EMC TIPS AND TRICKS FOR WIDE BANDGAP DEVICES

Jared Quenzer – Applications Engineer Manager

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

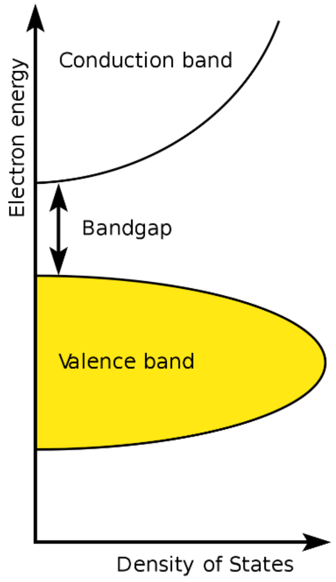
PUBLIC

AGENDA

- Benefits and drawbacks of Wide-Bandgap Devices (WBDs)
- EMI Mitigation Techniques
  - Conducted
  - Radiated

BENEFITS OF WBDS

- WBDs refer to transistors that use material with a wide gap between the valence band and the conduction band.
- Two main technologies: Silicon Carbide (SiC) and Gallium Nitride (GaN)
- SiC has the advantage of lower switching losses, higher power density and higher temperature compared to Silicon technology.
- Commercially available SiC transistors achieve 1700 Vdss and over 2000 W power.
- GaN have faster rise times, but transistors for sale are limited at 900Vdss and around 175 W power.

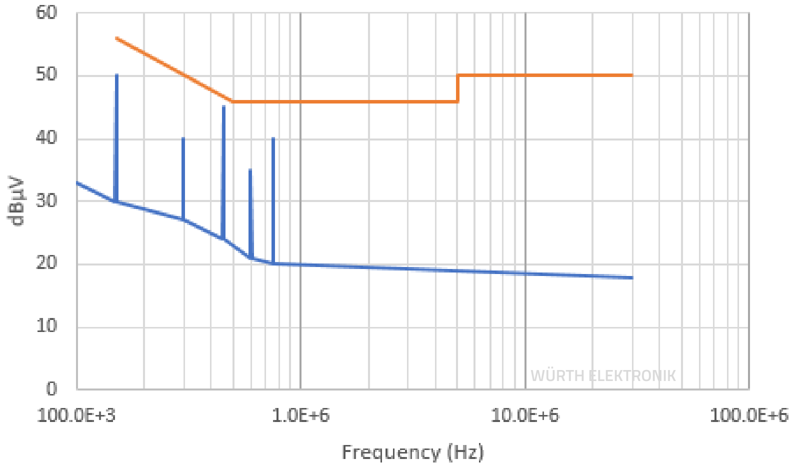


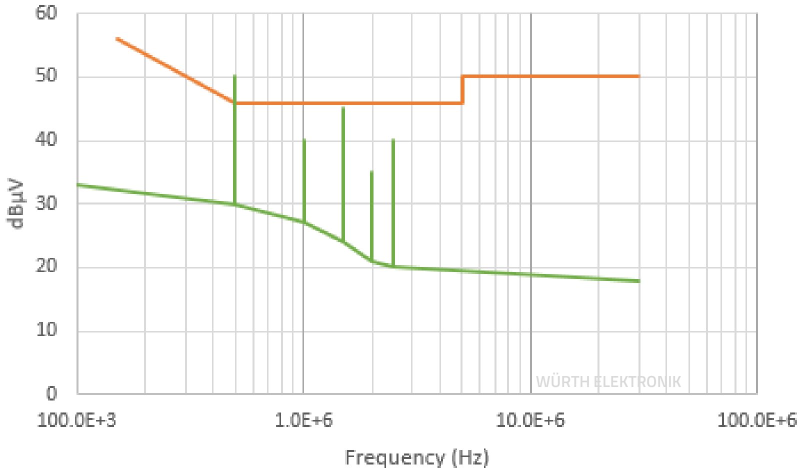
https://commons.wikimedia.org/wiki/File:Bandgap_in_semiconductor.svg

