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The Magic Behind The Ground Symbol Finally Demystified!



The simplest possible solution to speed up your time to market!

Francois Gagnon, Eng, PMP

Founder @ Mobius Électronique | Electronic

Quick Word About Mobius Electronic





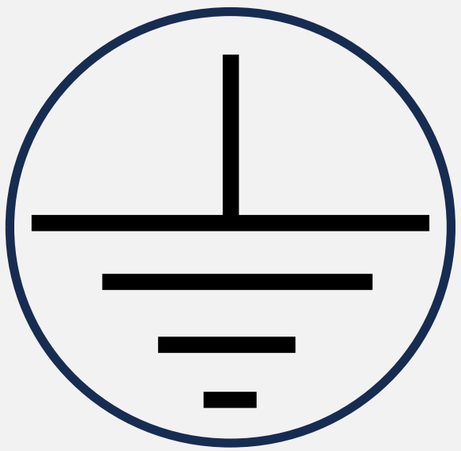
We accelerate our customer product time to market with either our product line or electronic and embedded software design services.

We specialize in high end instrumentation and high compute applications.

Agenda

1) Establish a Common Ground Knowledge!
2) Ground Split or Single Ground.
3) Conclusion.

Introduction



Of All the Conductors Used in Interconnecting Electronics, the Most Complex is the One That is Generally Ignored – The Ground!

Henry W. Ott, June 3rd 1997

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Let’s Start On a Common Ground!



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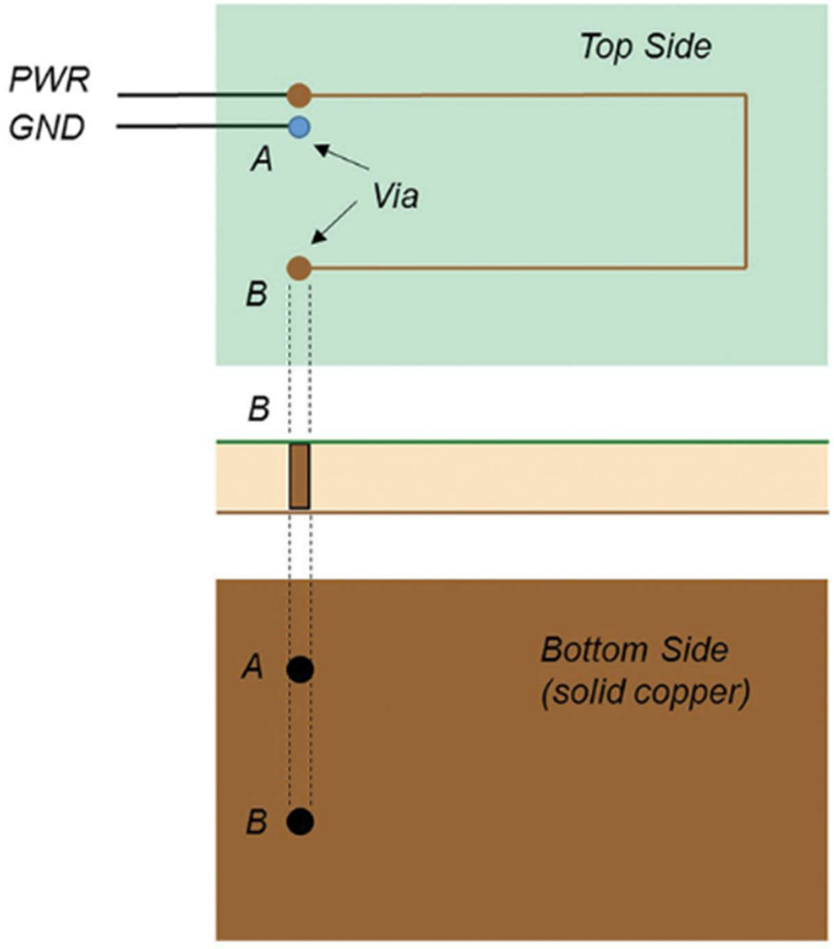
Ground Definition

An Equipotential Point or Plane That Serves as a Reference Potential For a Circuit or System.

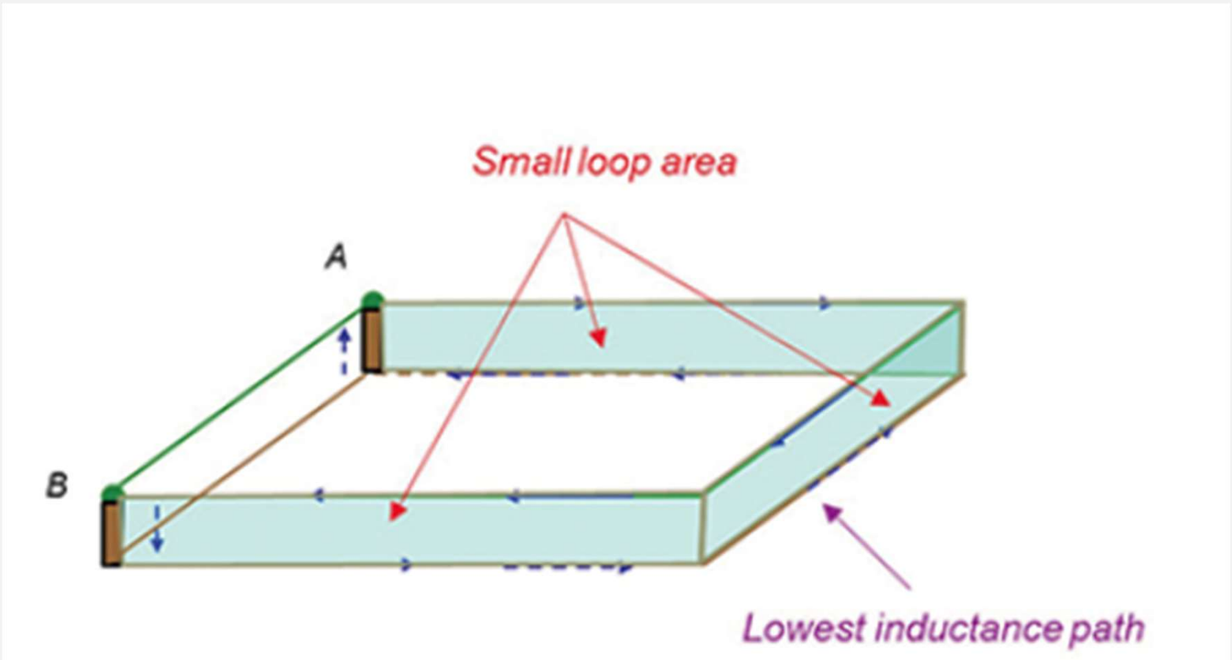
In Reality Two Physically Separated Ground Points Are Seldom, if Ever, At The Same Potential!

The ground is not a current sink!

Current Path in Ground Planes

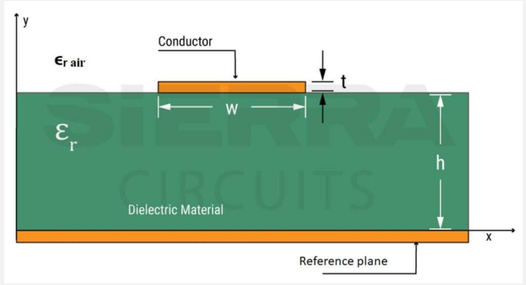


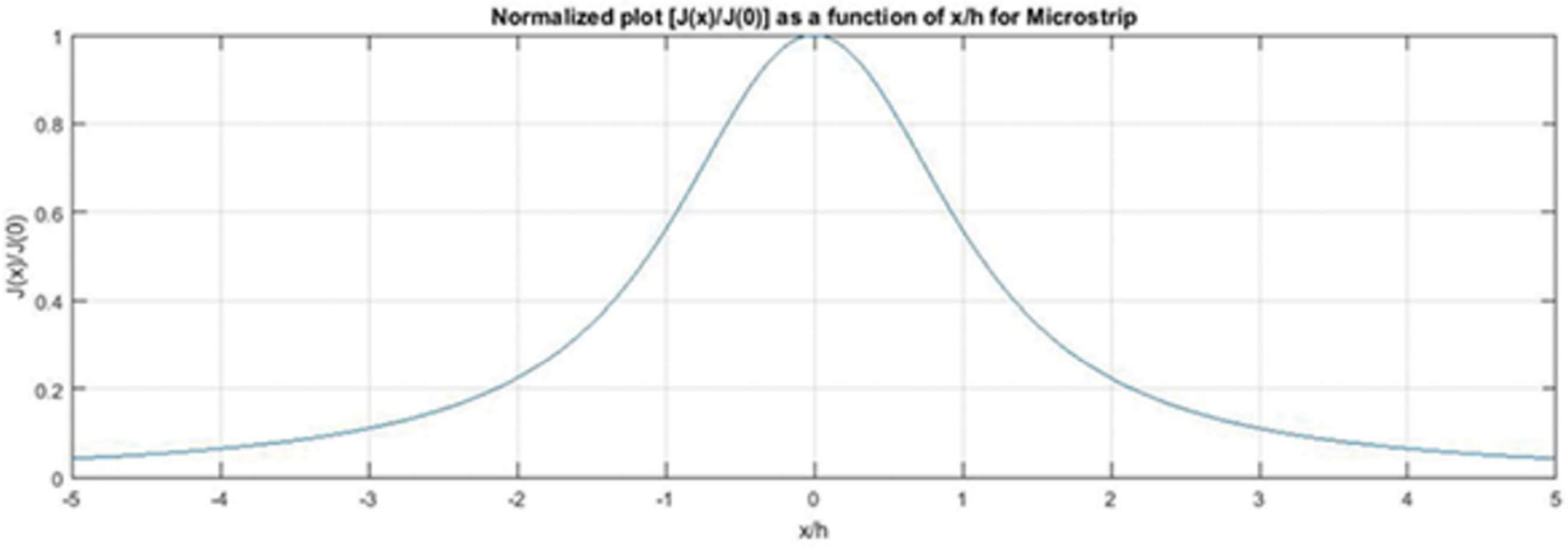
Current is Flowing Back to The Source by Following The Path of Least Impedance.



