signals up to 6GHz (λ / 10 = 5mm). This means that many tracks in a PCB are susceptible to picking up injected noise.

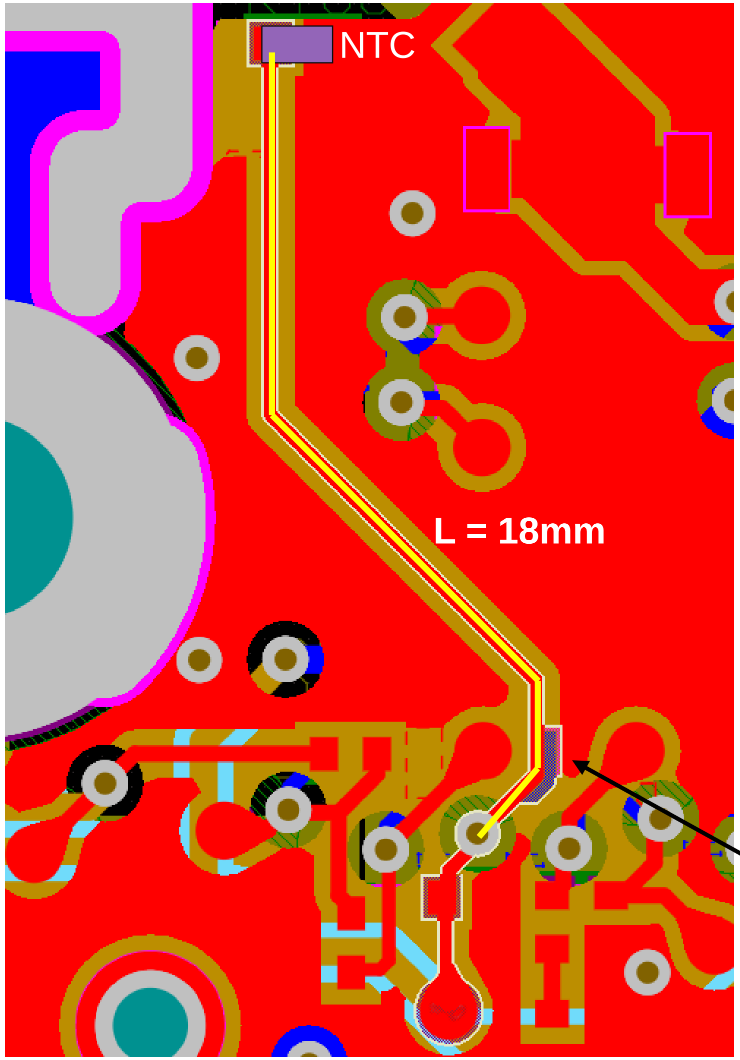
- Tracks longer than 5mm should be routed in the internal layers when possible, especially signals that connect to Hi-Z pins on the IC (feedback, enable, current setting, etc.).

- Whenever possible, use a 4-layer design. It allows for much smaller return paths, easier routing, and better thermals.

- Avoid cuts on return plane by close parallel vias. Instead, stagger and distance them to ensure correct copper flooding.

