ANSYS®

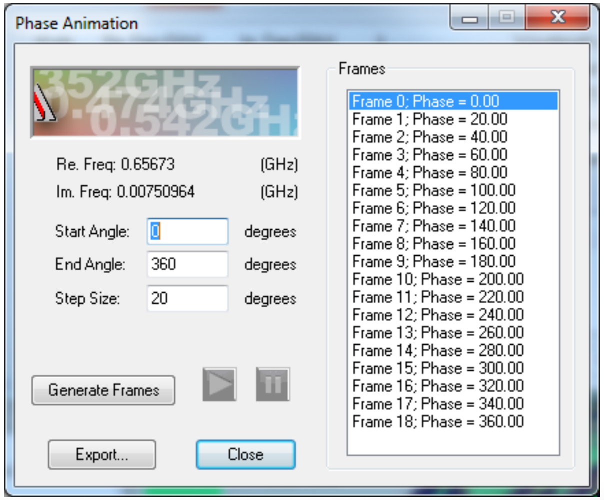
Session 2 Introduction

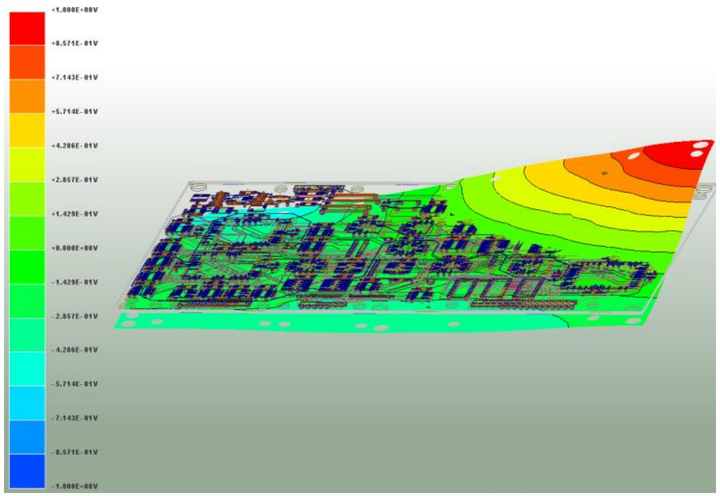
SIwave for Power Integrity Analysis

Workshop 2_1 – Resonant Mode Analysis

- **Resonant Mode Analysis**
  - PCB or IC packages containing power/ground plane structures can exhibit resonances at specific frequencies due to the cavities formed between power and ground planes structures.
  - Shorting vias and decoupling capacitors are used to connect these planes together and suppress resonances.
  - The resonant frequencies correspond to peaks in the impedance response of the PCB or package and can influence the integrity of the power delivery network
  - SIwave Resonant mode analysis can be used to solve for these frequency-dependent voltage swings between layers of a PCB or multi-layer package.

  - **Workshop 2_1** will illustrate the use of the resonant mode simulation capability and placement of capacitors on the PCB to suppress particular modes