https://commons.wikimedia.org/wiki/File:Efficiency.png

DRAWBACKS OF WBDS

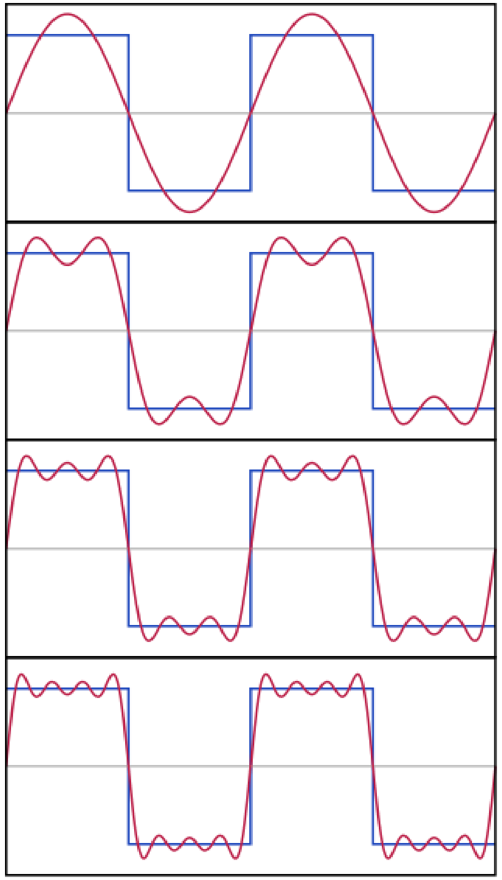
- Higher switching frequencies push the spectral energy into the most difficult section of the conducted emissions band.
- EMC standards might consider lower limit lines due to the ever-increasing number of devices occupying the same electromagnetic spectrum.
- Many reference designs either:
  - Do not show EMC test results
  - Admit making a WBD power supply that passes EMC is difficult and attempt a good layout, to have it not pass the first iteration.



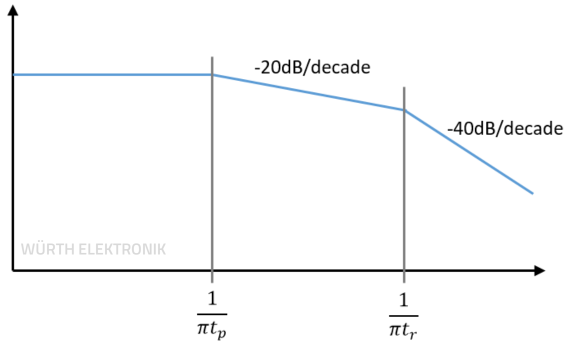


FAST DV/DT AND DI/DT

- Rise time dictates the envelope for higher frequency harmonics
  - 100ns rise time = 3.18 MHz
  - 10ns rise time = 31.8 MHz
- Fast changes in voltages or currents are the enemy when designing for EMC.
- Loop areas must be small and traces thick to minimize the inductance of the PCB traces.
- Larger gate resistor to slow down the gate
- Parasitic capacitances especially due to PCB layout are critical. Even with good PCB layout, filtering will be necessary.