Current Density

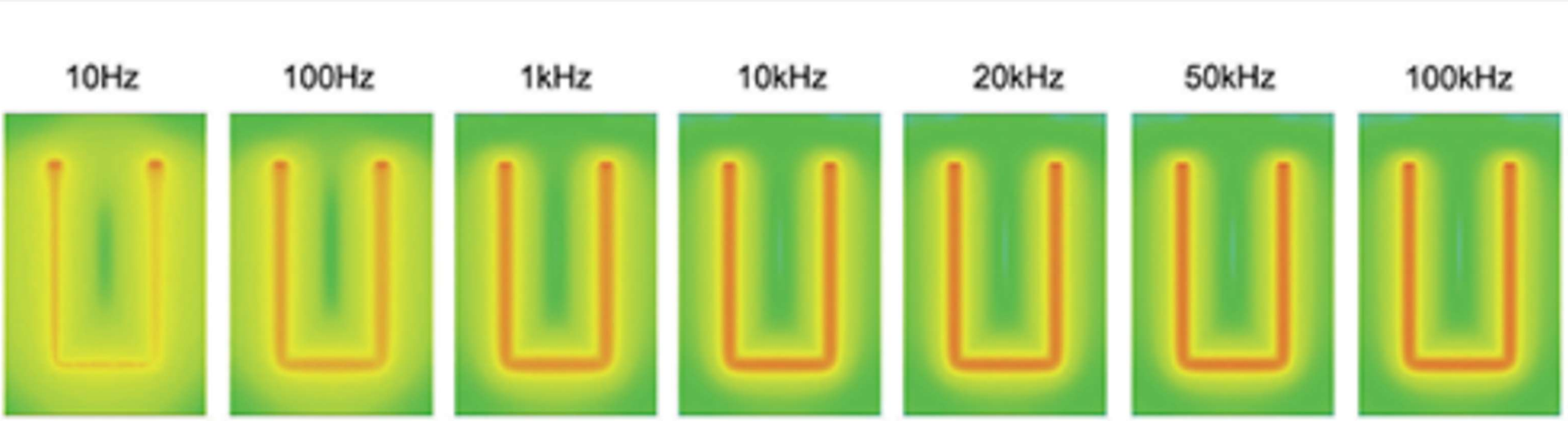
$$J(x) = \frac{I}{w\pi}\left[\tan^{-1}\left(\frac{2x-w}{2h}\right) - \tan^{-1}\left(\frac{2x+w}{2h}\right)\right]$$



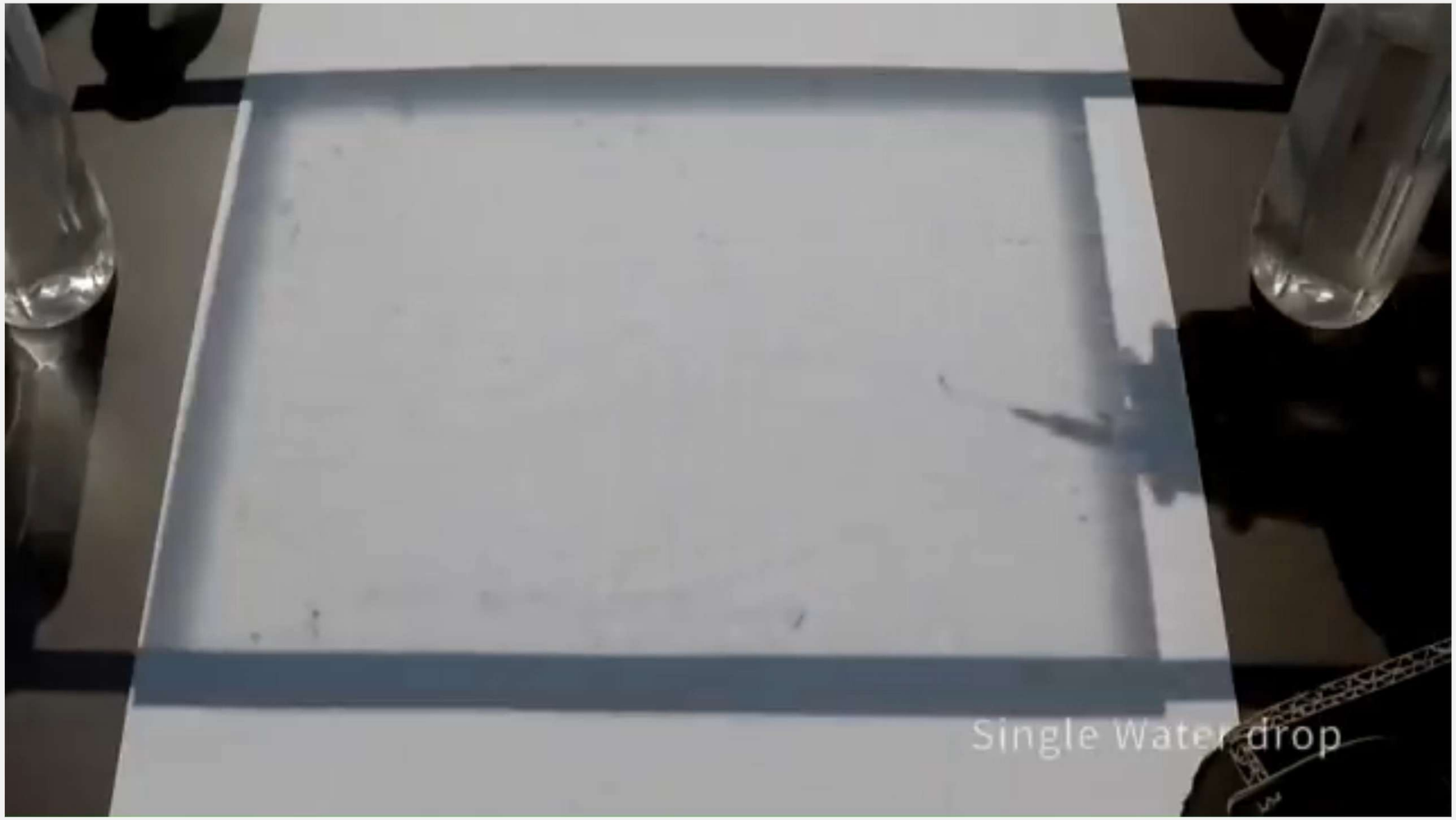


What is High Frequency?

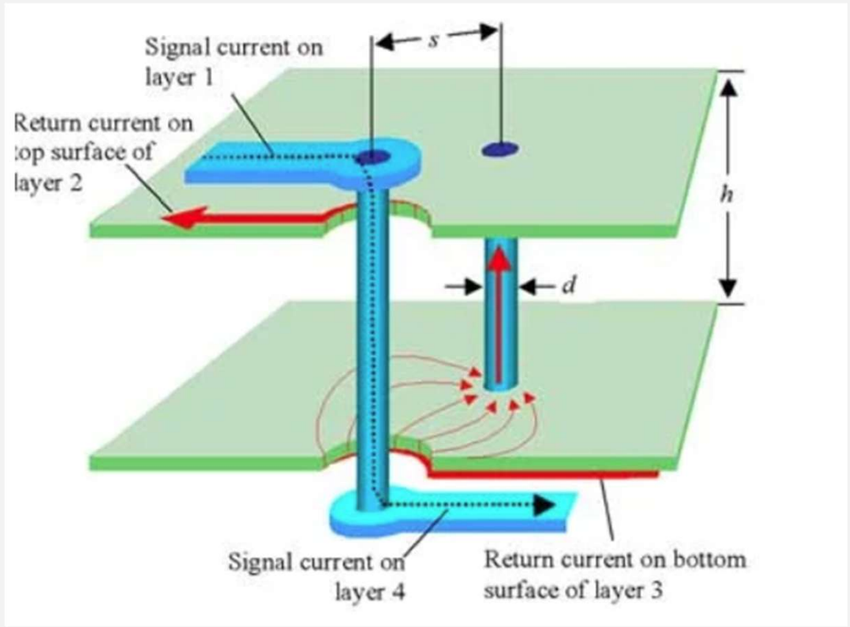
Return Current Density Simulation at different frequencies:



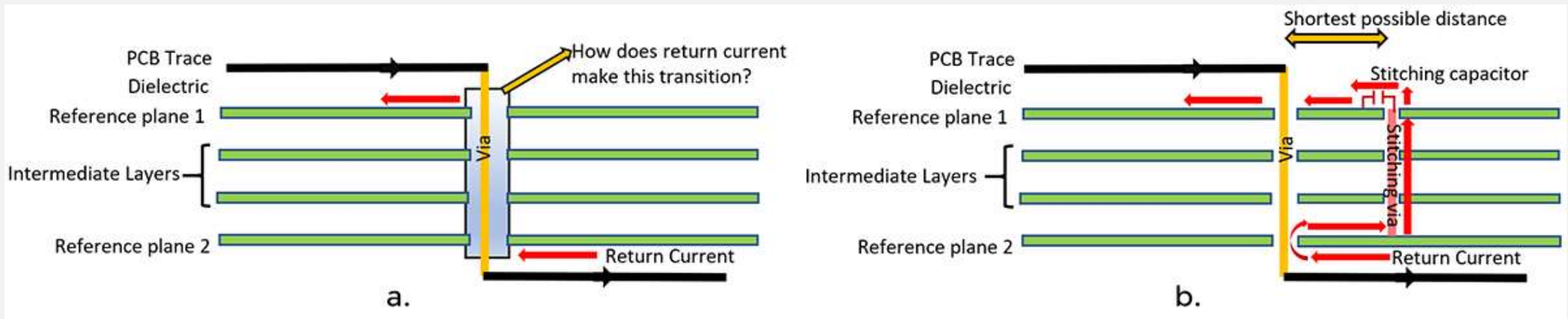
Water Drops Model



What If a Via is Used on Signal?

