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The Perils of Right-Angle Turns at DC

Presenter: Istvan Novak

INTRODUCTION

- Common misconceptions
- A simple test
- The basics
- Why right-angle turns are bad at DC
- Possible remedies

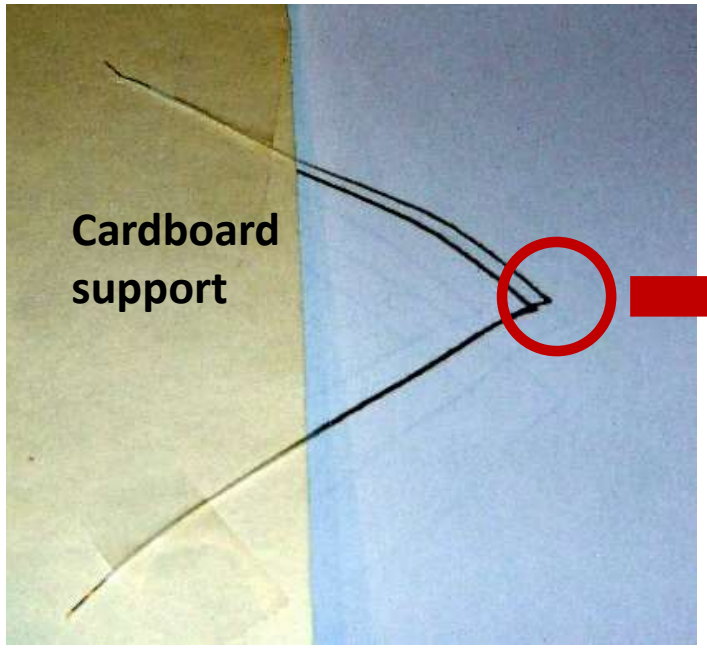
Common Misconceptions

Things at direct current (DC) are supposed to be easy, or maybe not?

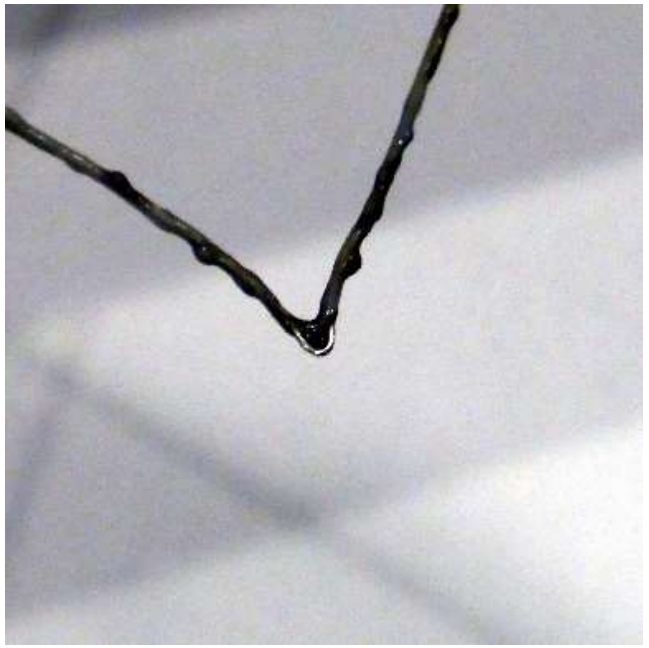
- At DC, current penetrates the conductor cross section uniformly 
- Doubling up plane shapes increases the current capability by 2x 
- Right-angle turns hurt only high-frequency or high-speed signals 

A Simple Test

30-gauge solid wire mounted at the edge of a cardboard sheet with (originally) white insulation with a sharp bend in the middle, after exposed to several ampere of DC current.



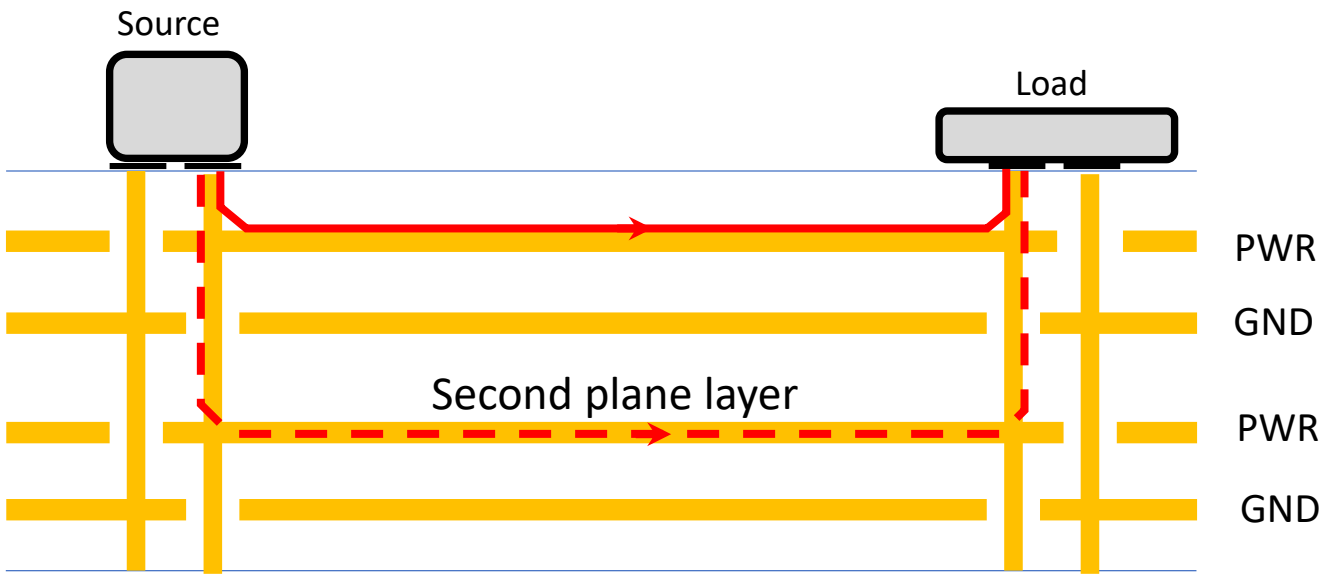
Full view



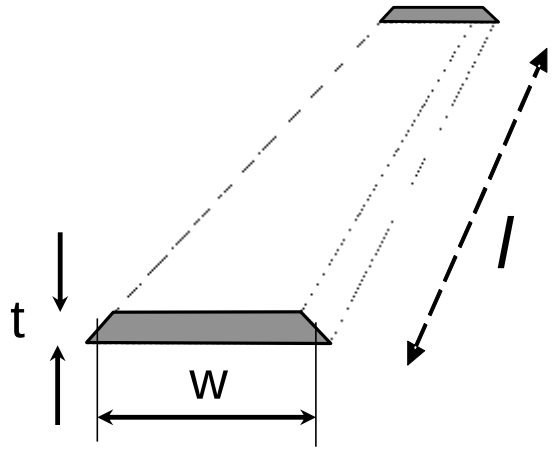
Close-up of the Bend

Misconception #2: Doubling Plane Shapes

- **Misconception:** Doubling plane layers increases current capacity by two-fold