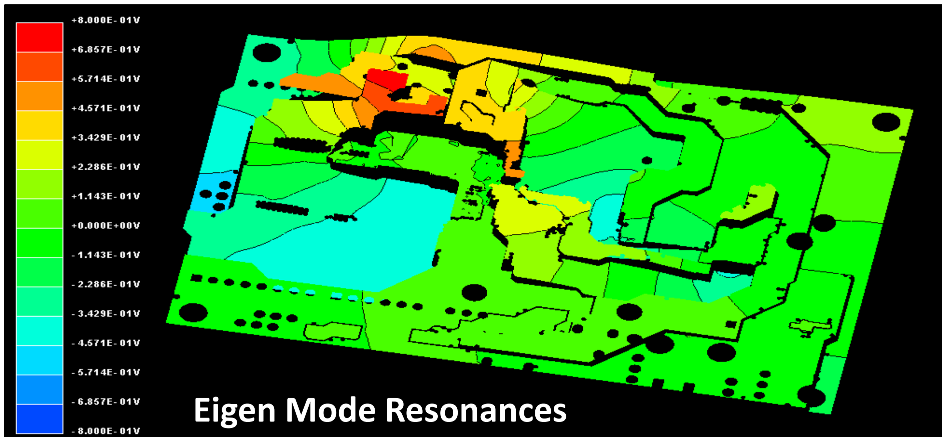


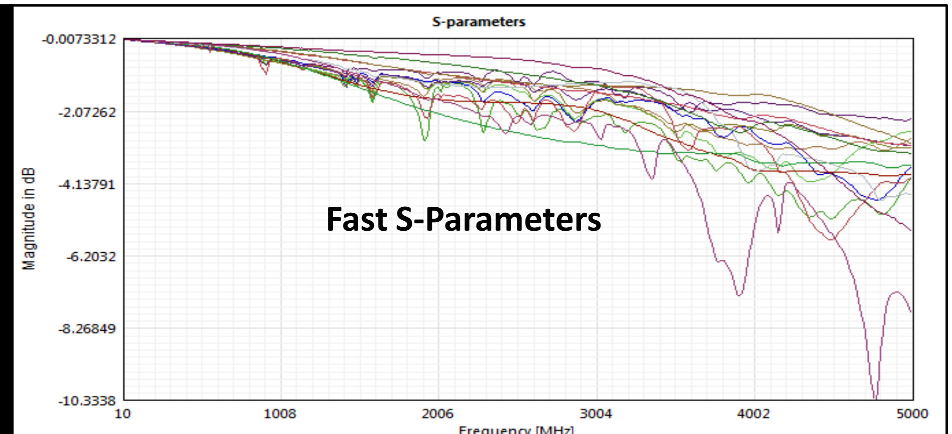


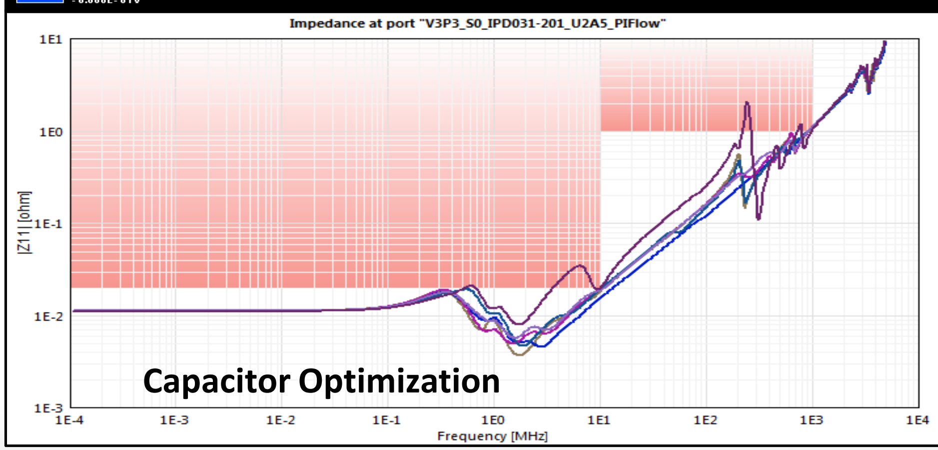
Workshop 2_2 - SIwave PI Overview

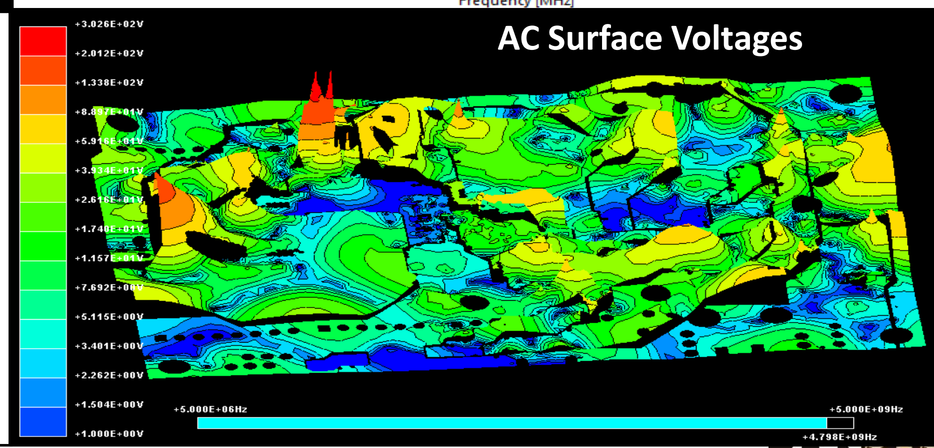
SIwave-PI – Includes everything from SIwave-DC. It also includes:

- S-Parameter Extraction
- Plane Resonance Analysis
- AC Frequency Sweep Solver
- PI Advisor Decoupling Capacitor Optimization