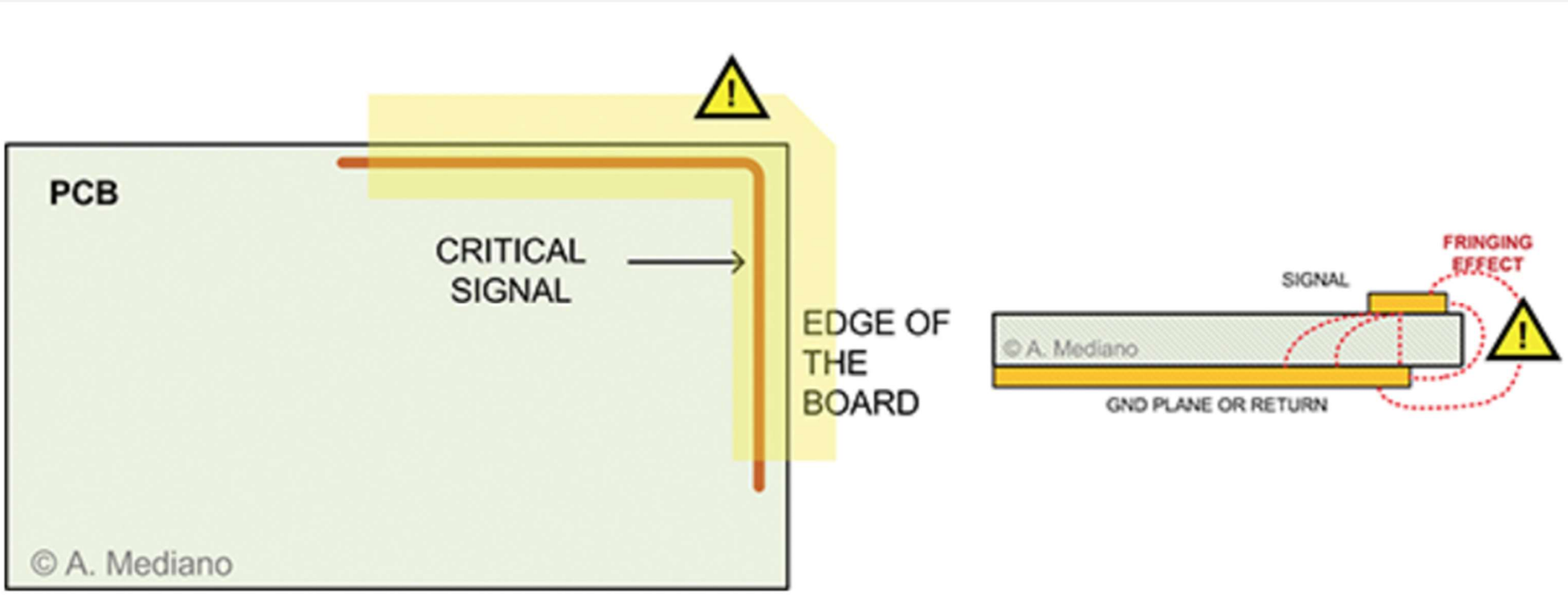


Even if trace is always referenced to ground plane, it can be an issue if no ground via is close to signal via!

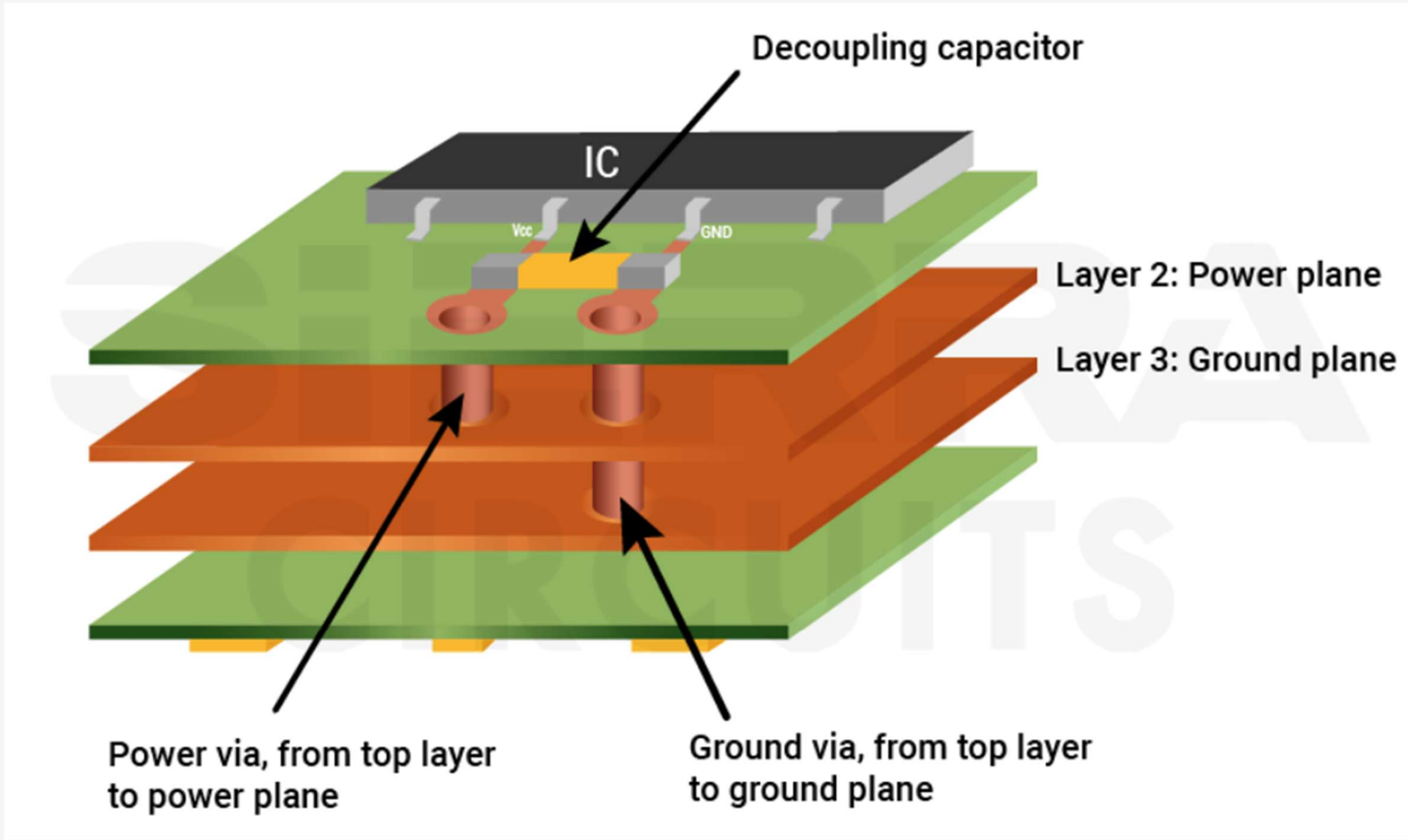


Return Current Close to Edge

- Can’t contain return current = Electromagnetic Emissions Issues.
- Ground barrier (commonly called ground stitching) is a good practice.



Understanding Current Loop



Plane Resonance & Decoupling



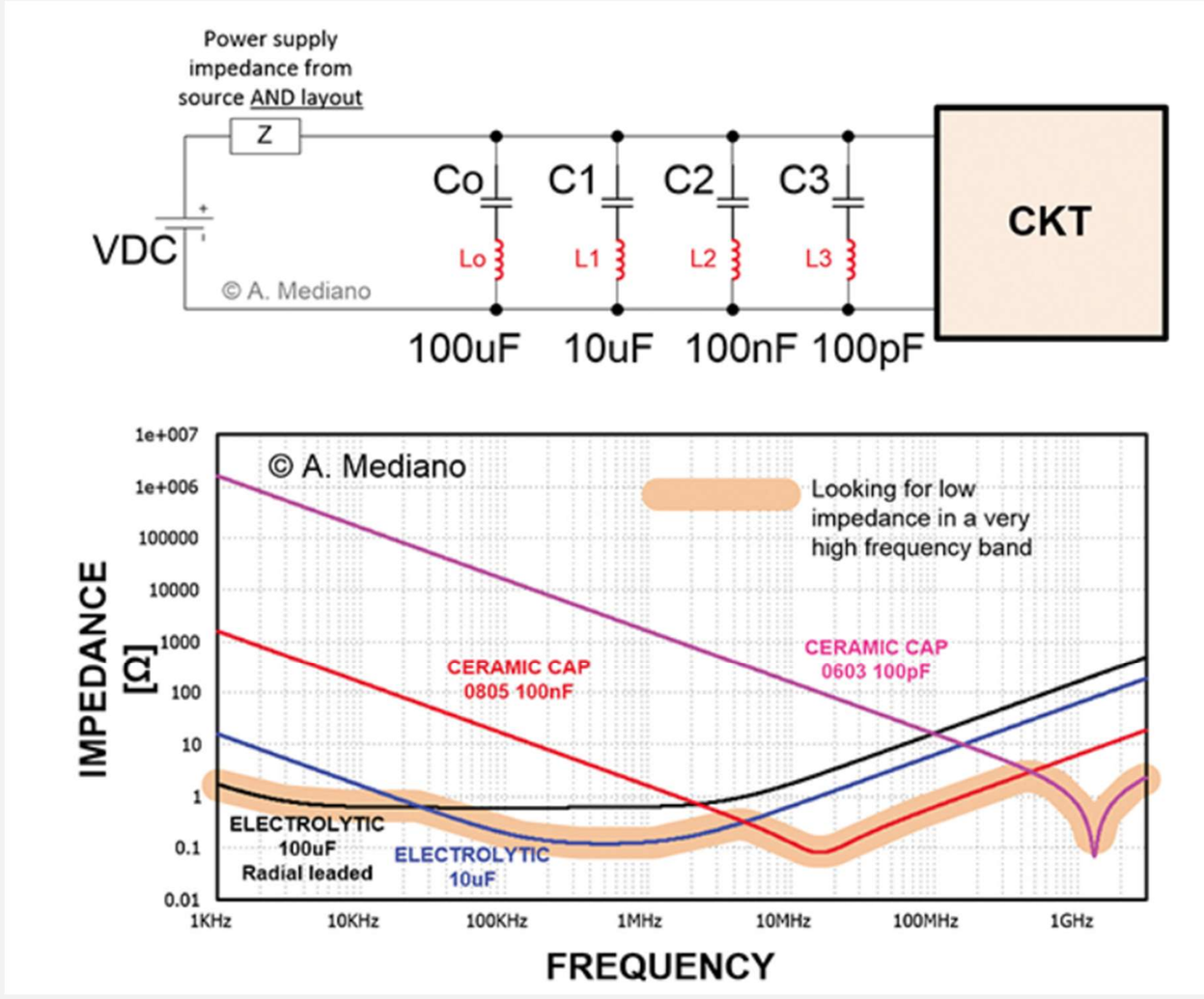
Some capacitor values can create plane resonance!!

It is very hard to predict decoupling capacitors effect ounce on the PCB.