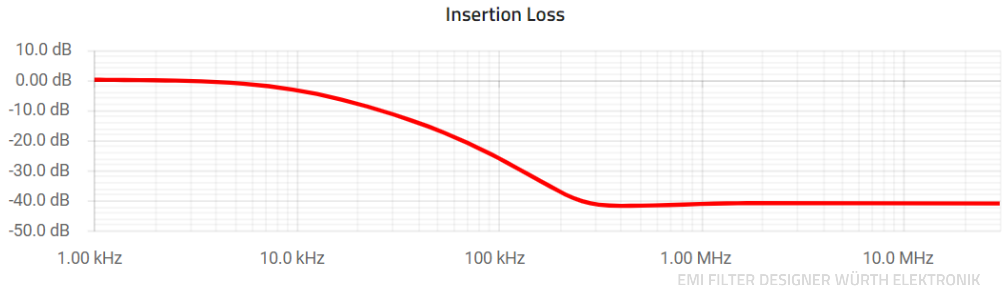


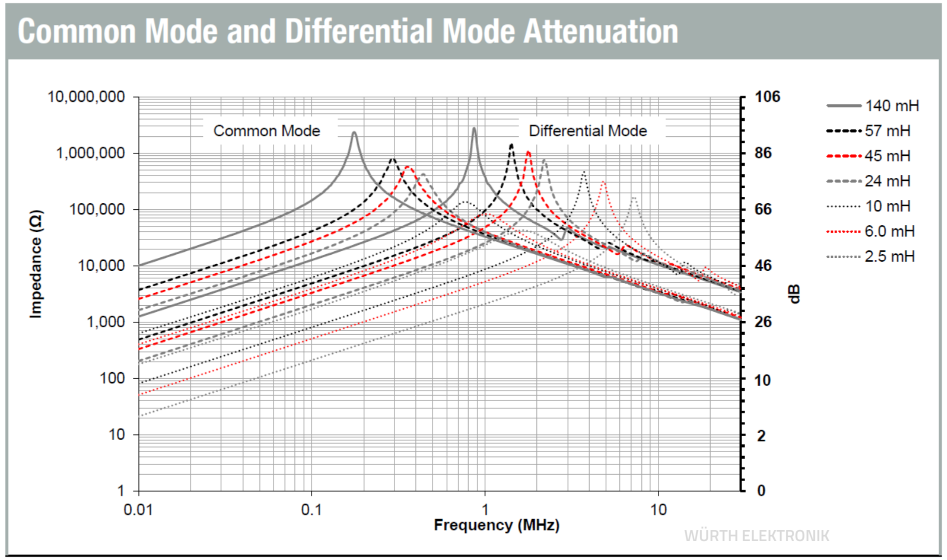
https://commons.wikimedia.org/wiki/File:Fourier_Series.svg



TECHNIQUES – CONDUCTED EMISSIONS

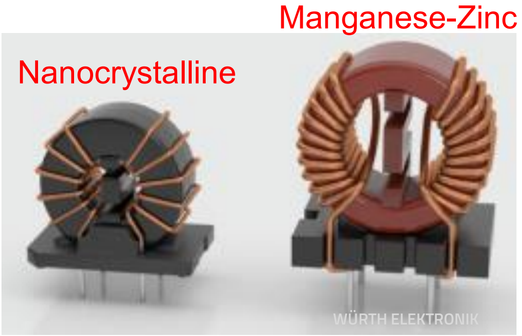
- Conducted Band <30MHz
- Differential mode
  - Can be filtered by multi-stage low-pass LC filters to target various frequencies.
  - Cut-off frequency at least 1 decade below switching frequency
  - Some common mode chokes (CMCs) include some differential mode attenuation.
- Common mode
  - Techniques discussed in detail earlier in this session





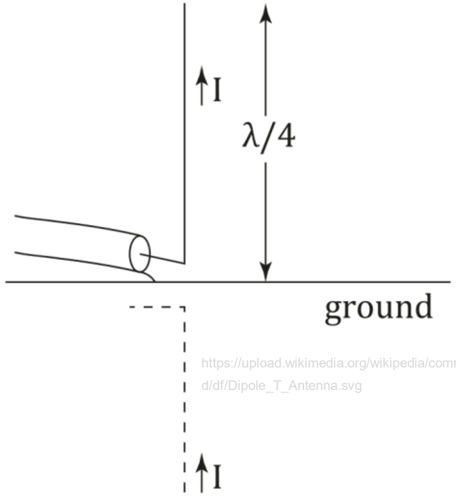
BOARD LEVEL TECHNIQUES – RADIATED EMISSIONS

- Mostly common mode noise above 30MHz.
- Parasitic capacitances
  - PCB layout, heatsinks, even the FETs themselves.
- Common mode chokes.
  - What core material is best?
  - MnZn - standard option
  - NiZn - Better for higher frequency
  - Nanocrystalline
    - Excellent wideband attenuation
    - Excellent density (more inductance in the same size).