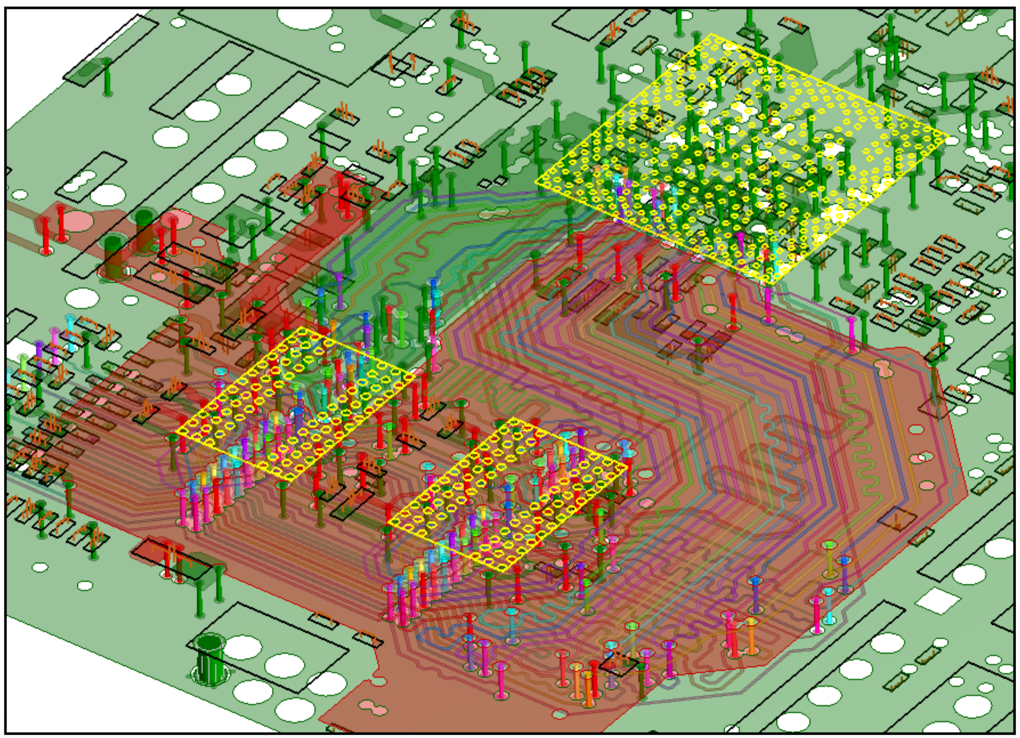


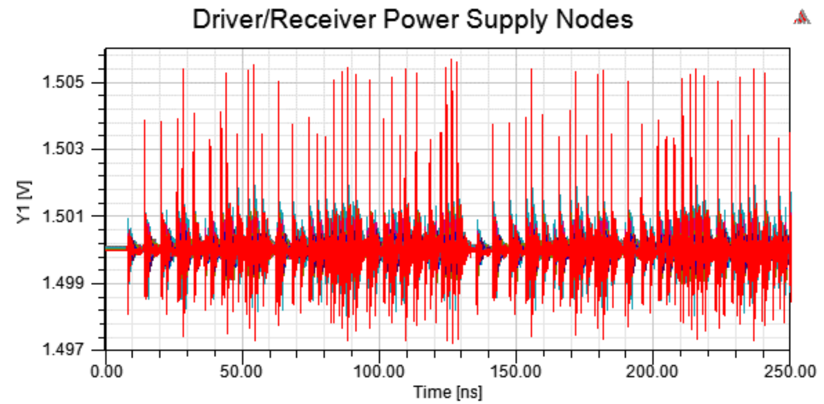


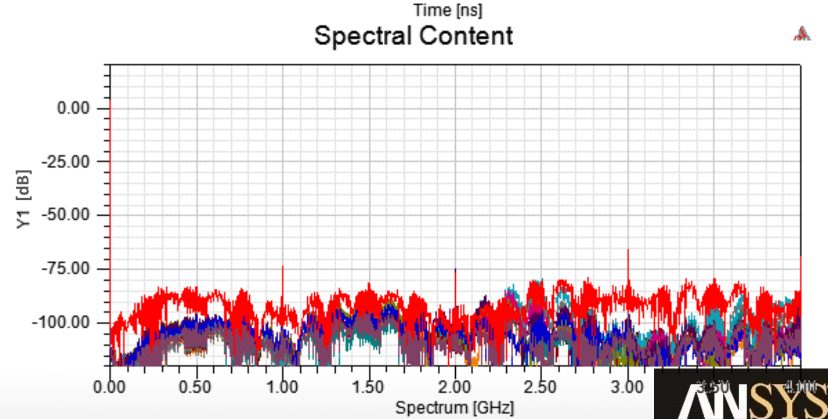
Why is Power Integrity Important?