Physical plane dimension and dielectric will define resonance frequency.

https://learnemc.com/ext/calculators/cavity_resonance/pcb-res.html

Decoupling Capacitor Value

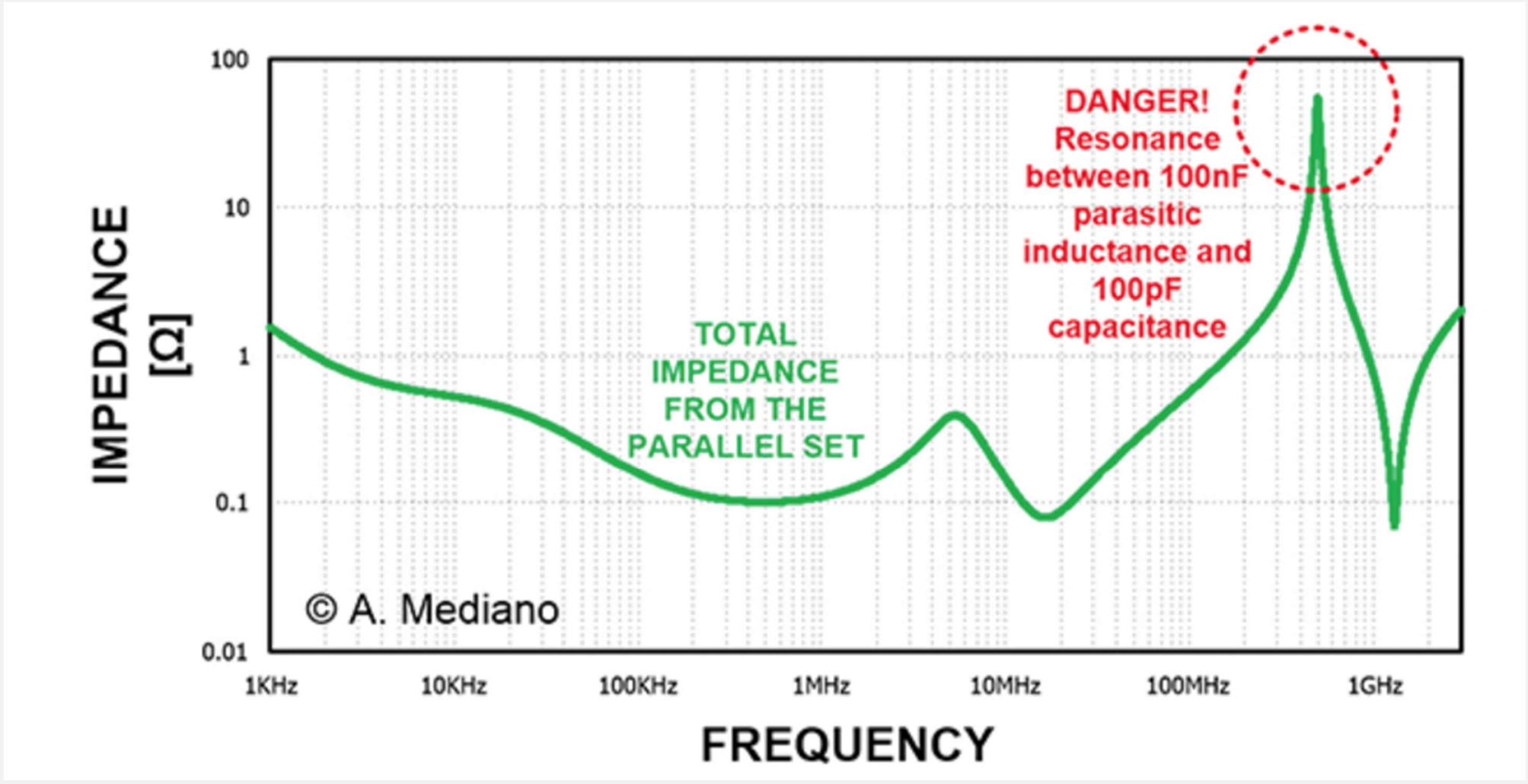


Rule of Thumb:

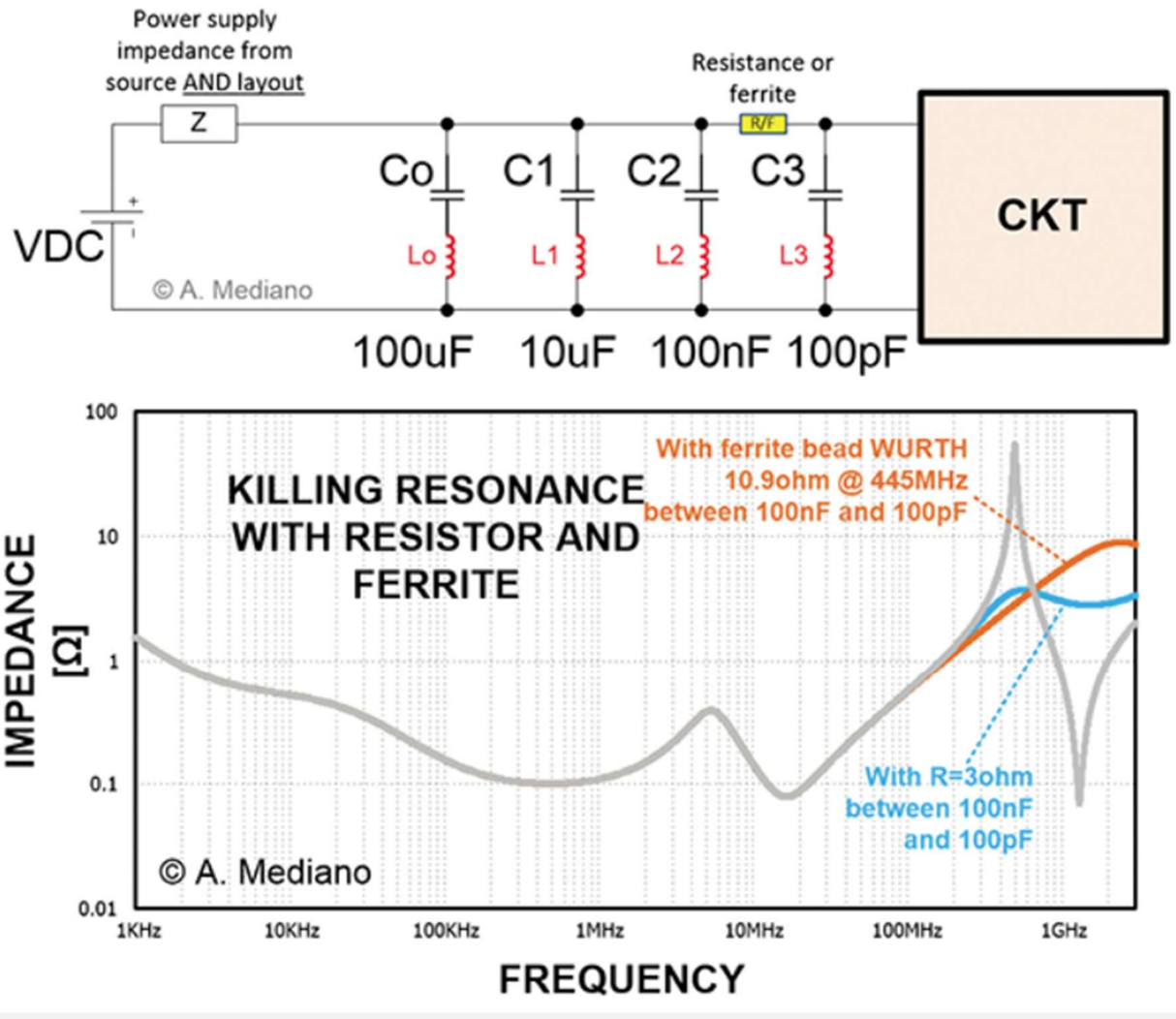
If multiple capacitor values are used for decoupling, try to spread values by a 10x factor.

Warning: There is no guarantee that you will not encounter a resonance problem.

Be Careful About Resonance



Potential Solution



Adding a bead can eliminate the resonance.

But be careful, in other cases it can worsen it!

Power Plane as Return Current?

- Is it possible to use a power plane as return current?
- Yes, but make sure to have good decoupling distribution!
- Select a power plane that represents the best PCB distribution.

What Have We Learned?

- Ground Plane:
  - Carries Return Current, not a Current Sink!
  - Physical Construction Dictates its Natural Resonance Frequency.
  - Bad Decoupling Choice Can Create Resonance.
  - Layout, Frequencies, Design Specifics are Defining the Ground Behavior.

- Return Current:
  - Current Distribution on Reference Plane Mainly Flowing Under the Trace.
  - Always Need to be Understood in 3D.
  - Close to PCB Edge = Electromagnetic Emissions!

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Ground Split or Single Ground?



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That Is The Question! For Some, It is Almost a Religion!

Let’s Start With the Conclusion!

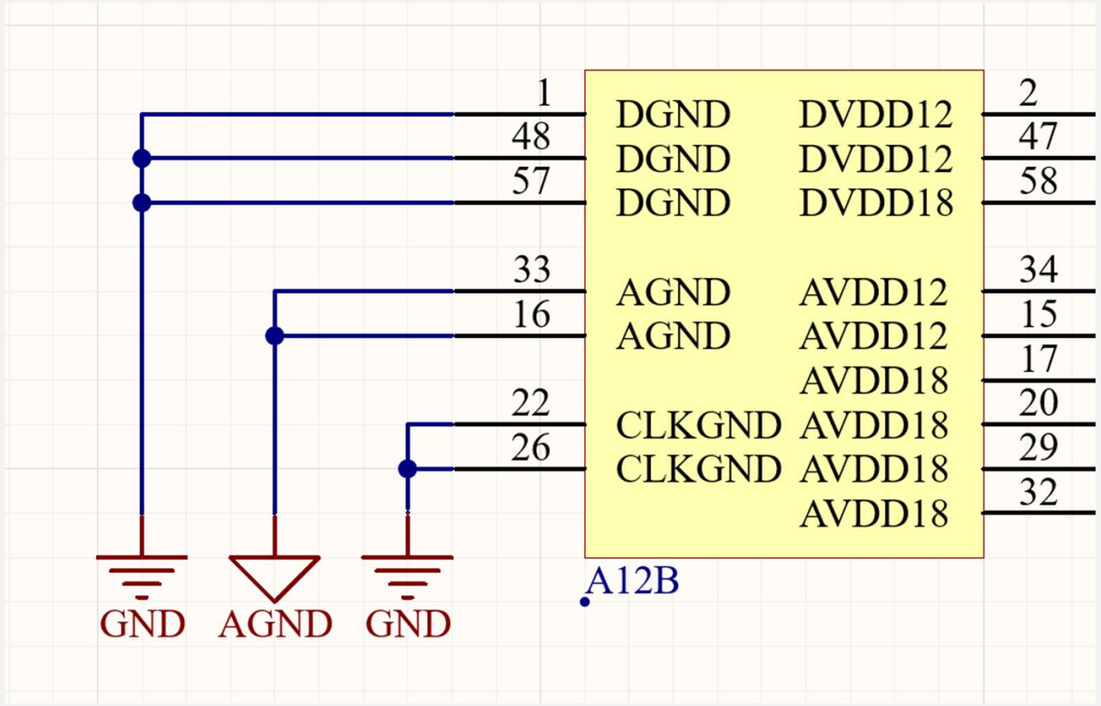
- You don’t master 3D PCB return current ?
- You are not completely sure of what you are doing?