Tips to Solve EMC Issues with Good Layout

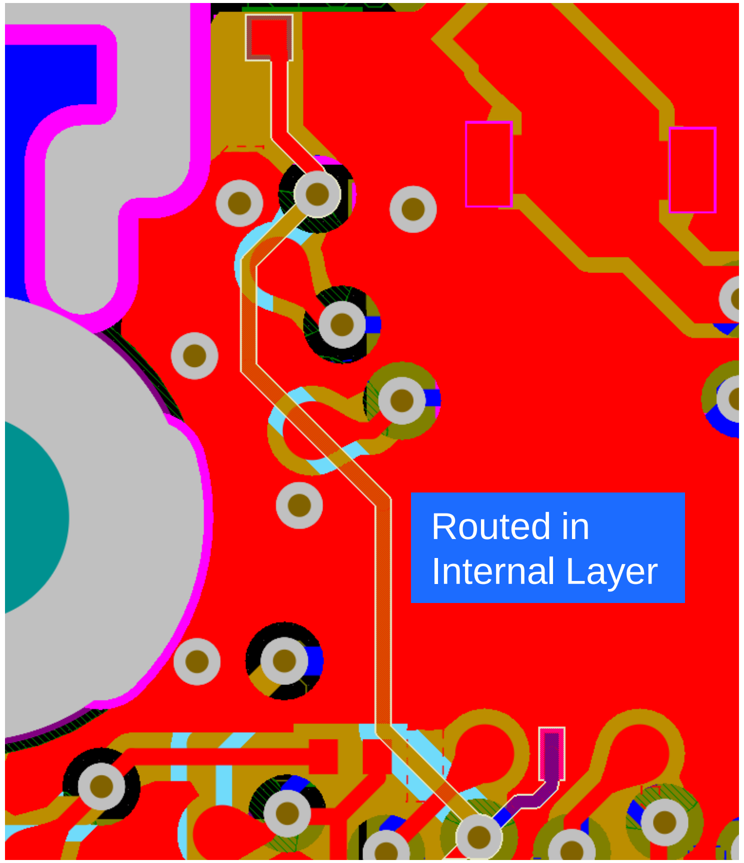
Not Recommended



$$f > \frac{300000}{0.018 \; x \; 10}$$

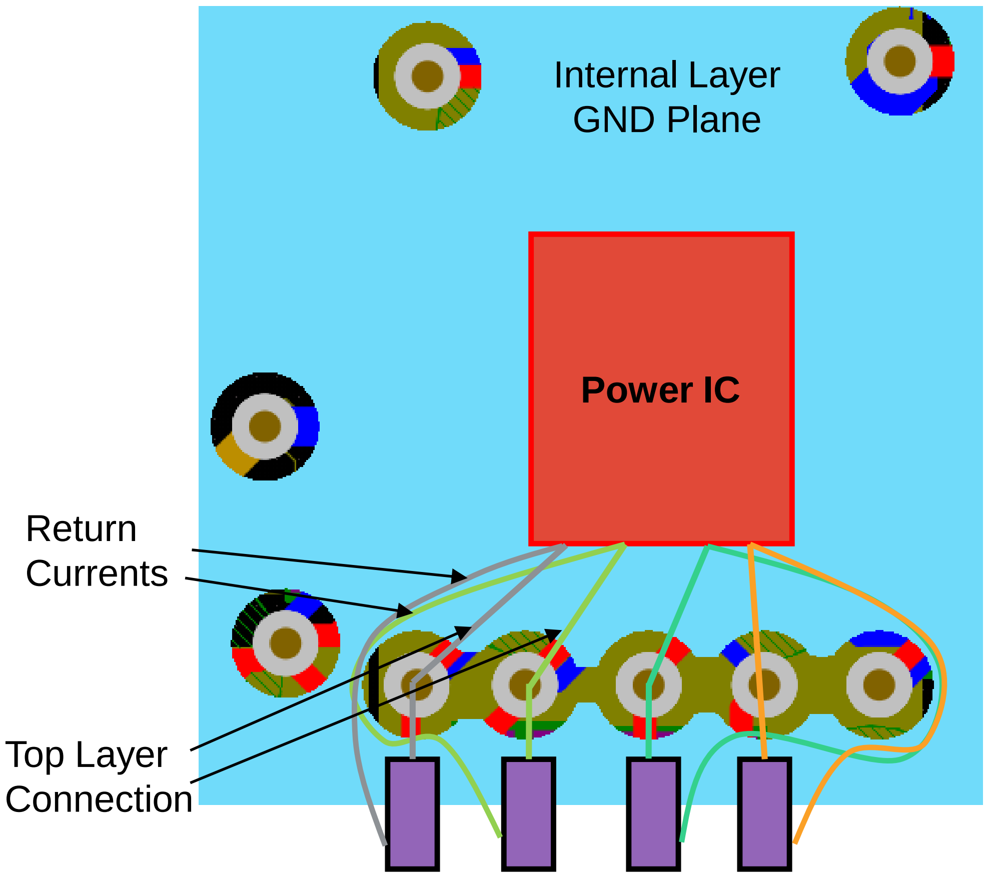
Potential issues occur with noise signals greater than 1.6GHz