Power Delivery Network

- Designs of today operate in conjuction with a number of clocks, oscillators, power supplies, and signaling standards. Supplying sufficient power means designing a Power Delivery Network capable of handling any perturbations or irregularities that these complex systems demand.
- The example below shows voltage for both the time and frequency domain simulation results of a memory interface. A good design will minimize the voltage ripple to ensure that all active devices have a stable and reliable voltage reference. Excessive perturbations in power could cause adverse affects to input and output margins or even couple to other power rails.



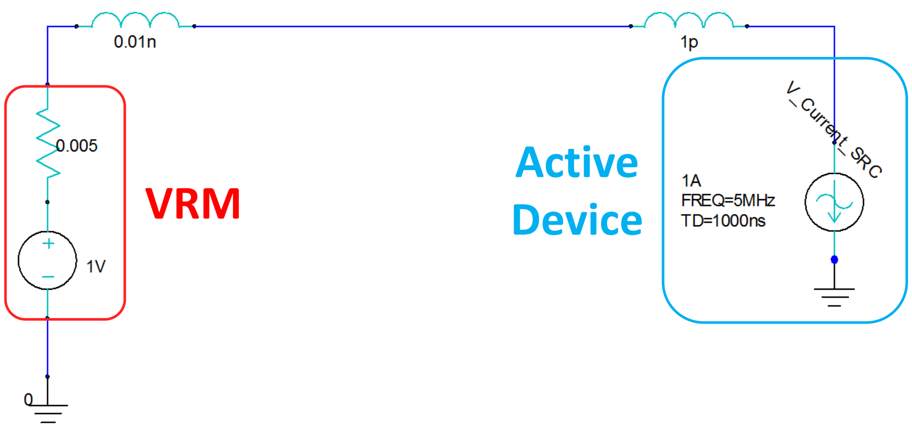




Supplying Power

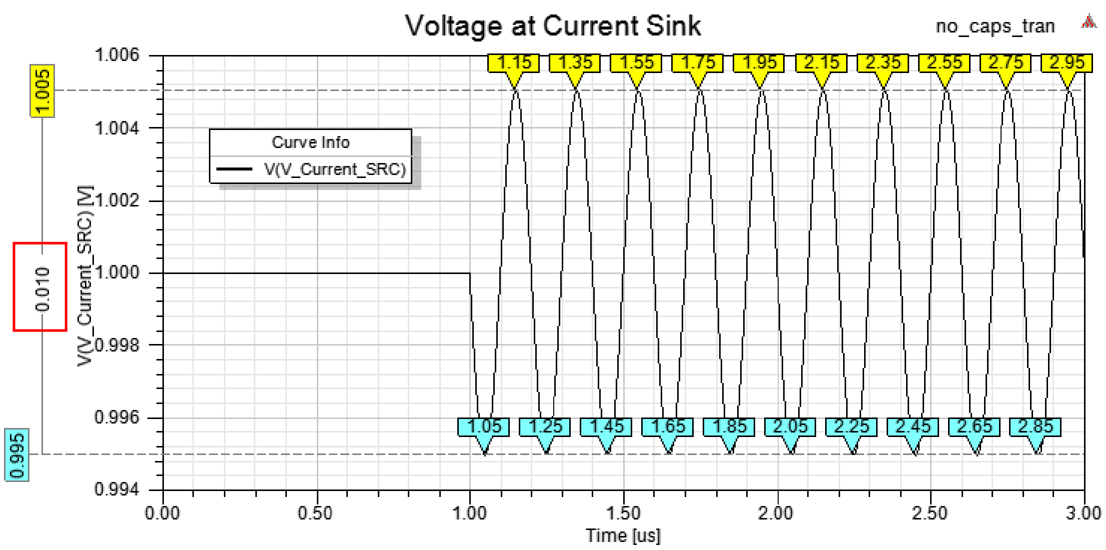
VRM Transient Simulation Setup

- Voltage Regulator Module (VRM) is modeled with a series source resistance of 5mΩ for this example.
- Active Device is modeled as a Current Sink
  - 1A Amplitude: $I_{pk-pk} = 2A$
  - Frequency = 5 MHz
  - Time Delay = $1\mu s$