Use a Single Ground!

- You control your return current?
- Your design contains either sensitive analog circuit or power electronic section?

Split Your Ground!

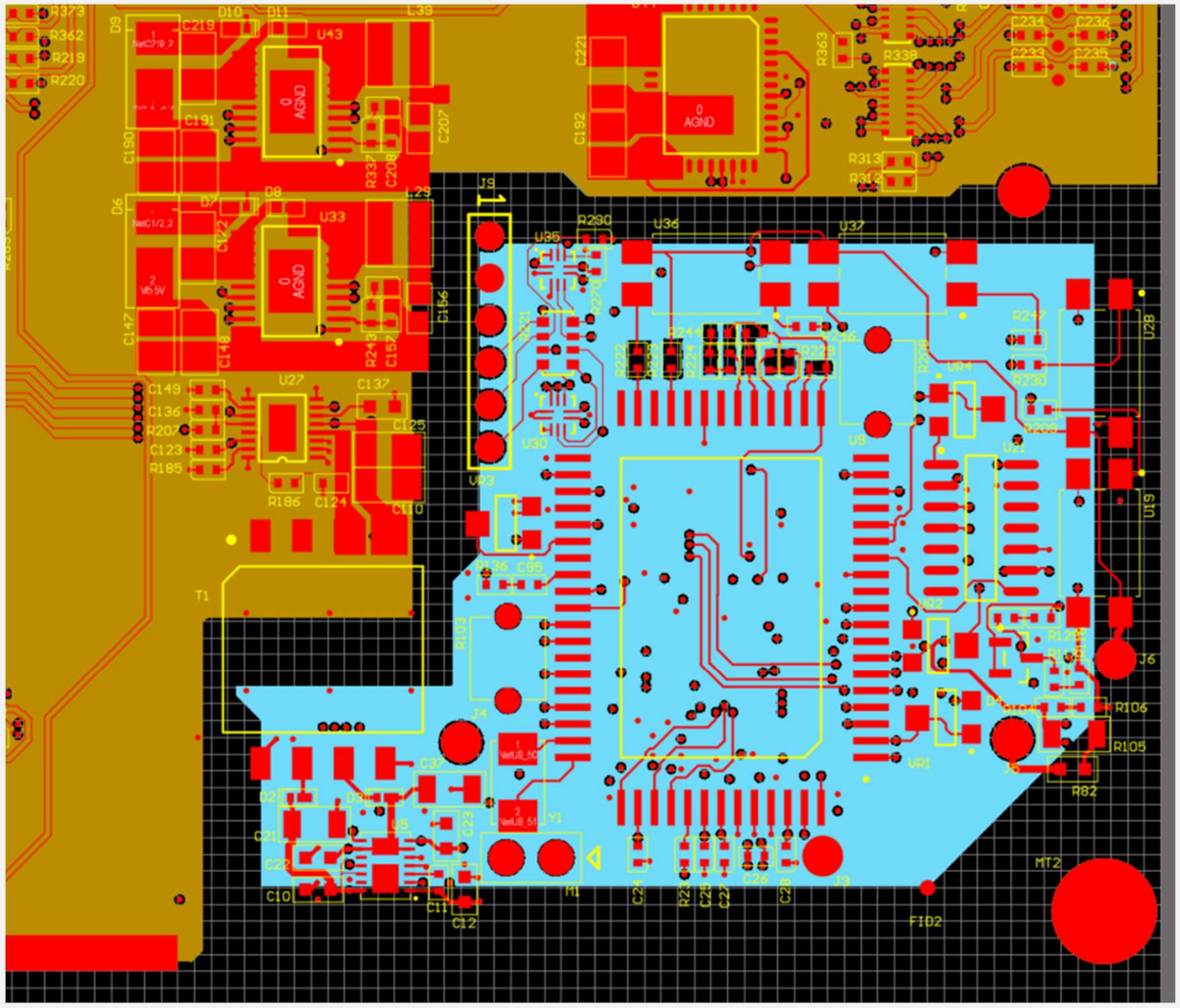
How Do We Split Ground?





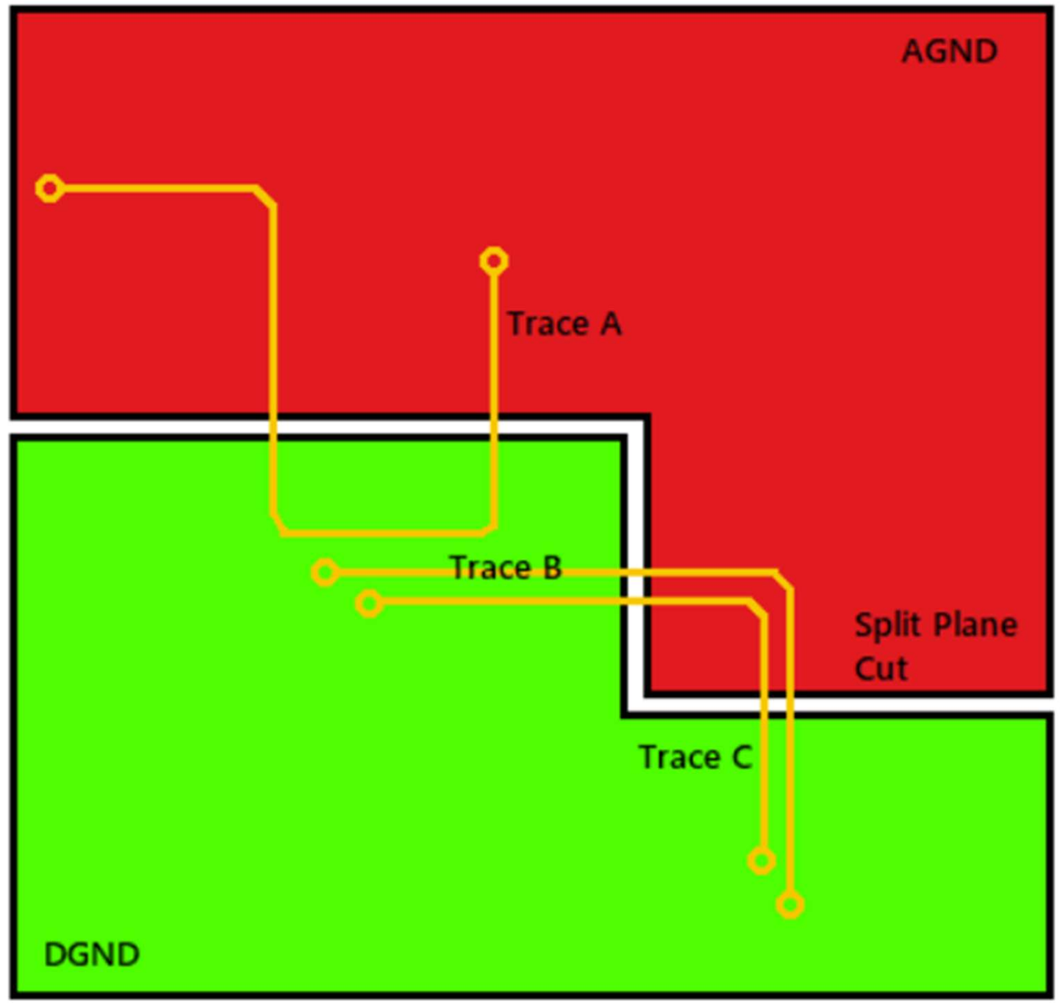
- Ground cases:
  - Isolated.
  - Separated with capacitive coupling.
  - Created with ground shape.
  - Unintentional ground split.
  - Separated with either bead or 0 Ohm resistors.

Case of Isolated Ground



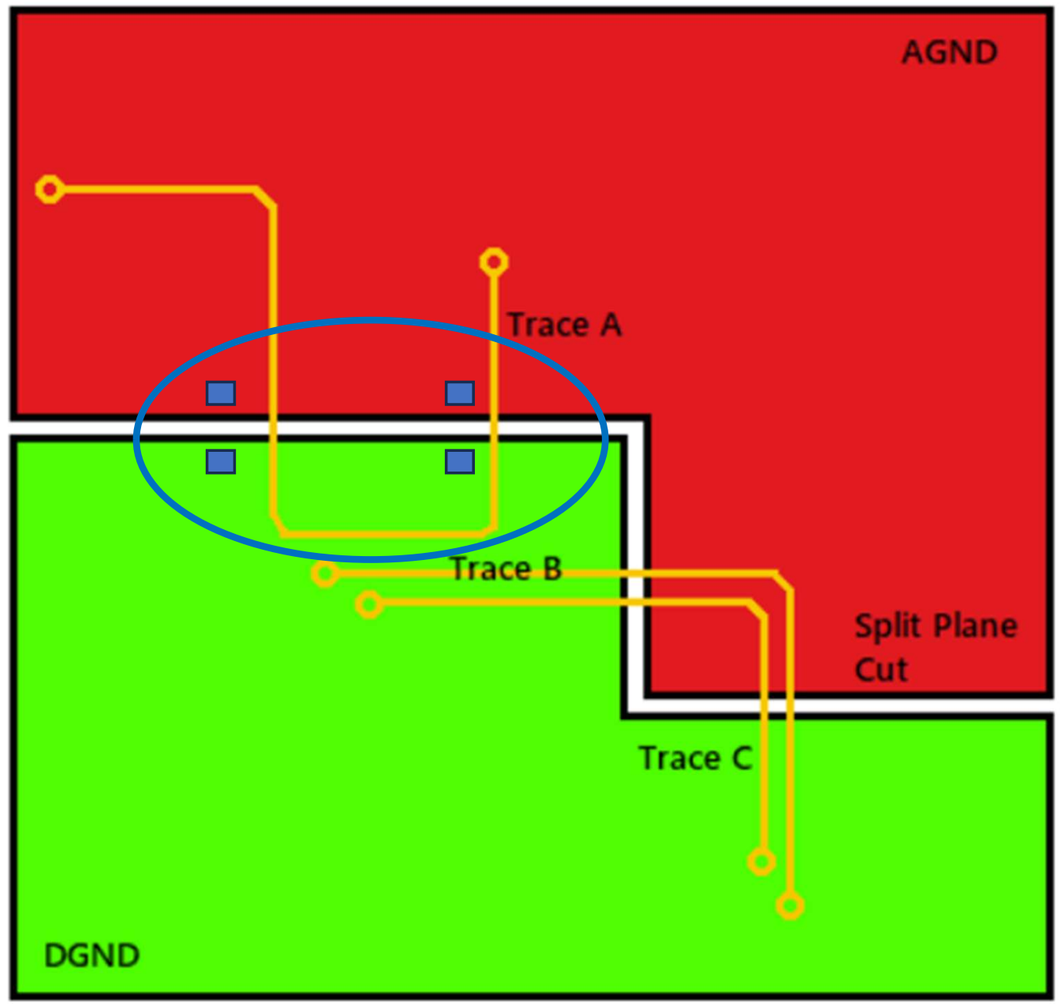
- Implies physical separation.
- Implies isolated power supply.
- Implies isolated I/O.
- Most probably implies electrical safety.
- Make sure to know which standard to meet and choose components accordingly.
- **IMPORTANT:** Make sure not to cross ground cut with signals!