Misconception #1: Current Density



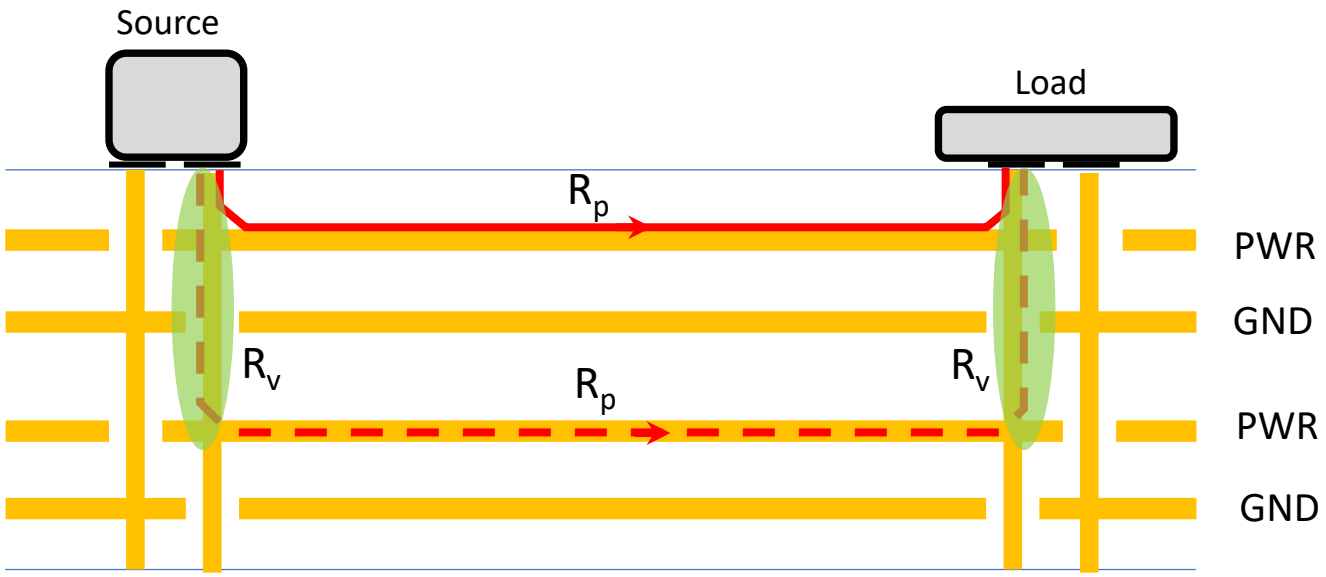
$$R_{DC} = \rho \frac{l}{wt}$$

- **Misconception:** Current density at DC is uniform
- **Truth:** True only if the current density is uniform through the connecting surfaces

Misconception #2: Doubling Plane Shapes

Truth:

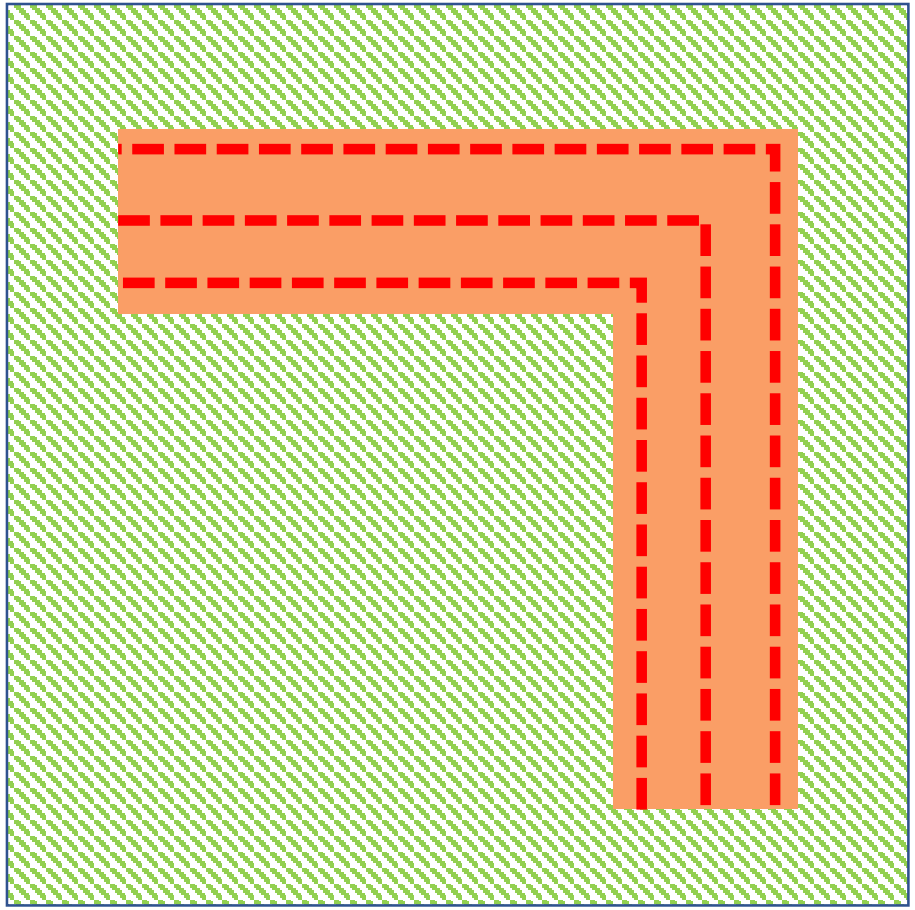
- Path length is unequal
- Upper path resistance: Rp
- Lower path resistance: Rp + 2* Rv
- Current sharing is not ideal