Example

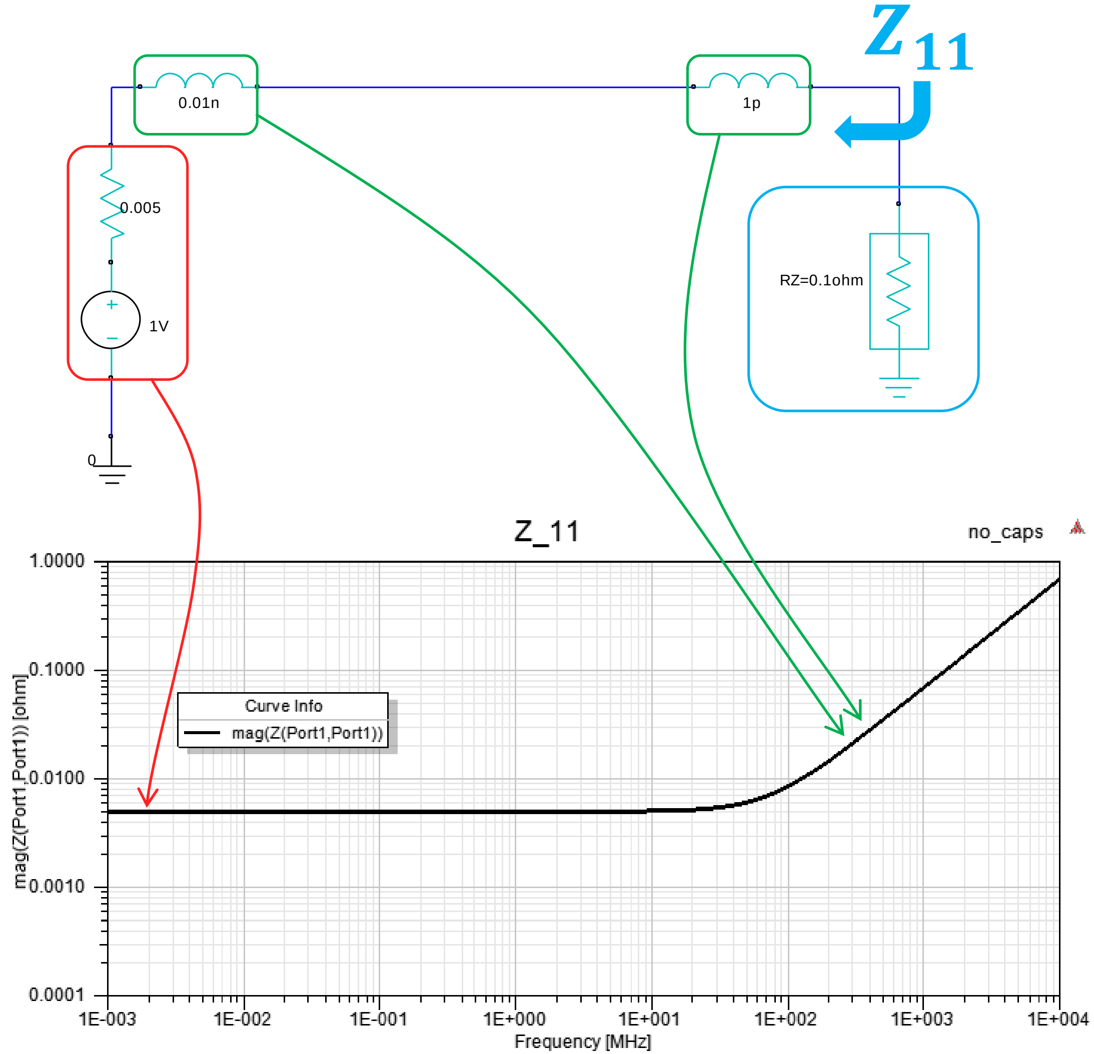
- $V_{ripple} = I\ (5MHz) * Z\ (5MHz)$
- $V_{ripple} = 5mV = 10mV_{pk-pk}$



Supplying Power

VRM Frequency Domain Response

- At DC, $|Z_{11}| = 5m\Omega$ which is the VRM series resistance.
- At $f \rightarrow \infty$, $|Z_{11}| \rightarrow \infty$ due to the path loop inductance. In this case, a total of 11pH.