Ground Cuts DC Signal



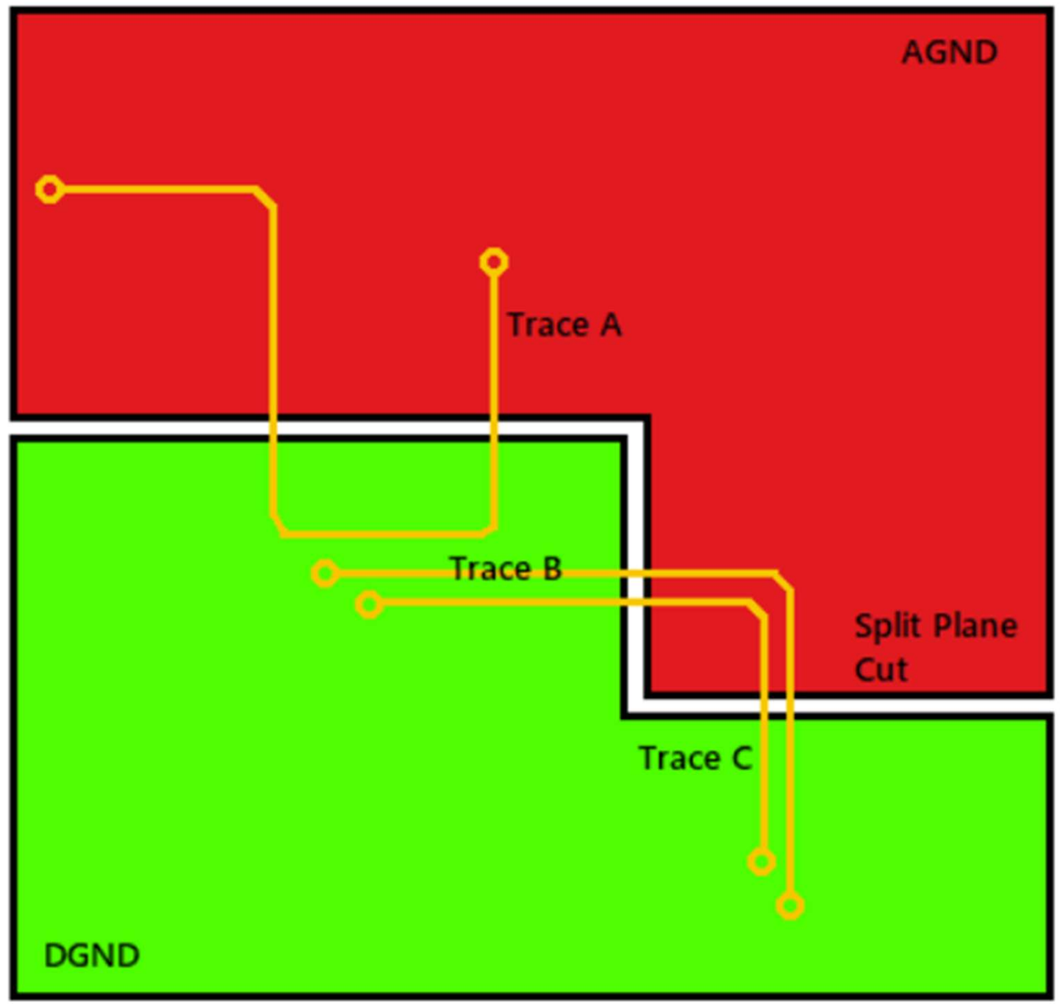
- What if Trace A is a DC signal?
- Always understand your specific case and analyse the options and risks of your decision.
- What are the risks that the DC signal will be contaminated with a digital signal that wants to flow back to its source?

Ground Cuts Static Signal



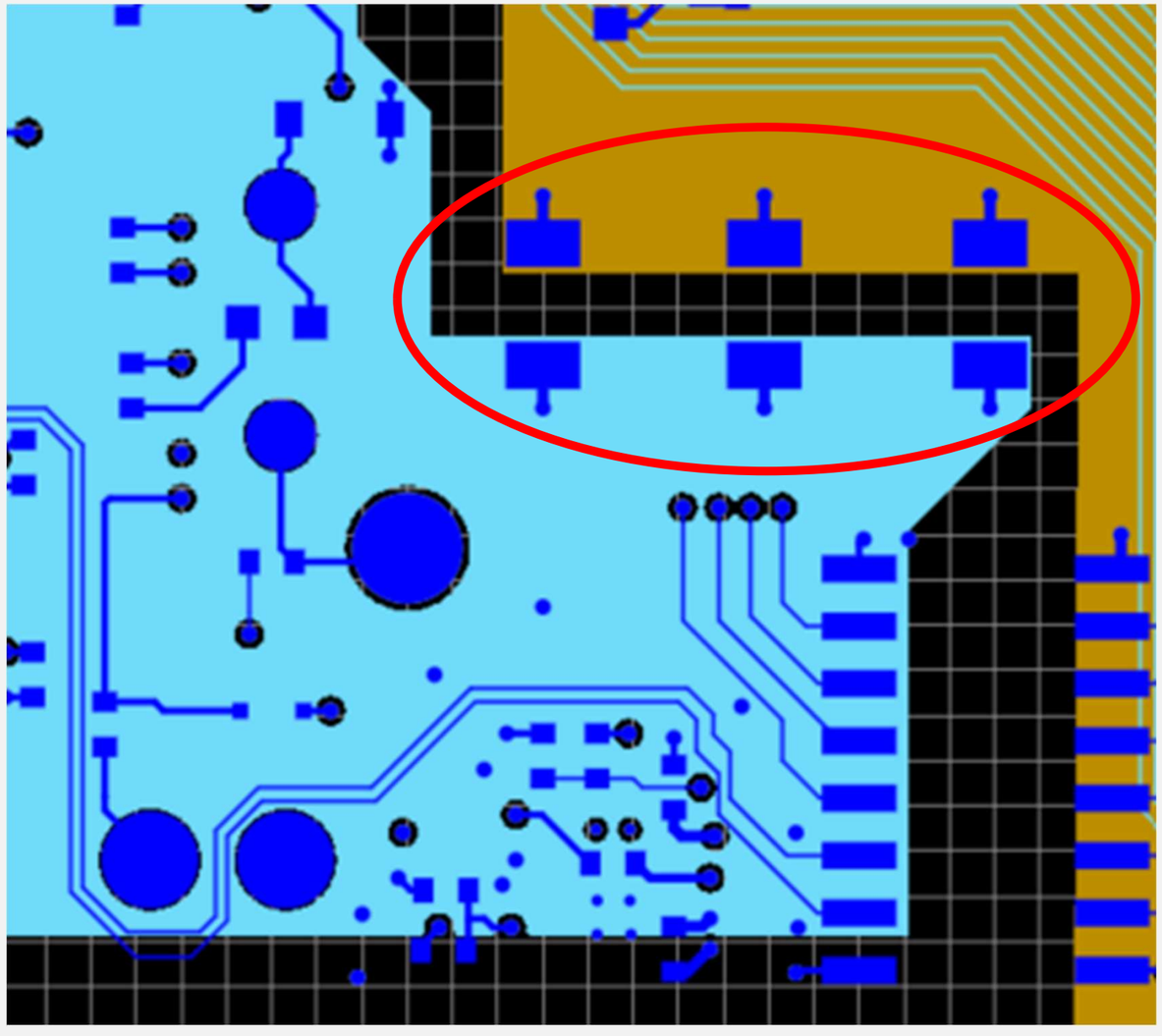
- What if Trace A is a control signal that changes state one time at startup?
- What are the risks that the signal will be contaminated with a digital signal that wants to flow back to its source?
- What is the impact of adding capacitors to control return current?