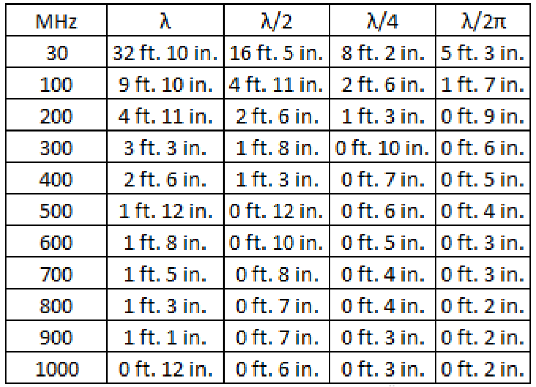


CABLE FERRITES

- Purpose is to attenuate common mode currents on the cable.
- When to use a cable ferrite?
  - Cables 2ft-8ft in length are good radiators in the 30MHz-100MHz frequency range.
- Best to start by minimizing the conducted emissions, then work on radiated emissions.
- Place the cable ferrite as close to the noise source as possible.



https://upload.wikimedia.org/wikipedia/commons/d/df/Dipole_T_Antenna.svg



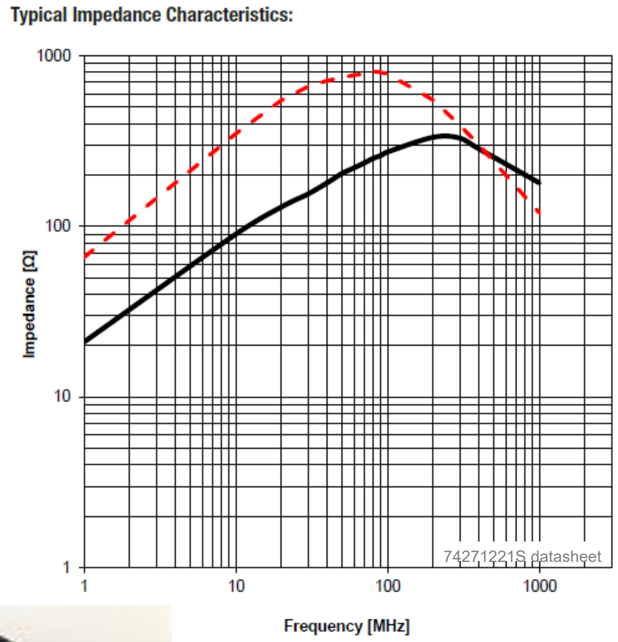
MHz	λ	λ/2	λ/4	λ/2π
30	32 ft. 10 in.	16 ft. 5 in.	8 ft. 2 in.	5 ft. 3 in.
100	9 ft. 10 in.	4 ft. 11 in.	2 ft. 6 in.	1 ft. 7 in.
200	4 ft. 11 in.	2 ft. 6 in.	1 ft. 3 in.	0 ft. 9 in.
300	3 ft. 3 in.	1 ft. 8 in.	0 ft. 10 in.	0 ft. 6 in.
400	2 ft. 6 in.	1 ft. 3 in.	0 ft. 7 in.	0 ft. 5 in.
500	1 ft. 12 in.	0 ft. 12 in.	0 ft. 6 in.	0 ft. 4 in.
600	1 ft. 8 in.	0 ft. 10 in.	0 ft. 5 in.	0 ft. 3 in.
700	1 ft. 5 in.	0 ft. 8 in.	0 ft. 4 in.	0 ft. 3 in.
800	1 ft. 3 in.	0 ft. 7 in.	0 ft. 4 in.	0 ft. 2 in.
900	1 ft. 1 in.	0 ft. 7 in.	0 ft. 3 in.	0 ft. 2 in.
1000	0 ft. 12 in.	0 ft. 6 in.	0 ft. 3 in.	0 ft. 2 in.

WÜRTH ELEKTRONIK

WÜRTH ELEKTRONIK

CABLE FERRITES

- 1 turn vs multiple turns
  - Adding 2x more turns does not always mean increasing the impedance by 2x since you are essentially adding more turns on an inductor.
  - This increases the inductance, which actually shifts the self-resonant frequency lower in frequency while also increasing the impedance.
  - This is why for most applications the maximum recommended number of turns is 2-3.