Example

- $V_{ripple} = I\ (5\ MHz) * Z\ (5\ MHz)$
- $V_{ripple} = 1A * \boldsymbol{5m\Omega}$
- $V_{ripple} = 5mV = 10mV_{pk-pk}$

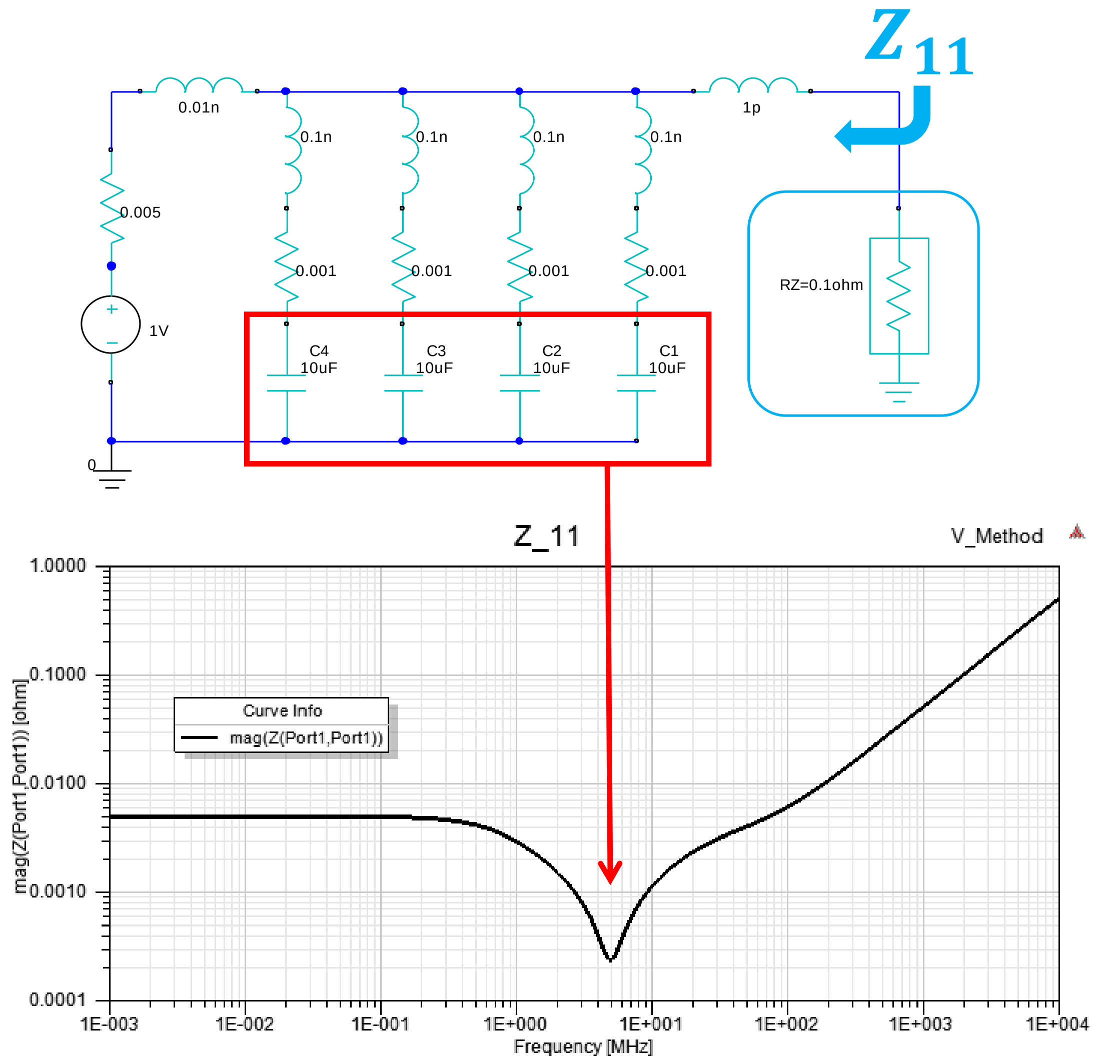
V Method

V Method

- All capacitor values are chosen to be the same in order to lower the impedance magnitude at a specific frequency. The resultant impedance plot resembles a V shape.
- In this example, if a device requires 1A at 5MHz, it will see $|Z_{11}| = 0.24m\Omega$.
- $f_{resonance} = \frac{1}{2\pi\sqrt{LC}}$
- $f_{resonance} = \frac{1}{2\pi\sqrt{(0.1nH+1pH)*10\mu F}}$
- $f_{resonance} = 5.01MHz$