Ground Cuts Differential Signal



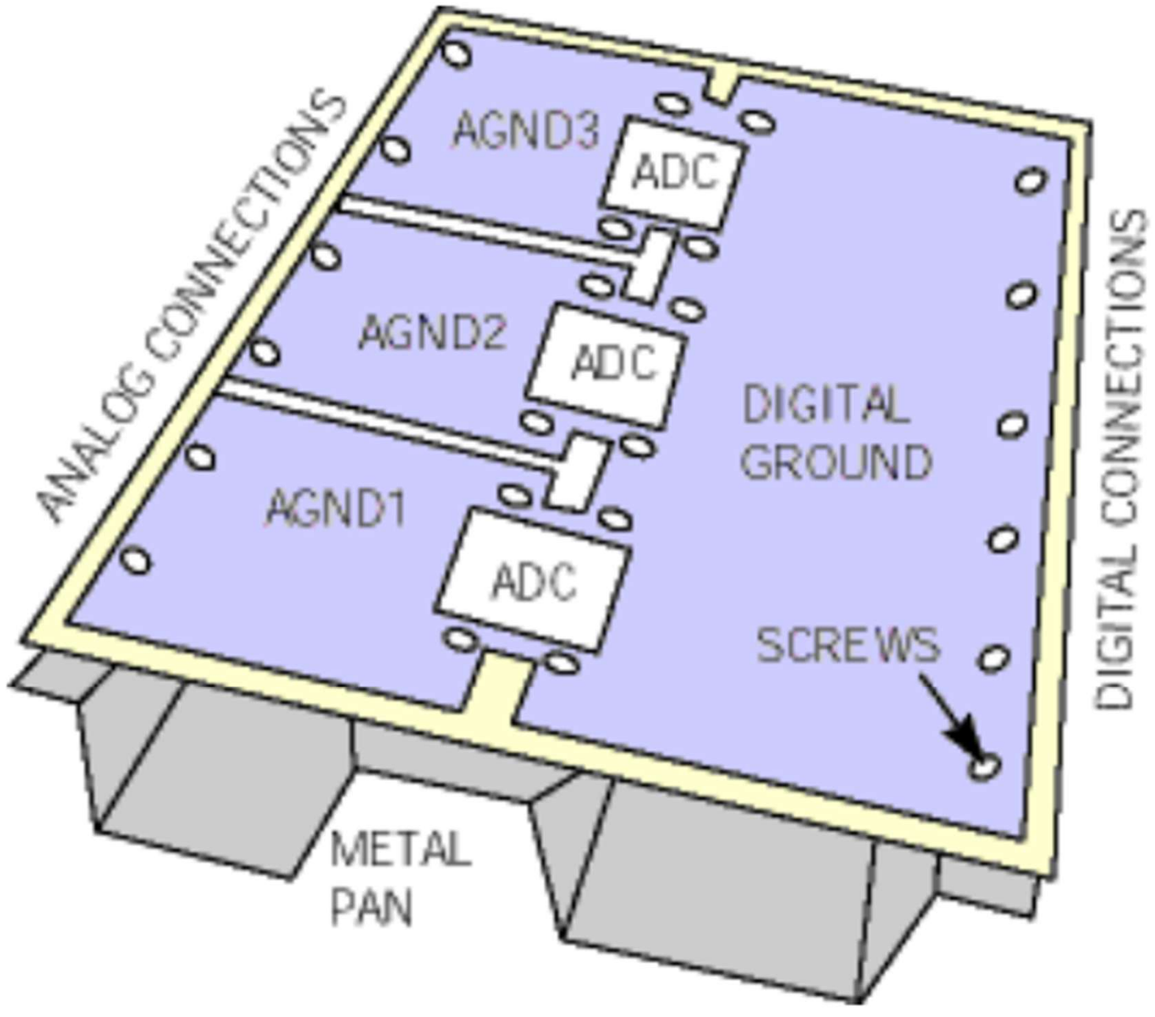
- What if Trace B and Trace C are differential signals?
- True differential signals rarely exists. They are most of the time pseudo differential signals.
- Are they routed tightly coupled?
- In any case, crossing split plane creates a single ended impedance discontinuity.

Case Isolated Capacitive Coupling



- Why might you consider adding caps at power transformer ground boundary?
- Transformer parasitic capacitance might couple high frequency noise on secondary that can’t find any return path to its source.
- Make sure to understand your electrical safety requirement to choose the right capacitors. Fail safe Y capacitor to be considered.

Ground Split by Layout Shape

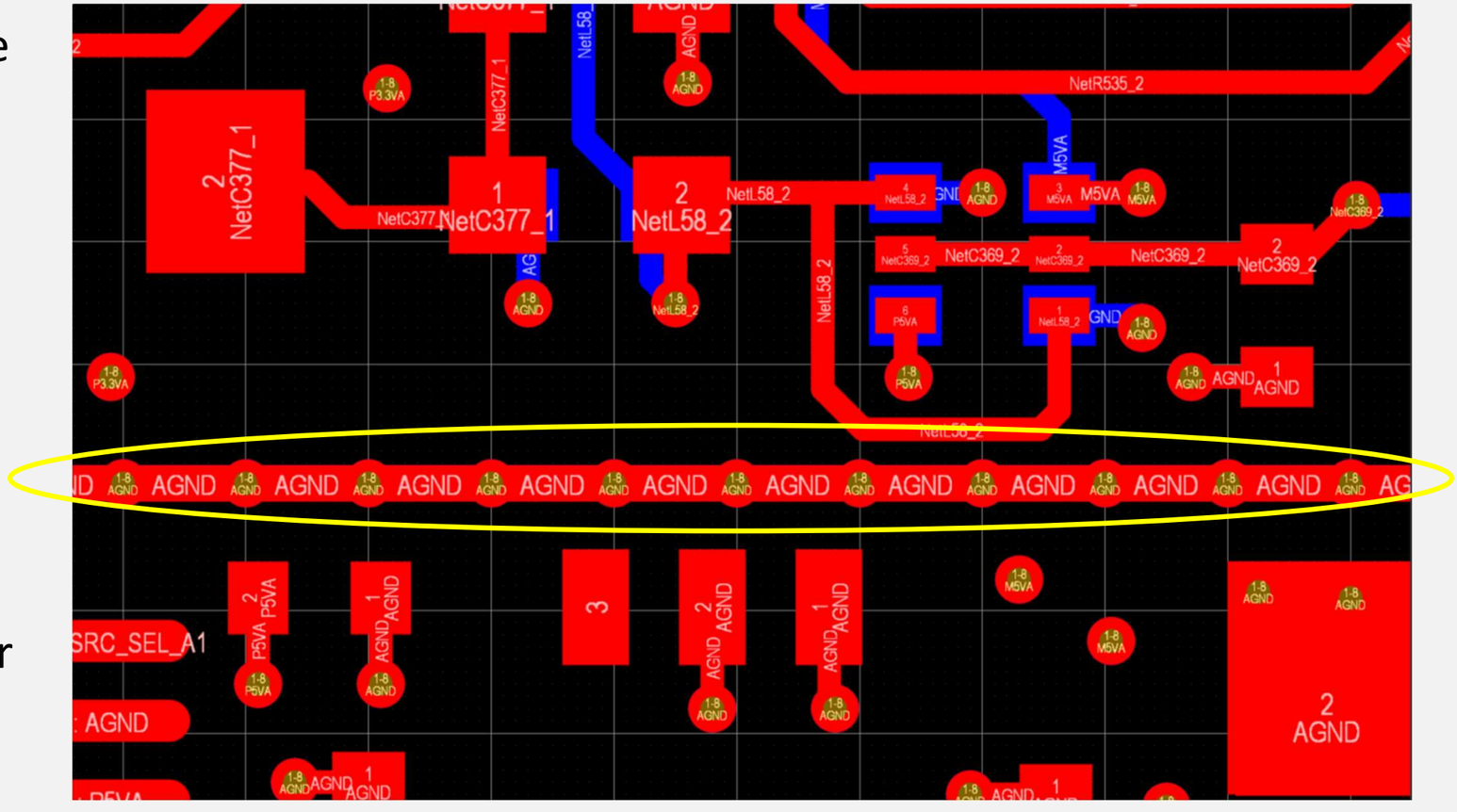


- Implies connecting analog and digital ground using the same symbol in your schematic.
- Often suitable for ADC or DAC where ground junction is made at converter.
- Need to route control signals over continuous ground close to converter or plan for another ground continuous path.
- Consider minimizing control signal from Digital to Analog section: Thay carry high speed noise.

Ground Stitching

Ground stitching is good practice to:

- Prevent EMC at PCB edge.
- Add extra isolation between ground section.
- Via distance to be adjusted based on design highest frequency content.
- Typically for 1Ghz 5mm via spacing can be enough. You can go down to 1.5-2.5mm for higher frequencies or higher attenuation.
- How do you determine the highest frequency?



$$\frac{\lambda_G}{20} \leq D \leq \frac{\lambda_G}{10}$$

$$\lambda_G = \frac{3 \times 10^8}{f \times \sqrt{\epsilon_{r_eff}}}$$

Introduction of Knee Frequency

Definition of the Knee frequency

$$f_{3dB} = \frac{K}{Tr_{10\%-90\%}}$$

Pulse Type	K
Exponential 1st order	0.35
Exponential 2nd order	0.34
Gaussian	0.32

Note:

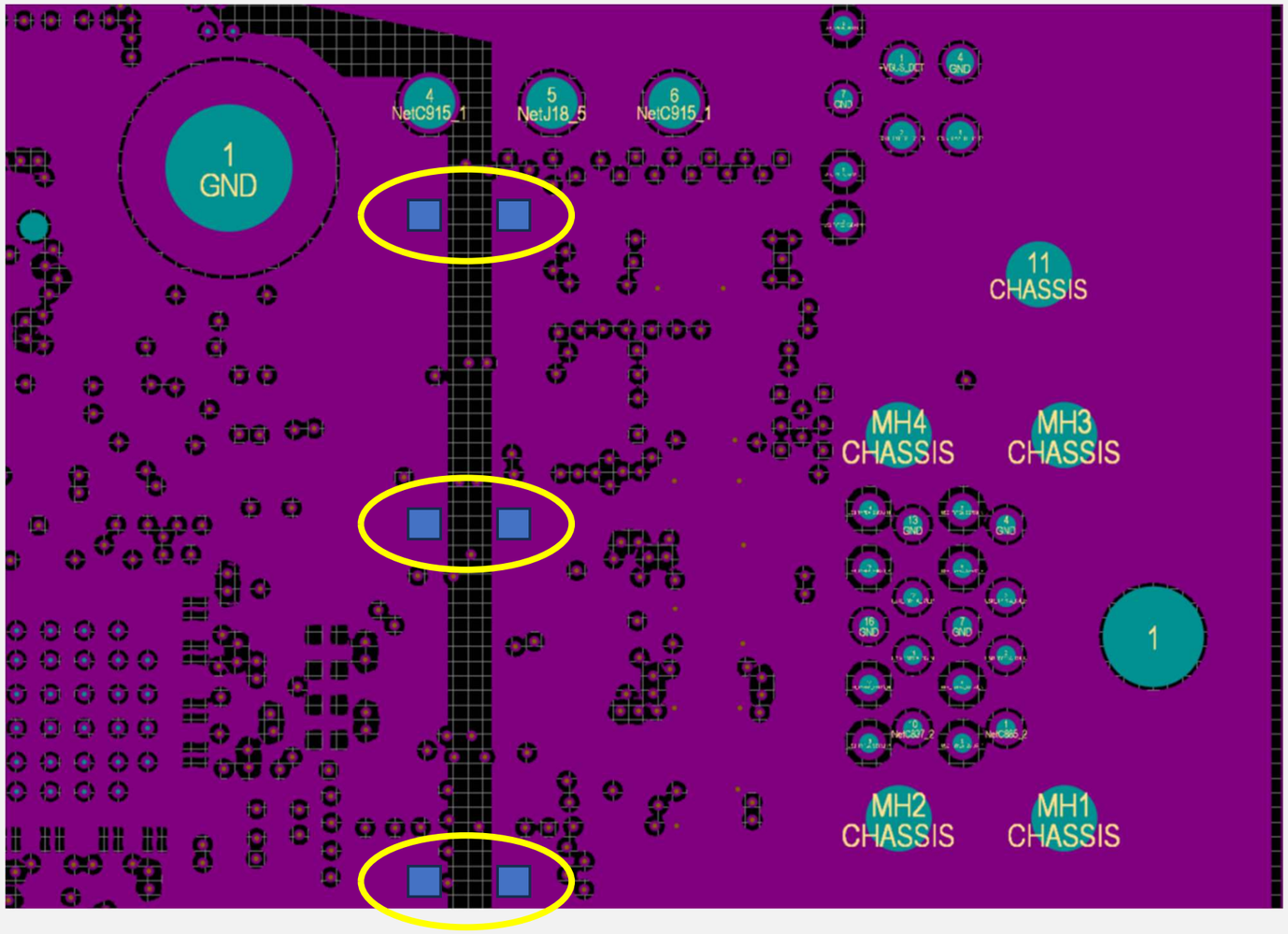
- Pulse shape hardly matters
- K = 0.35 is typically used
- K = 0.5 for conservative approximation
- Imprecise measurement