Recommended



Tips to Solve EMC Issues with Good Layout

Wide Current Loops Due to Insufficient Via Spacing

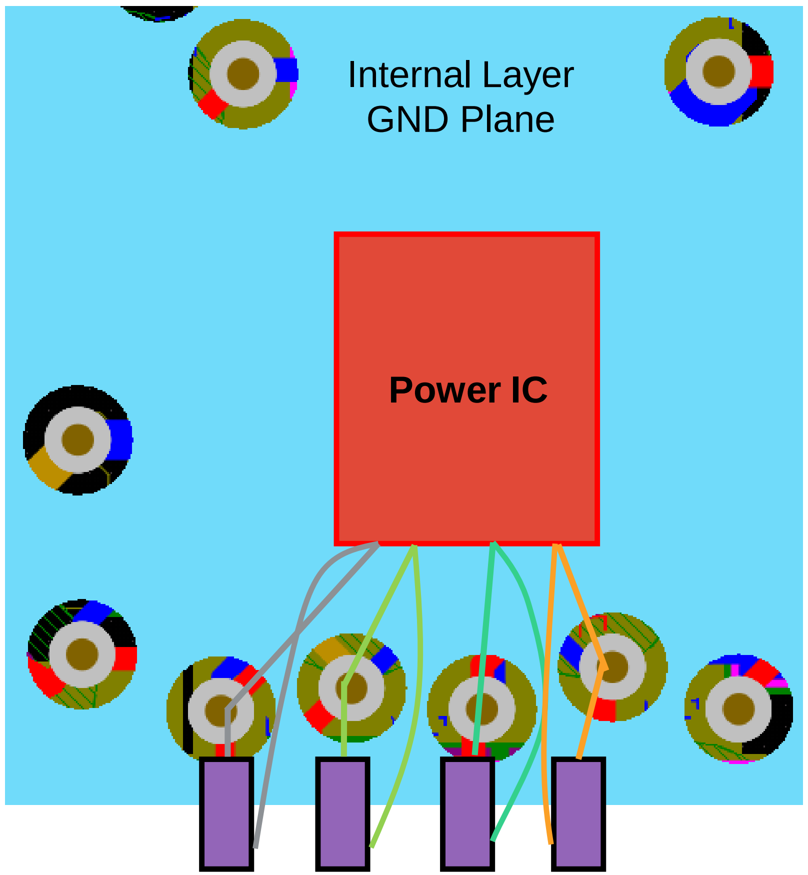


Overlapping return paths may create crosstalk

Wide signal loops tend to be susceptible to noise

Passive Analog Components

Sufficient Via Spacing

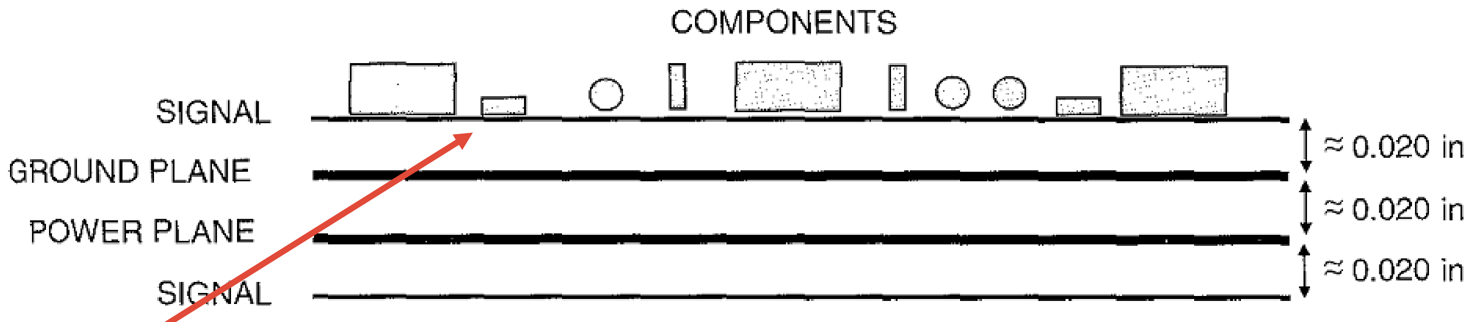


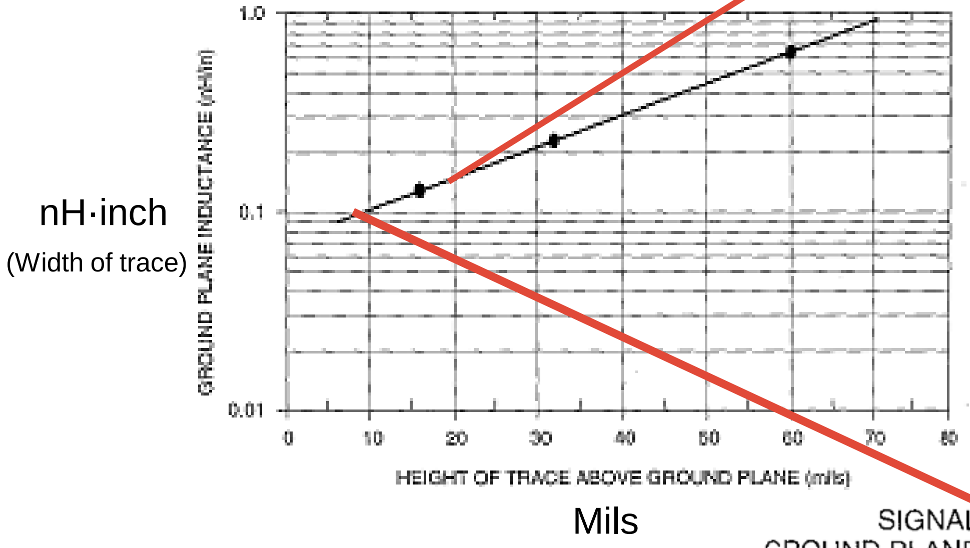
Enough spacing between vias allow for copper to flood between them