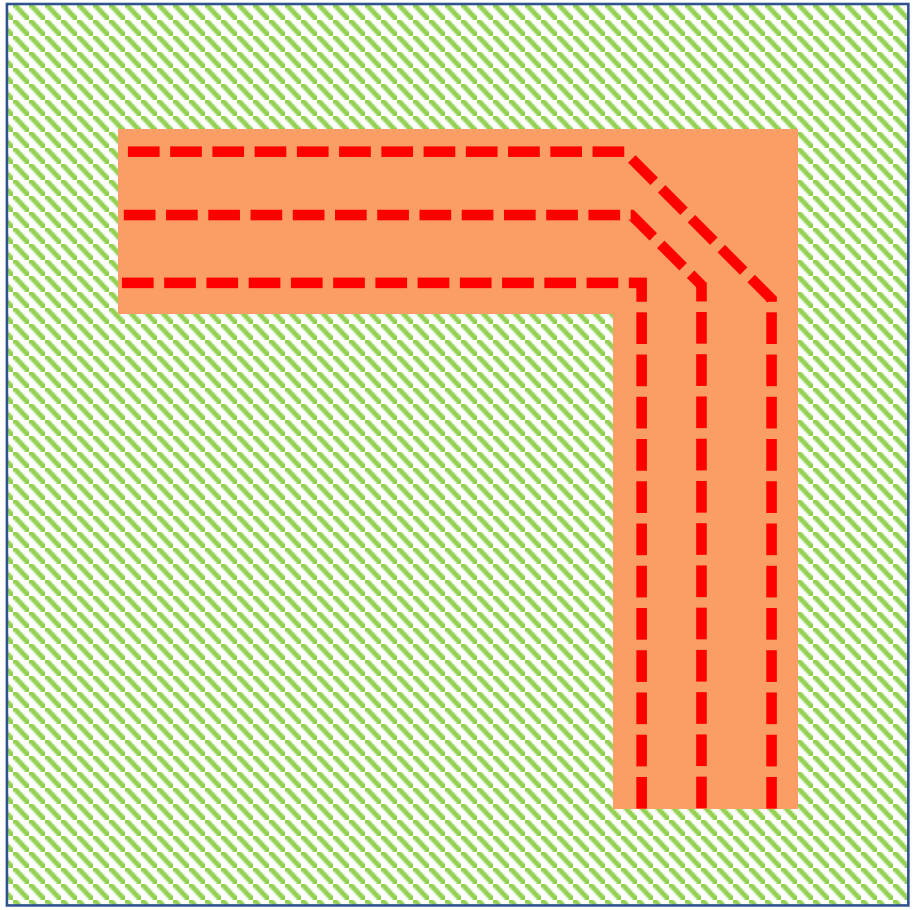


Misconception #3: DC at Right-Angle Turns

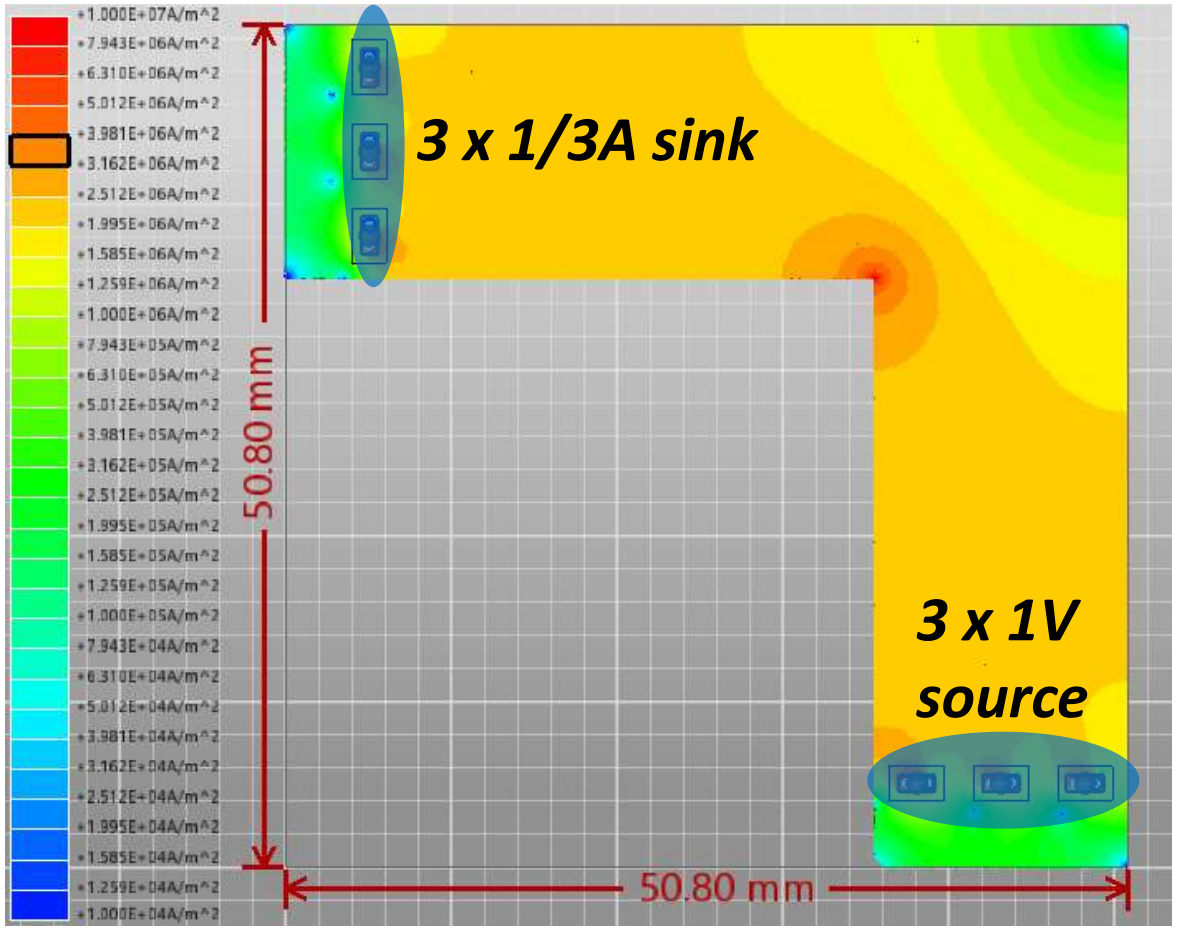
Misconception: Sharp turns are bad only for high-speed signals