Advantage:

- Simply defined based on rise time
- Easy benchmark of frequency effect

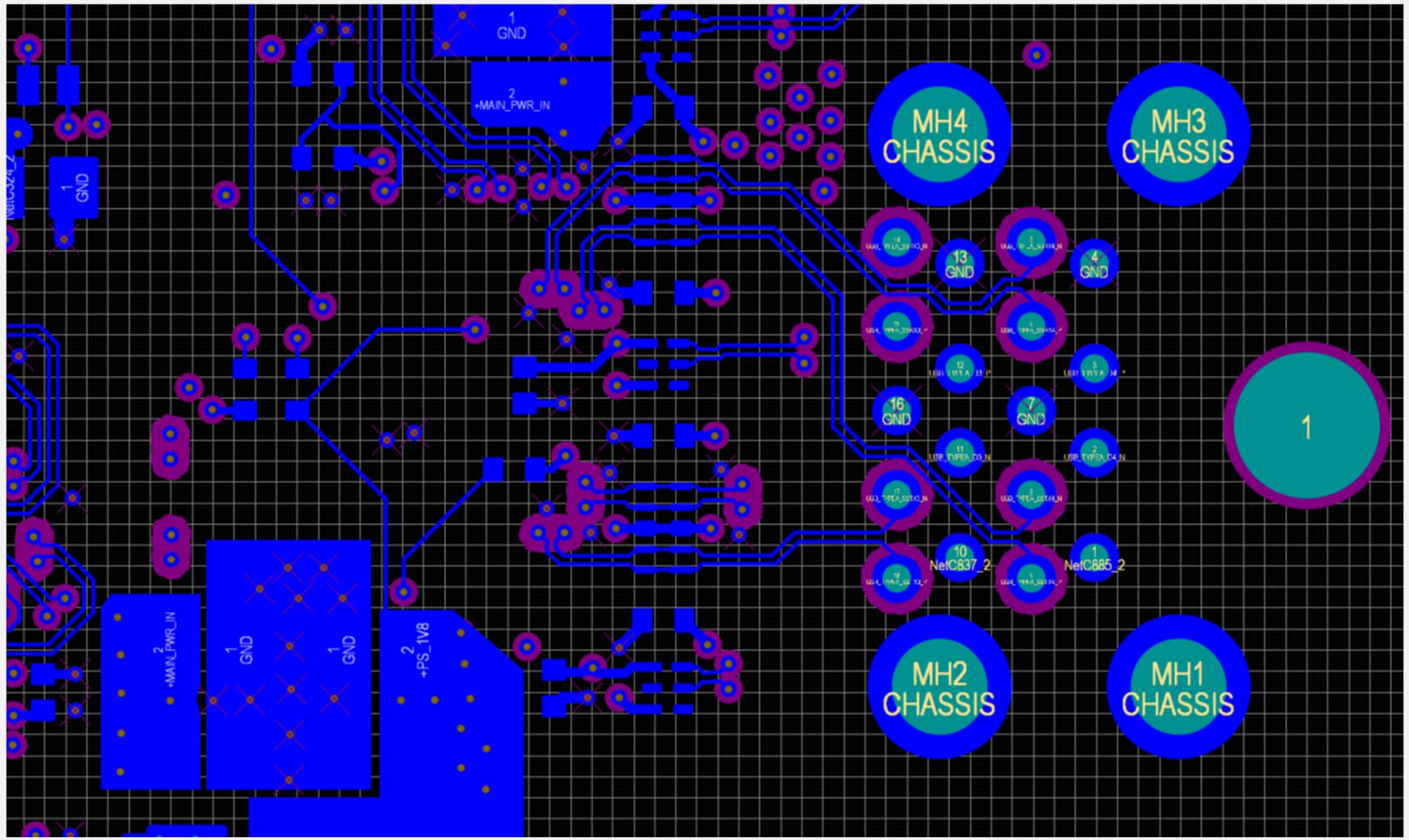
KU THE UNIVERSITY OF KANSAS — Rock Chalk, JAYHAWK!

Chassis Ground Case



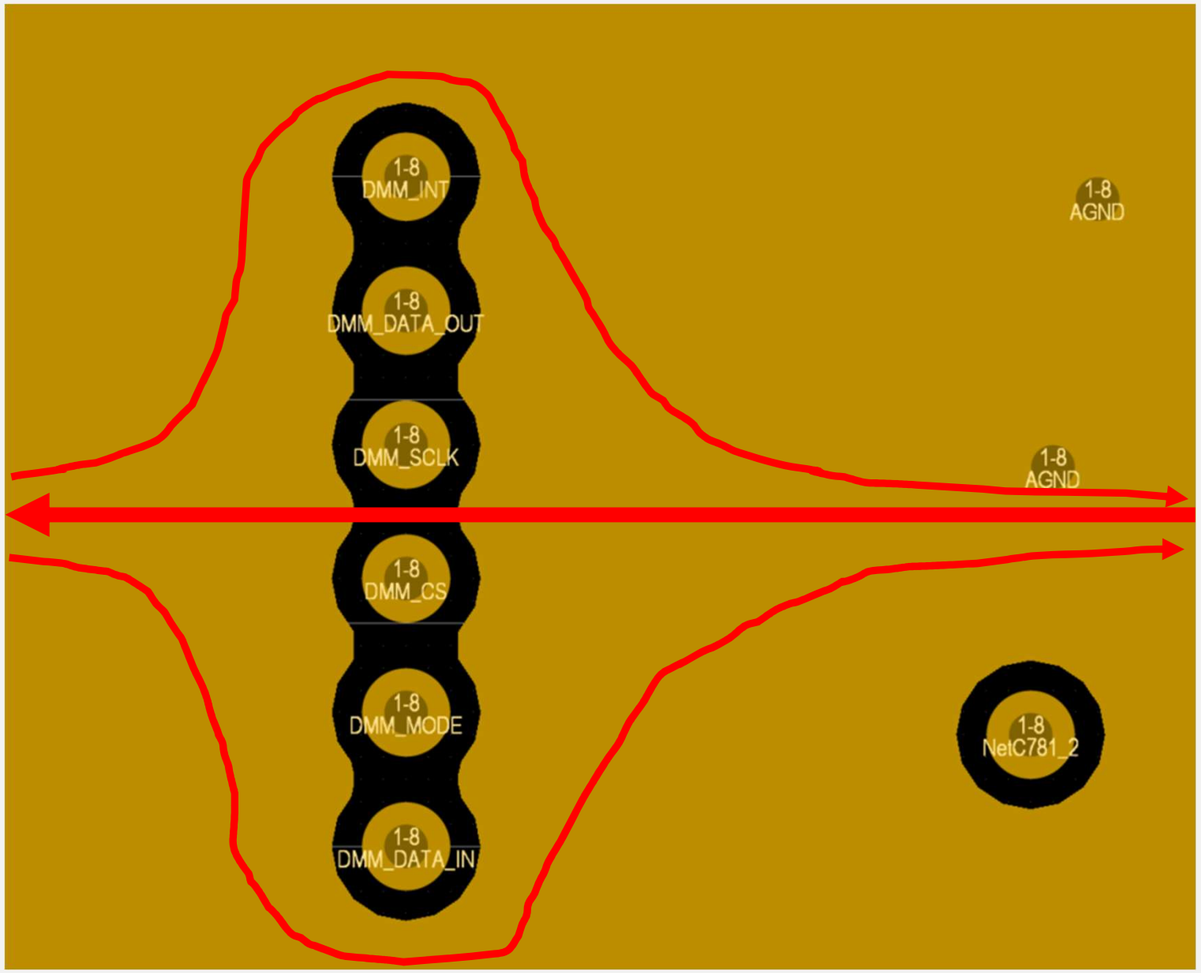
- Common Practice to Separate Chassis Ground From System Ground.
- Provide Multiple Footprints on Top and Bottom to Short Chassis Ground with System Ground Using Either Resistors or Bead.

I/O Signal Routing



Route High Speed Signal to I/O Connector Referenced to Their Ground.

Unintentional Ground Split



- Unintentional Ground Split can create noise and EMC issues.
- Must verify your PCB layout before releasing.

Conclusion

- Ground Must be Considered as a Critical Design Element, Well Thought Out and Deserves More Than Guesswork.
- You Need to Develop the Reflex to Know and Visualize Your Return Current in 3D on Your PCB.
- In Power Electronic, Ground Split is a Must, But You Need to Know What You are Doing!

Thank you!

Feel free to contact me if you have any question!



Francois Gagnon, Eng, PMP

Founder @ Mobius Électronique | Electronic

If you want to connect on LinkedIn!

References

- https://incompliancemag.com/
- Electromagnetic Compatibility Seminar, Henry Ott, June 3rd 1997
- Advanced EMC Design Seminar, Dr. Bruce Archambeault, IBM, March 2003
- https://www.protoexpress.com/
- https://learnemc.com/
- https://electronics.stackexchange.com/
- https://www.sigcon.com/index.html
- https://www.pcb-hero.com/
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