Example

- $V_{ripple} = I\ (5\ MHz) * Z\ (5\ MHz)$
- $V_{ripple} = 1A * \mathbf{0.24m\Omega}$
- $V_{ripple} = 0.24mV = 0.48mV_{pk-pk}$



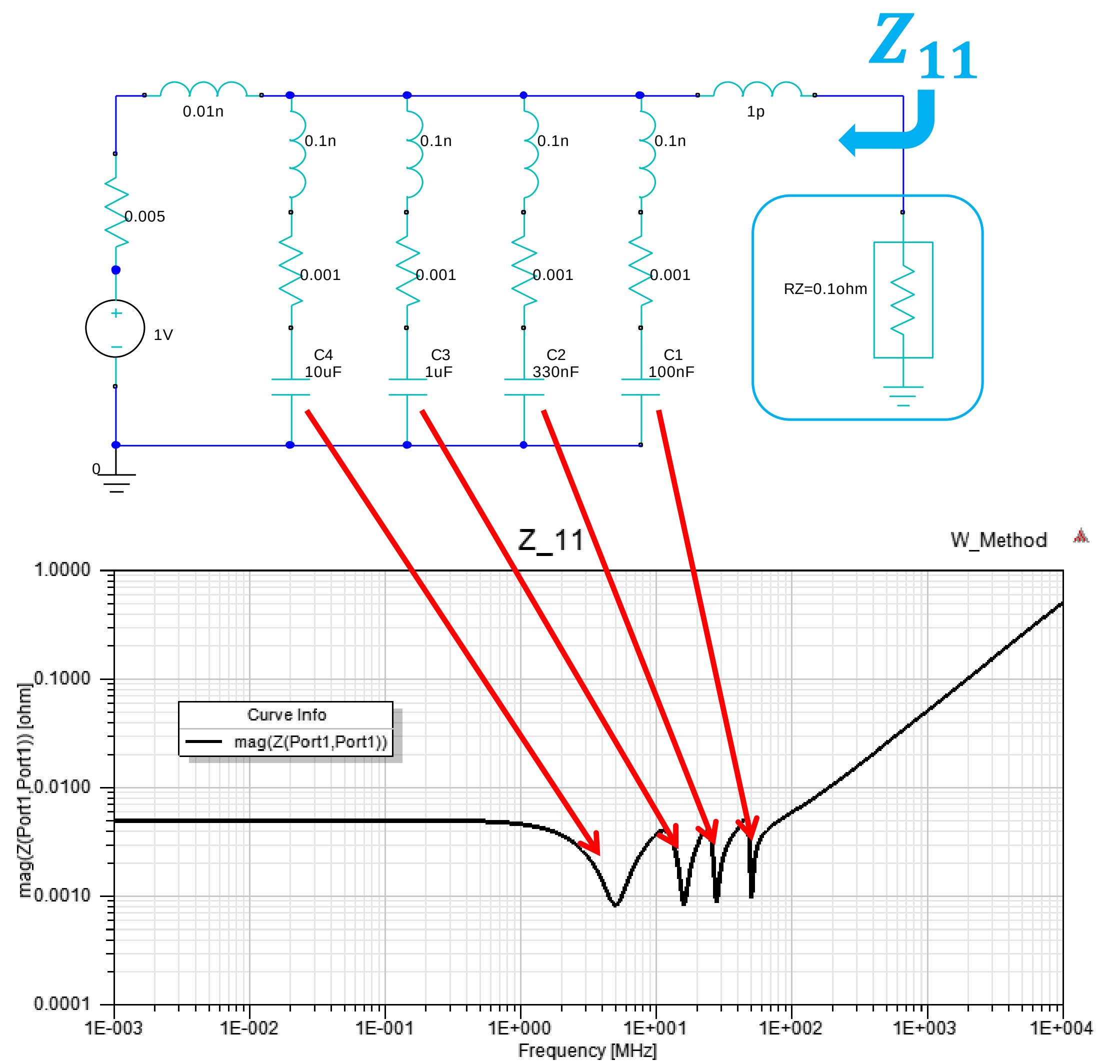
W Method

W Method

- Choose different capacitor values to be more effective across a broad range of frequencies. The resultant impedance plot resembles a W shape.
- $f_{res,C4} = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{101pH*10\mu F}} = 5.01\ MHz$
- $f_{res,C3} = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{101pH*1\mu F}} = 15.8\ MHz$
- $f_{res,C2} = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{101pH*330nF}} = 27.6\ MHz$
- $f_{res,C1} = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{101pH*10nF}} = 158\ MHz$