Truth: Current crowds at sharp corners, resistance increases



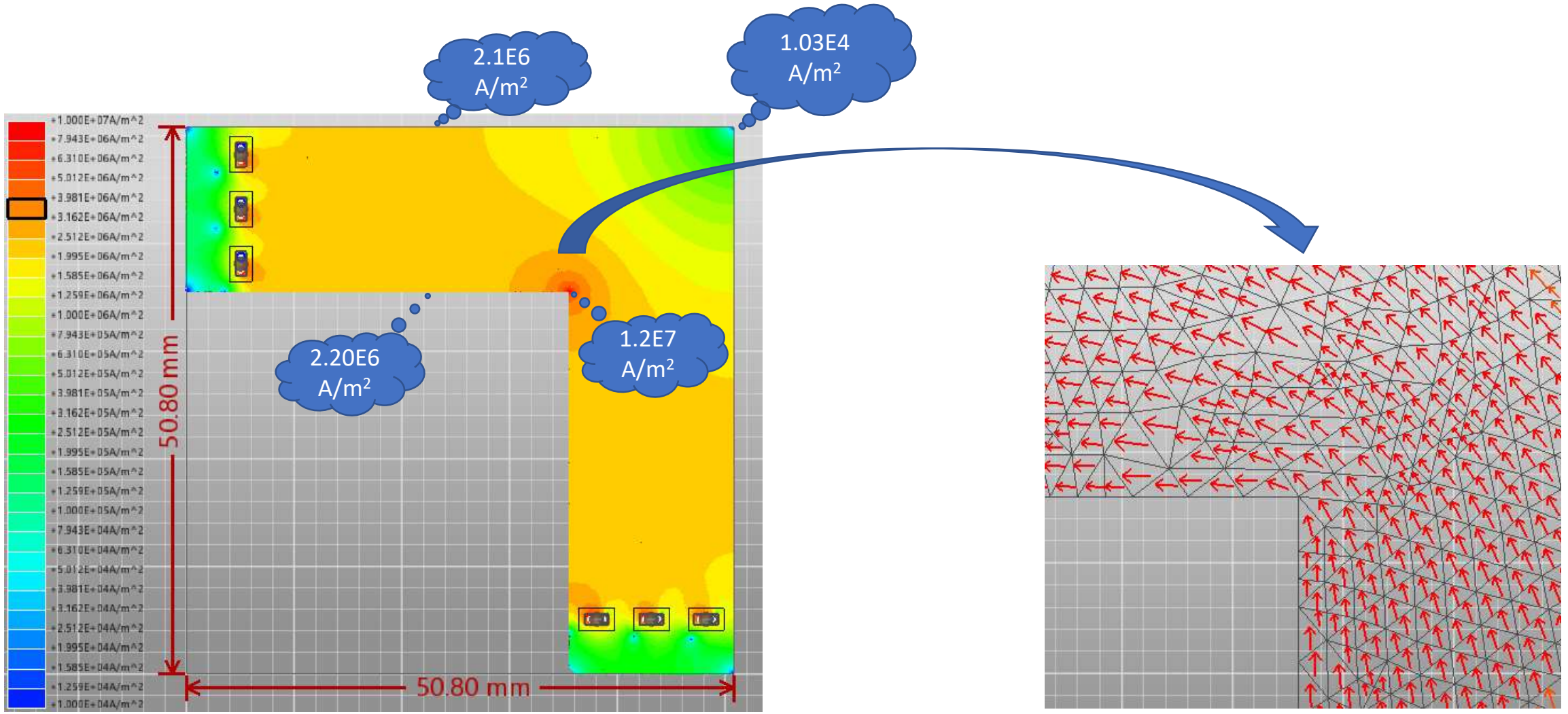


Misconception #3: DC at Right-Angle Turns

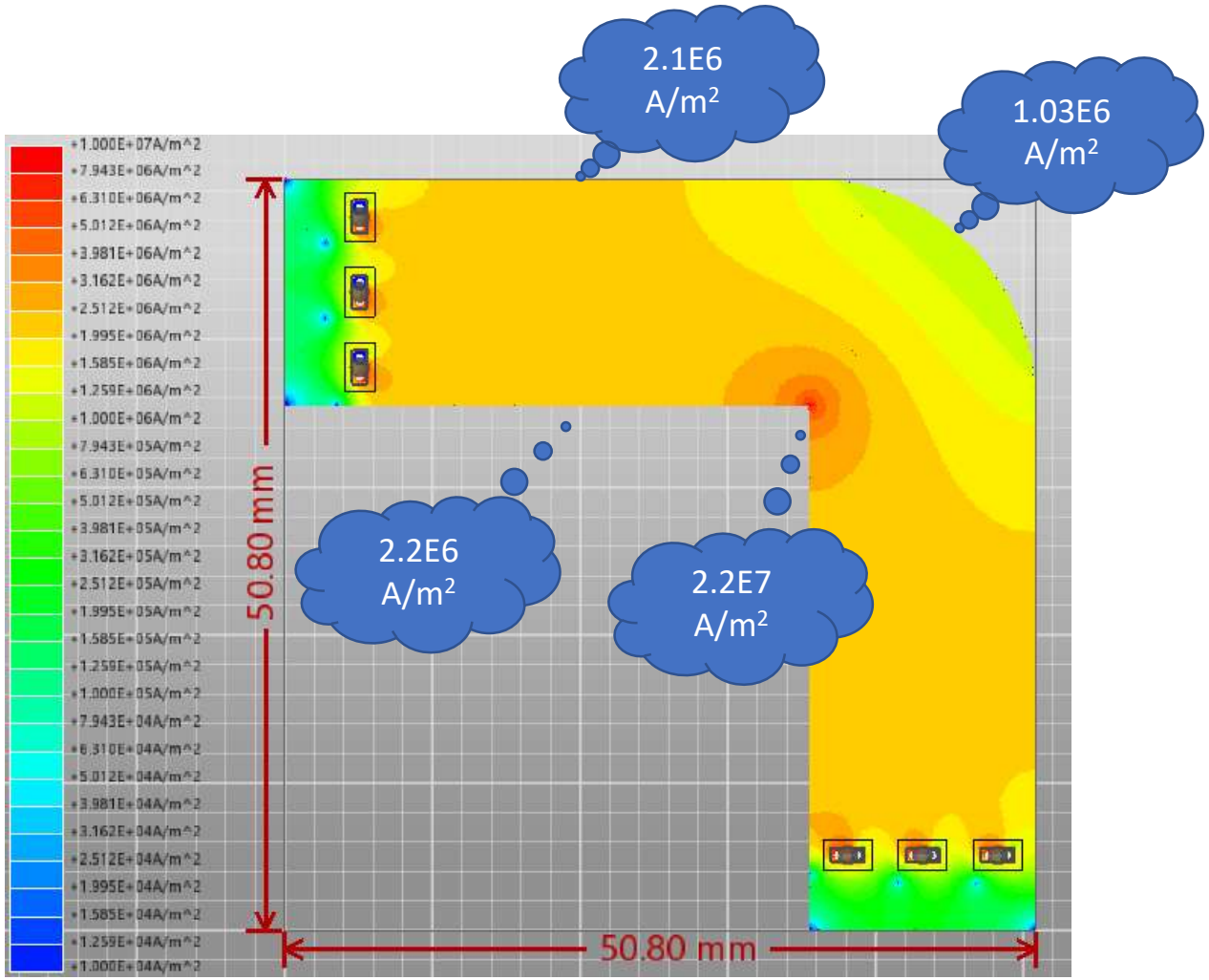


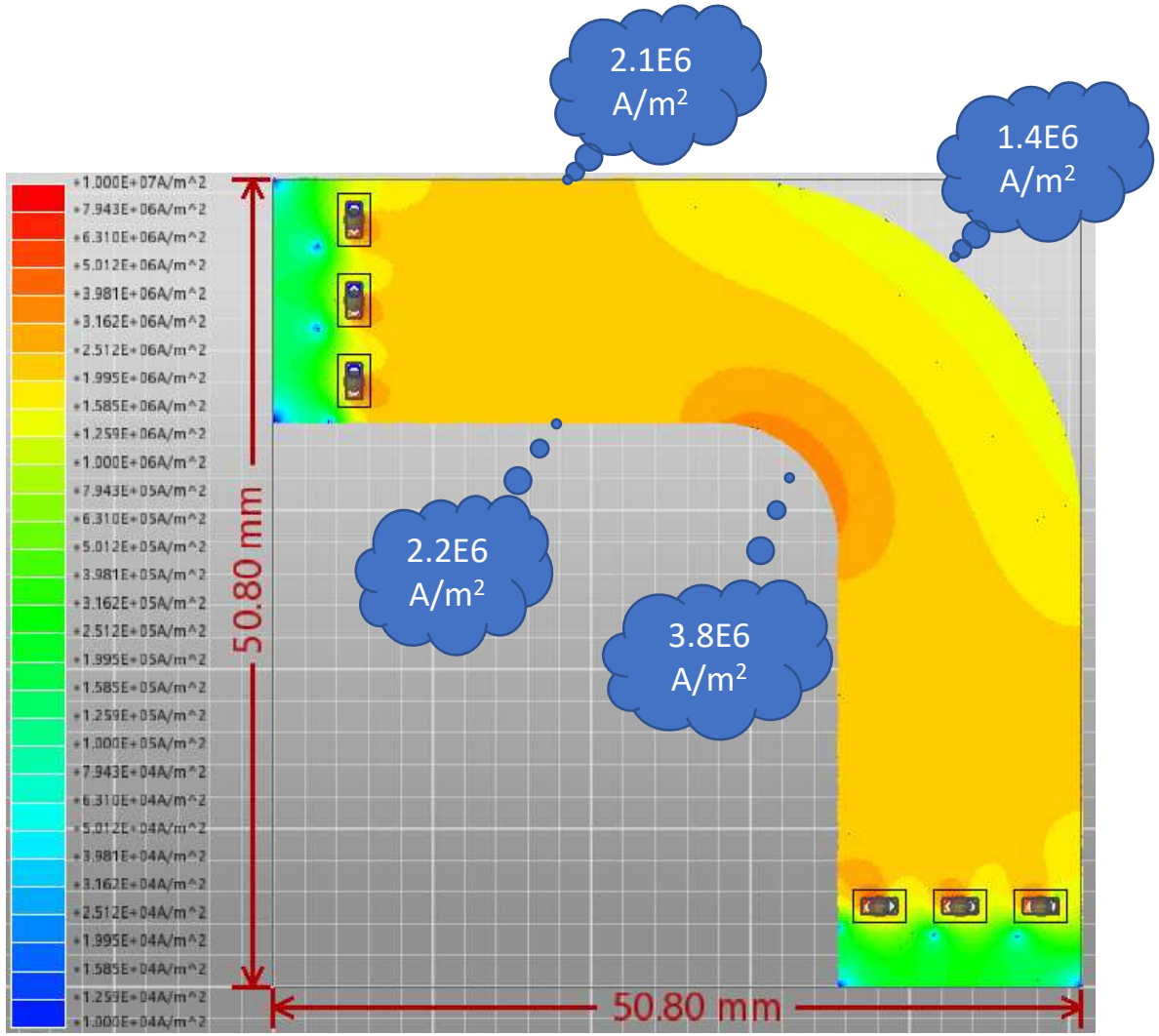
- Two-layer board
- Top layer: L-shaped POWER
- Bottom layer: square GND
- 30.5 µm copper
- 5.8E7 S/m conductivity
- Lower right: Three via pairs with three 1V voltage source
- Upper left: Three via pairs with three 1/3 A current sink