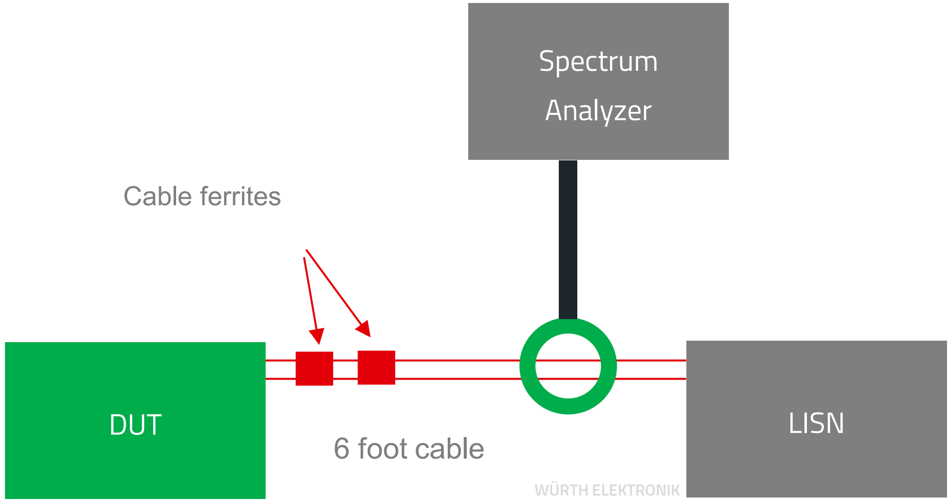


74271221S datasheet

WÜRTH ELEKTRONIK

CABLE FERRITES

- DUT is 500kHz SMPS using SiC MOSFET[1]
- Radiated emissions can be estimated by measuring cable currents with current probe[2]



1) CREE SiC C2M0040120D (1200V, 60A, 40mΩ)

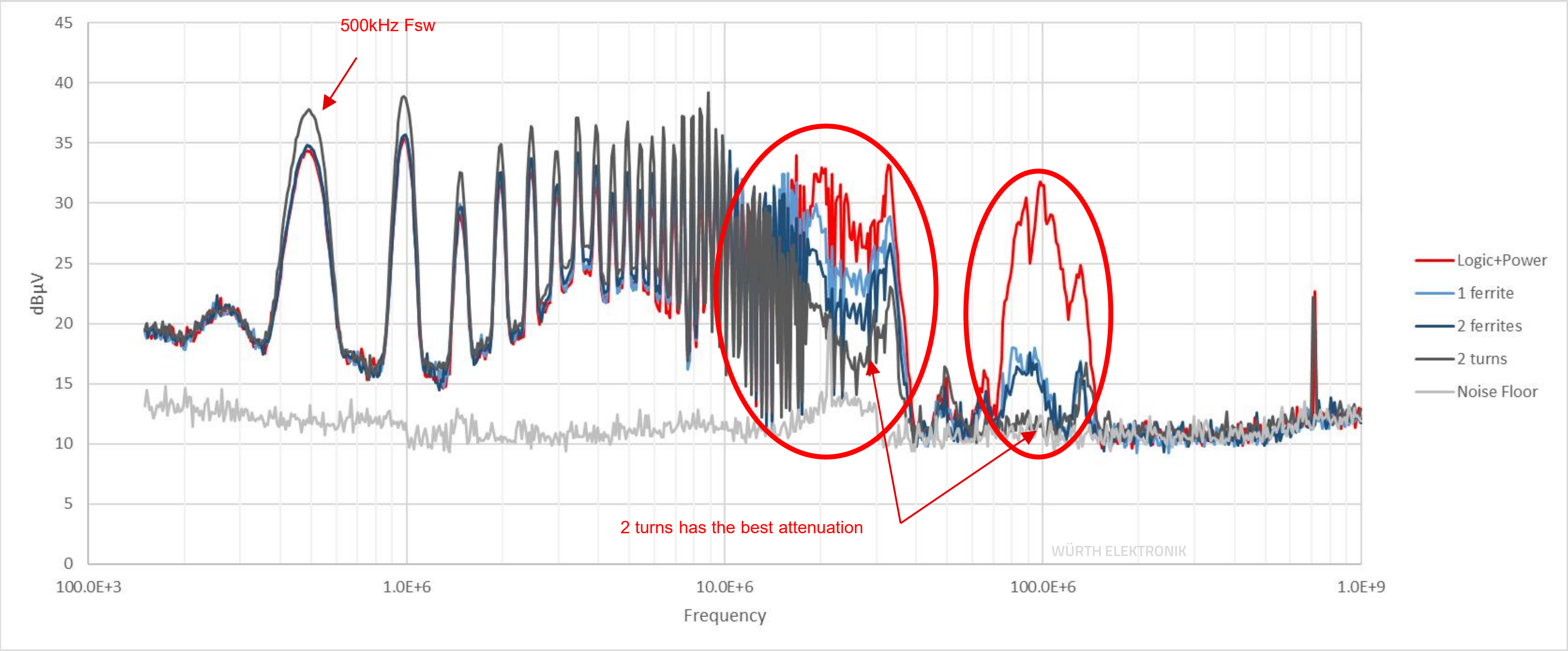
2) Dr. Clayton Paul, Henry Ott and countless other authors. This website has a good summary: https://emcfastpass.com/current-probe-e-field-emi-testing/