Layer Stack

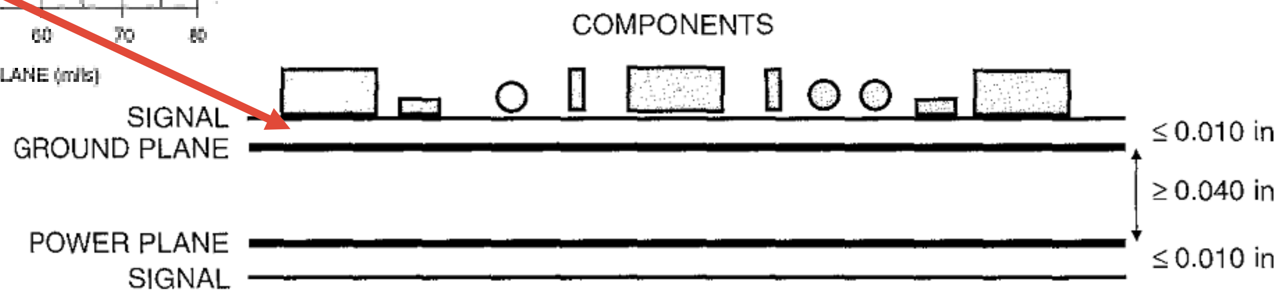
Inductance from any trace to its return plane depends on Prepreg thickness and trace width

At any point of a given signal trace, there is a certain amount of inductance to its return in the plane underneath



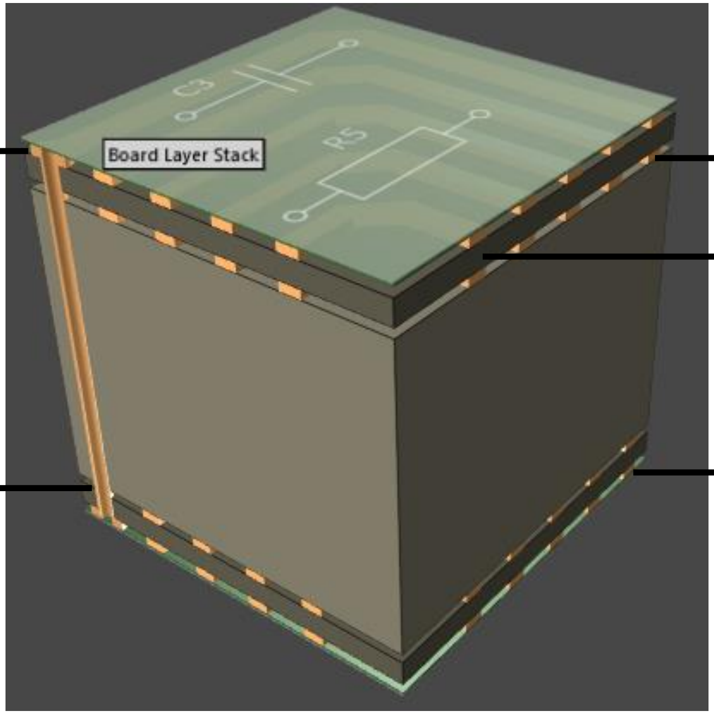


Use 50-250µm between signal Layer and GND plane!



Source: Henry W. Ott, Electromagnetic Compatibility Engineering, John Wiley, 2009

Layer Stack



Copper Thickness:

- External Layer: 70µm (2oz)
- Internal Layer: 35µm (1oz)

- By minimizing prepreg thickness the magnetic fields radiated by the converter are reduced.
- 70µm Cu thickness helps dissipating heat from IC to limit T_J rise in an automotive environment ($T_A \leq 125$ºC).
- Additional copper platting can be added to the external layers to further increase thermal performance.

MPS

Questions?