Misconception #3: DC at Right-Angle Turns



Misconception #3: DC at Right-Angle Turns

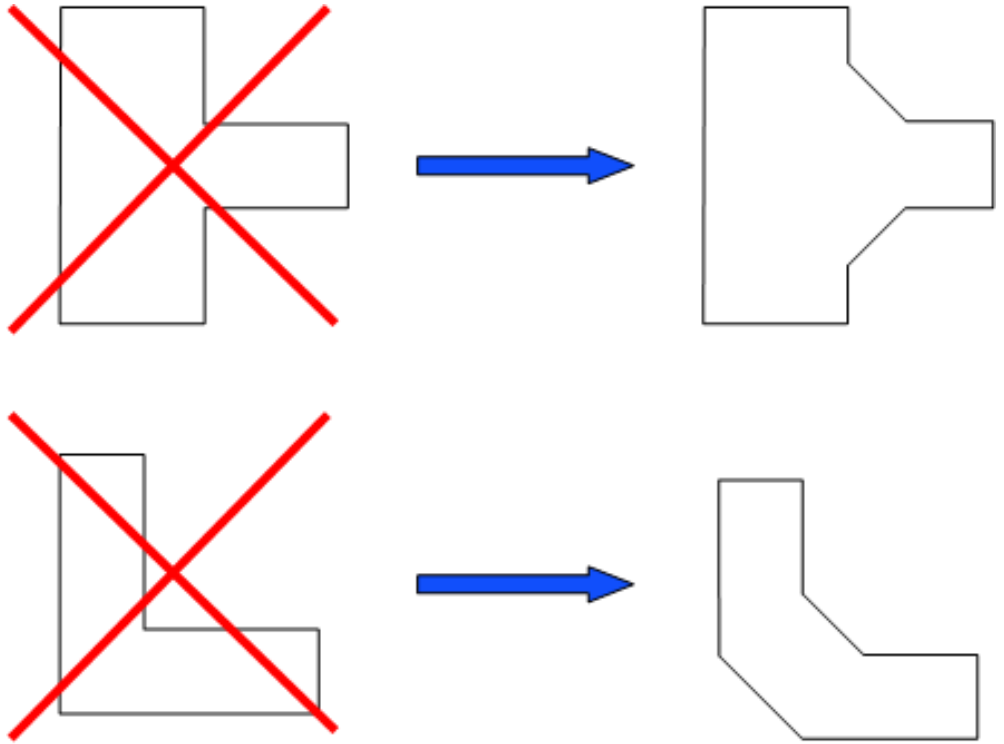




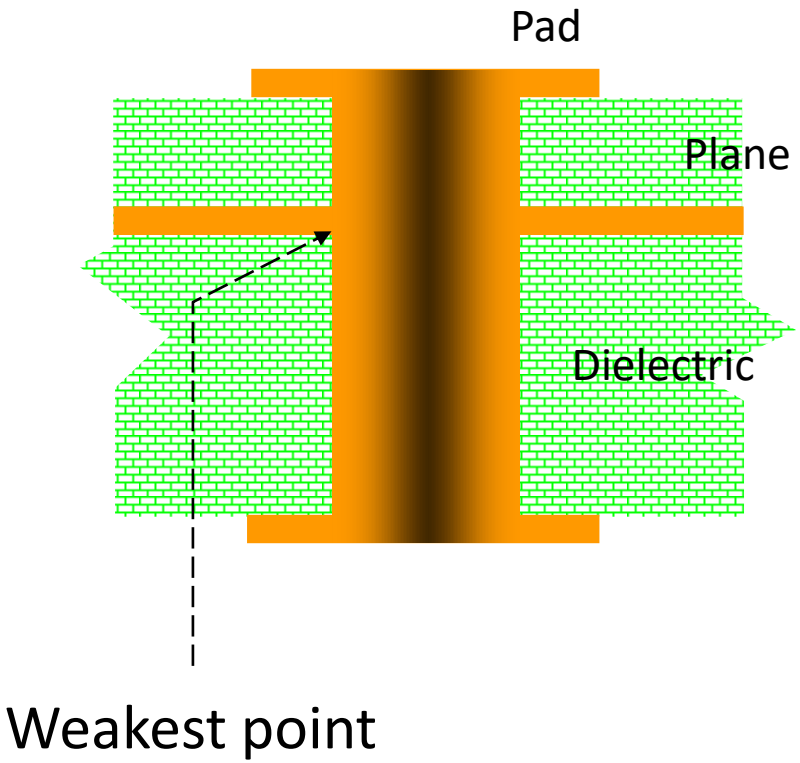
Mitigation Options

Avoid sharp corners:

- Use 45-degree increments, or
- Use arc



We Can’t Eliminate All Right-Angle Turns



Remember: In multi-layer PCBs there are a lot of right-angle turns at via-plane transitions (at the weakest point).

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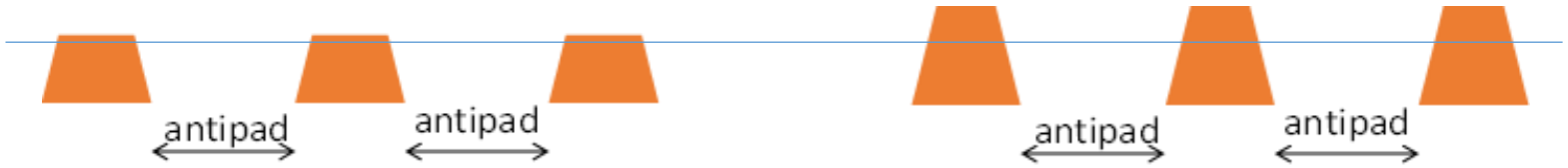
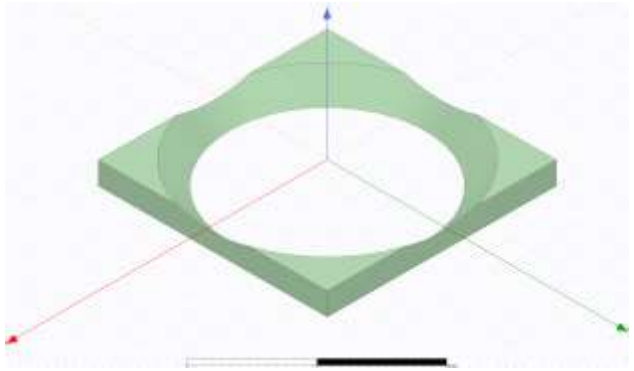
For Signal Integrity questions, contact: **SIG@samtec.com**