QUIZ

- What will have the best overall attenuation?
  - A) 1 cable ferrite with 1 turn
  - B) 2 cable ferrites with 1 turn (on the same end of the cable)
  - C) 1 cable ferrite with 2 turns

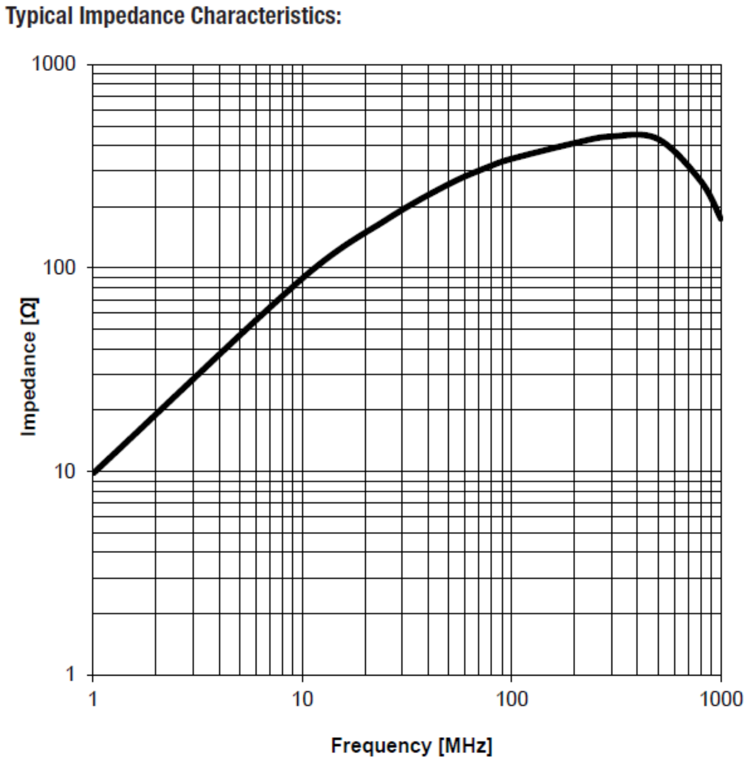
CABLE FERRITES

- Test Results: 1 turn vs 2 turns vs 2 ferrites



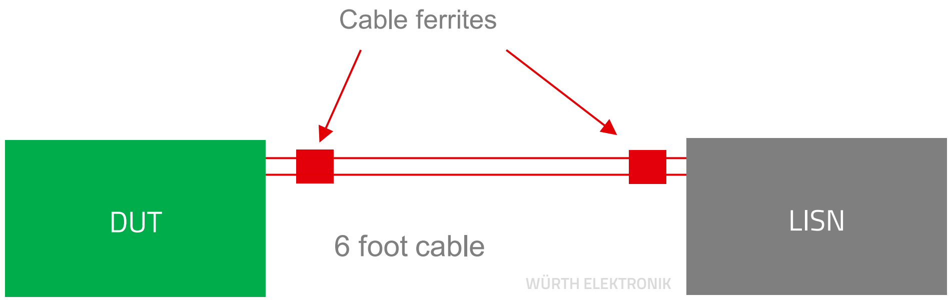
500kHz Fsw

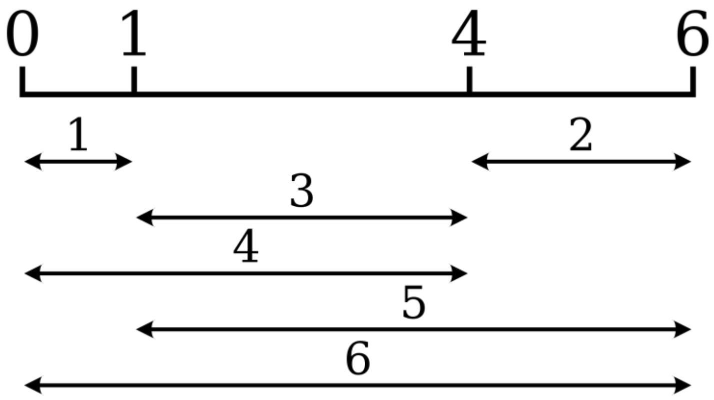
2 turns has the best attenuation


Typical Impedance Characteristics:

CABLE FERRITES

- Common in the real world to use one cable ferrite on each end instead of two cable ferrites side by side in my experiment.
- The actual attenuation depends on the wire diameter, the wire impedance with respect to ground, the sleeve position and the ferrite material.[1]
- Multiple sleeves should be positioned at locations by optimal Golomb rulers.