Example

- $V_{ripple} = I\ (5\ MHz) * Z\ (5\ MHz)$
- $V_{ripple} = 1A * \mathbf{0.832m\Omega}$
- $V_{ripple} = 0.832mV = 1.664mV_{pk-pk}$



Simulation of Physical Structures

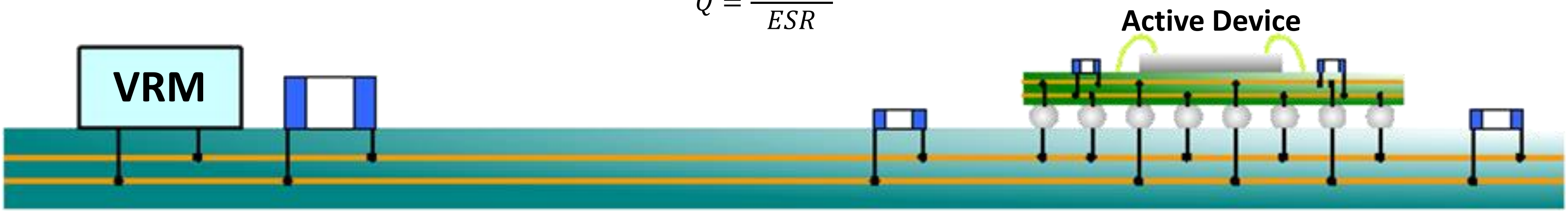
Circuit Simulation vs. Electromagnetic Field Solvers

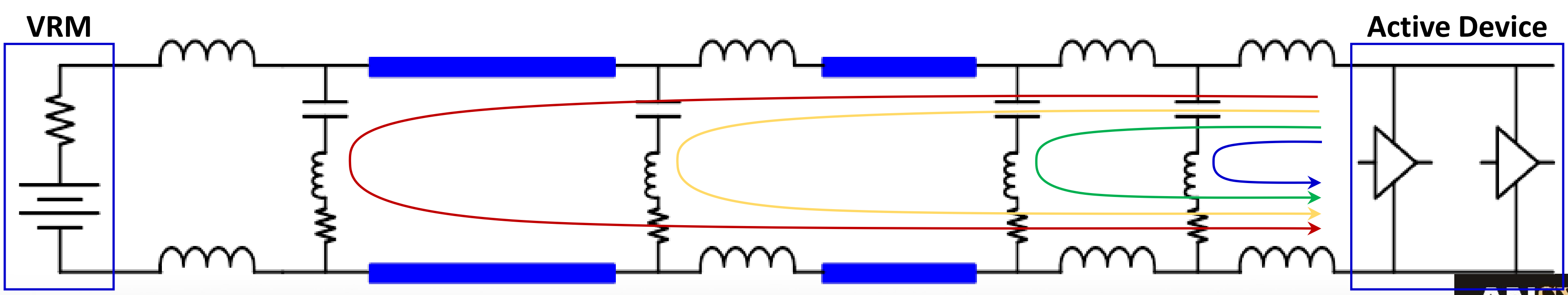
- Real, physical designs have many more inductive loops, capacitive planes, and resistive paths which were not depicted in the previous example circuit. In order to account for all of the effects of physical layout and geometry complexities, a field solver such as SIwave, Sentinel-PSI, or HFSS must be used.
- In any of the methods shown, loop inductance plays a vital role in determining the frequency of effectiveness. The L-C combination dictates the resonant frequency of adding or changing a capacitor value at a specific location.

$$f_{resonance} = \frac{1}{2\pi\sqrt{LC}}$$

- Equivalent Series Resistance (ESR) and conductor path resistance affects the quality factor (Q) of the placed component.

$$Q = \frac{\left|\frac{1}{2\pi f C}\right|}{ESR}$$





PI Advisor Setup and Solution Process

PI Advisor Decoupling Capacitor Optimization

SIwave with PI Advisor will help you determine which capacitors are the most effective for your design goals.

- Genetic Algorithm to determine effectiveness of capacitors in predefined locations.
- View selected Capacitor Schemes against the defined profile.
- Loop Inductance from an Active Device location to each associated Capacitor location.