Backup

Etch Factor on Planes

Heavier copper leaves less copper on top

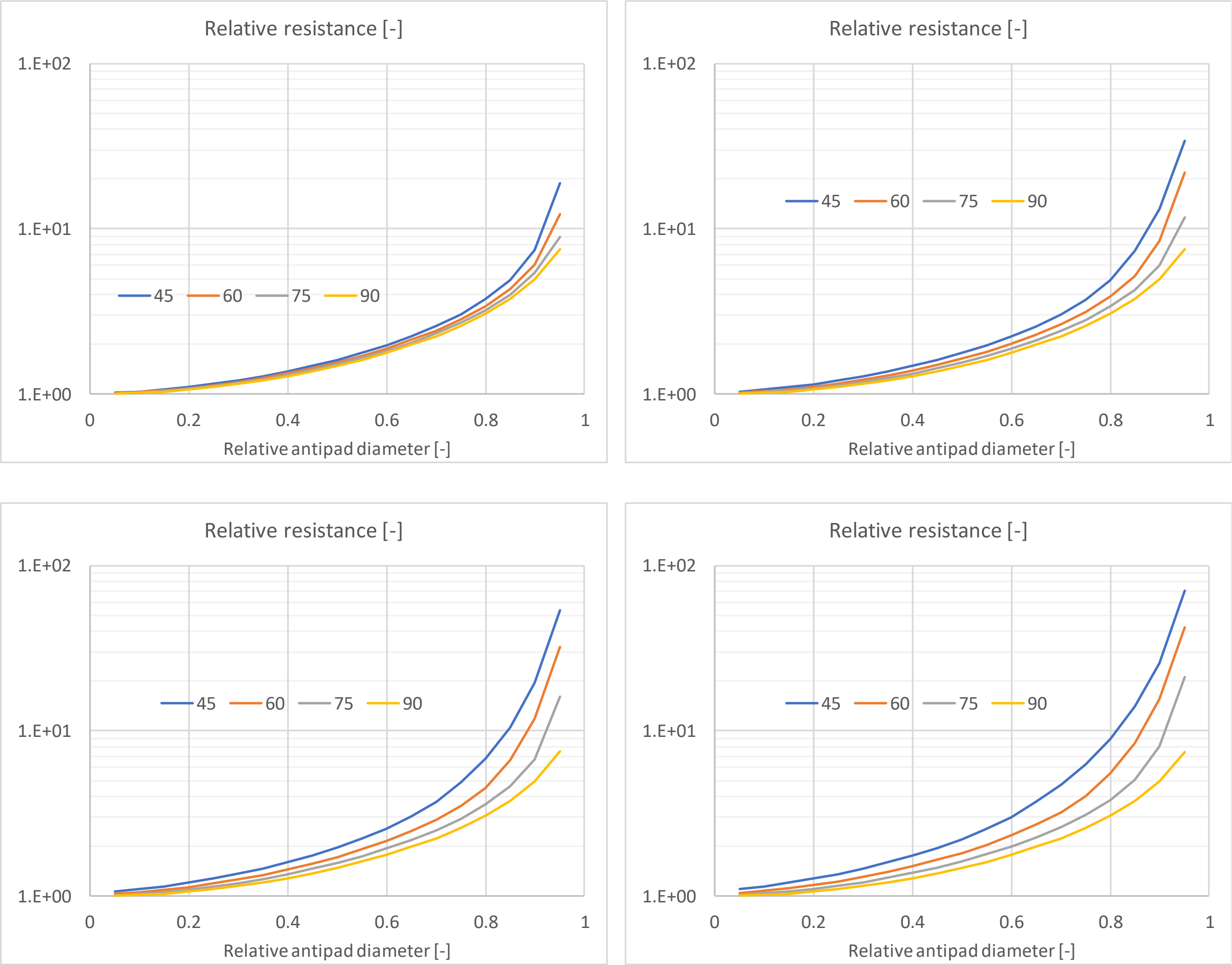




Name	Value	Unit	Evaluated Value
a	1	cm	1cm
metalThickness	0.1	cm	0.1cm
d1	0.85	cm	0.85cm
numFacets	0		0
etchFactorAngle	45	deg	45deg
etchFactorExt	metalThickness/tan(etchFactorAngle)		0.1cm
d2	d1+2*etchFactorExt		1.05cm

"Etch Factor Impact on SI&PI," DesignCon 2019

Etch Factor on Planes



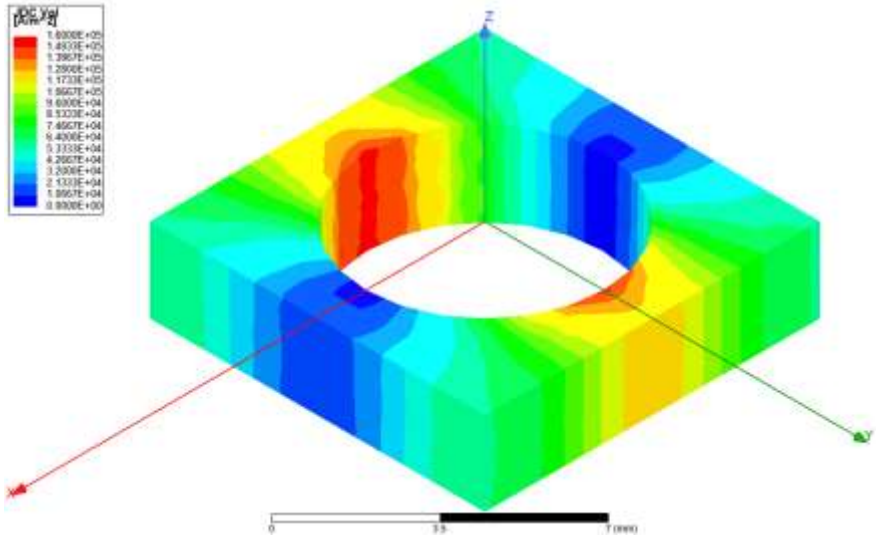
Resistance increase with respect to the sheet resistance of solid plane

“Etch Factor Impact on SI&PI,” DesignCon 2019

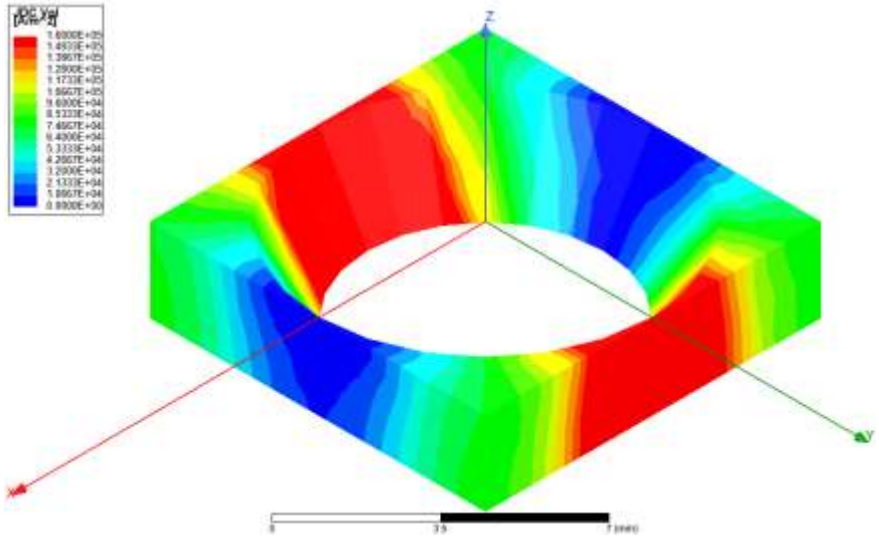
Etch Factor and Current Density

0.7(28mils) antipad diameter, 0.2(8oz) copper thickness

90-degree wall



60-degree wall

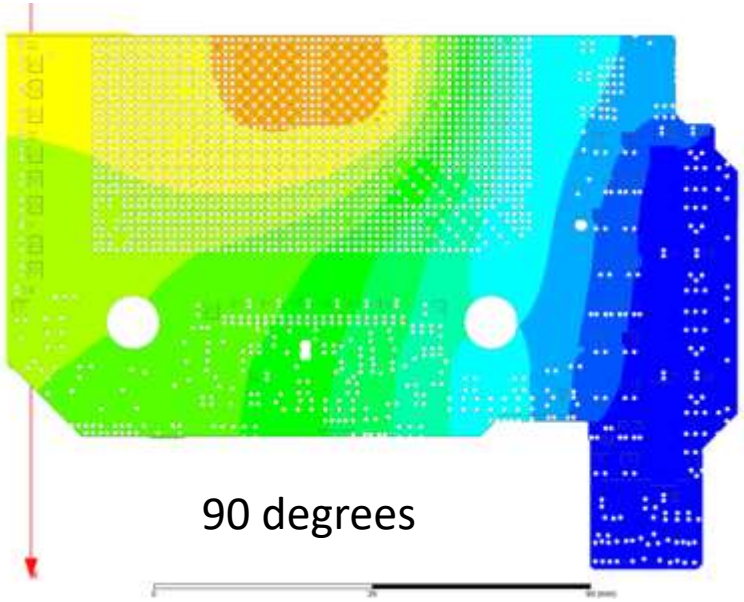


"Etch Factor Impact on SI&PI," DesignCon 2019

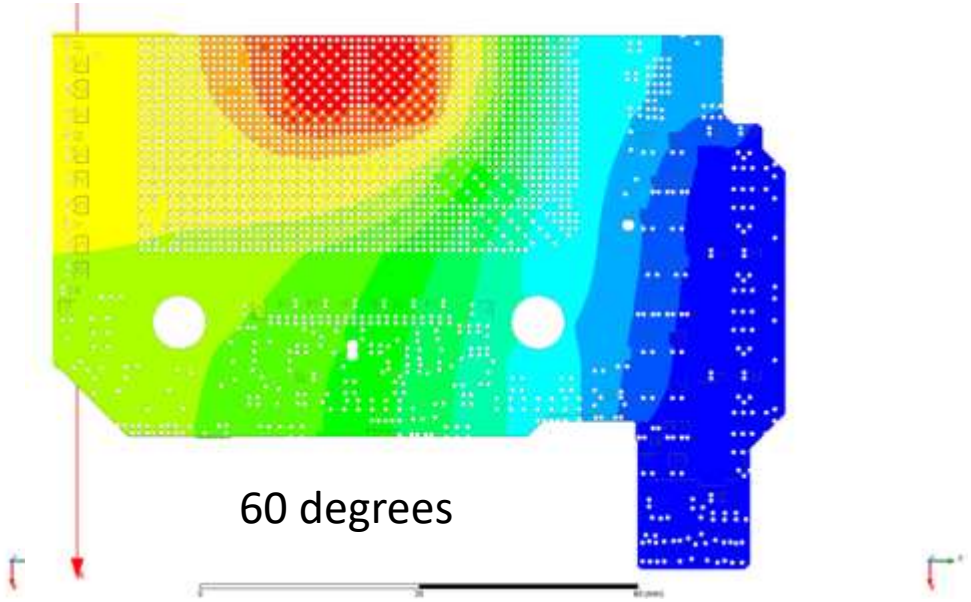
Production Board, Detailed Mesh

90deg >> 60deg etch factor makes 10% difference in resistance. Equivalent to rising the PCB temperature by 25C

0.155 mOhm



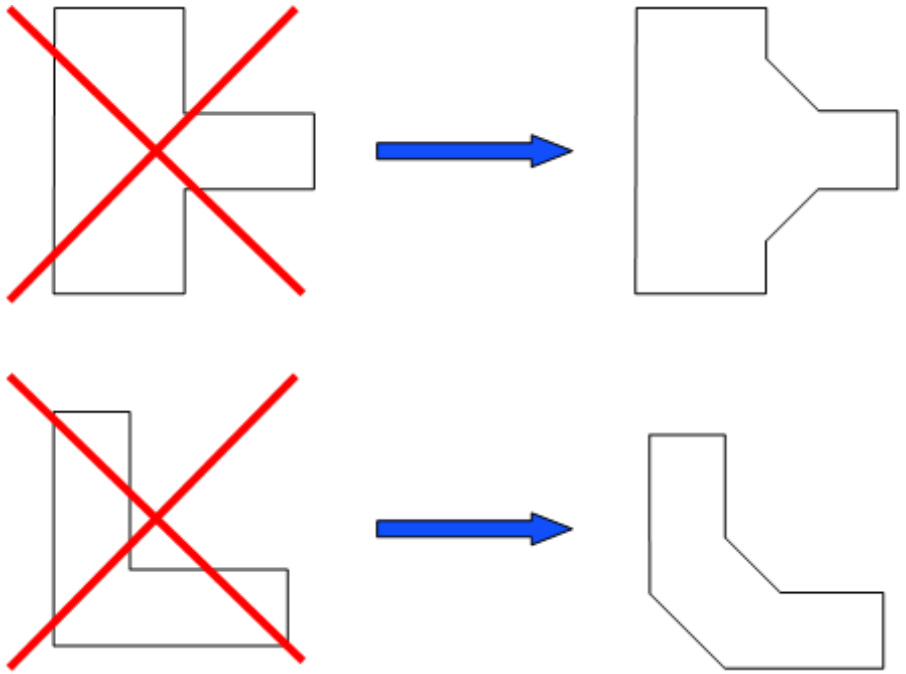
0.173 mOhm

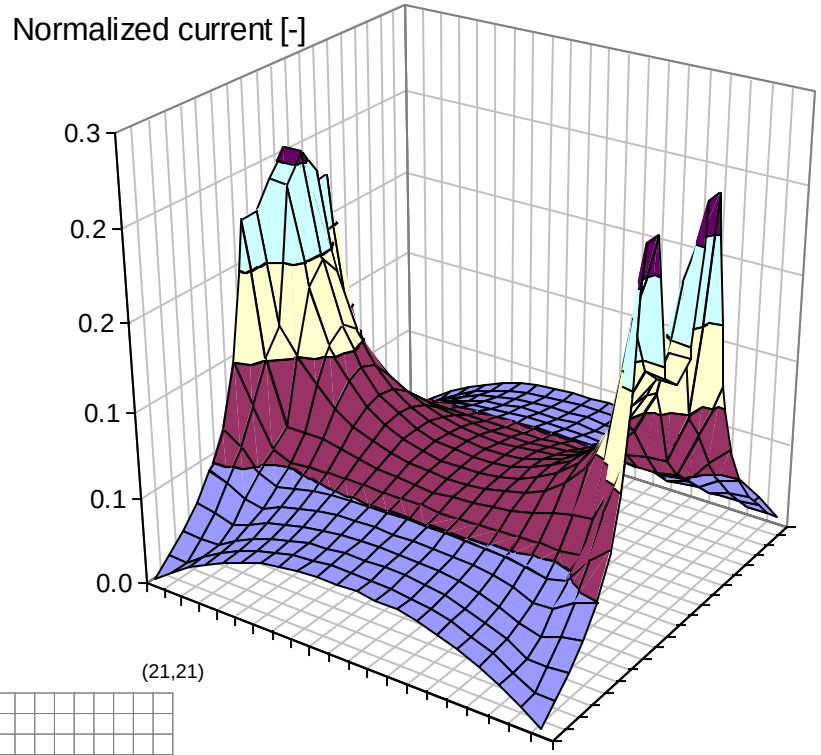


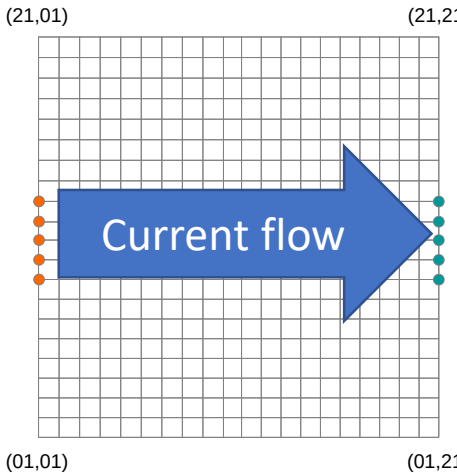
"Etch Factor Impact on SI&PI," DesignCon 2019

Mitigation Options to Reduce DC Loss

- Avoid sharp corners
- Make plane wider perpendicular to current flow
- Feed loads from multiple sides







Mitigation Options to Reduce DC Loss