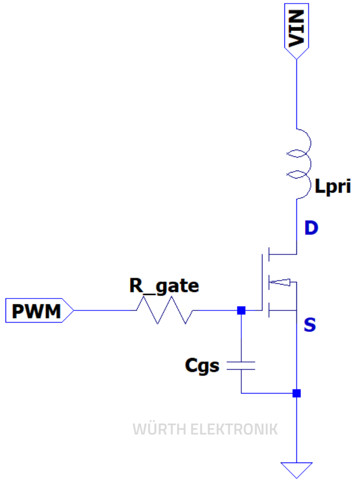
https://commons.wikimedia.org/wiki/File:Golomb_Ruler-4.svg

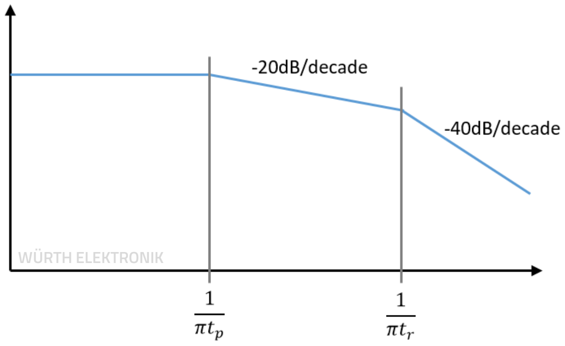
---

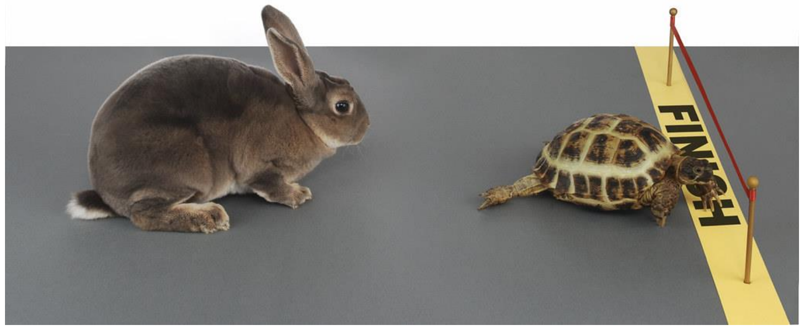
[1] Cable Ferrite Performance Assessment by Steffen Shulze

GATE DRIVE RESISTOR

- Increasing the gate resistor (R_gate) increases the RC time constant which charges the internal gate capacitance (Cgs) slower.
- This allows I_{DS} to ramp up slower.
- This increases the risetime which reduces the harmonic envelope dictated by $\frac{1}{\pi t_r}$
- Also could use a ferrite bead.
- Keep in mind you are likely paying more money for a SiC just to drive it slower.
- Your goal is to get your product to market so don't let EMI issues cause delays.
- *"Slow and steady wins the race"*

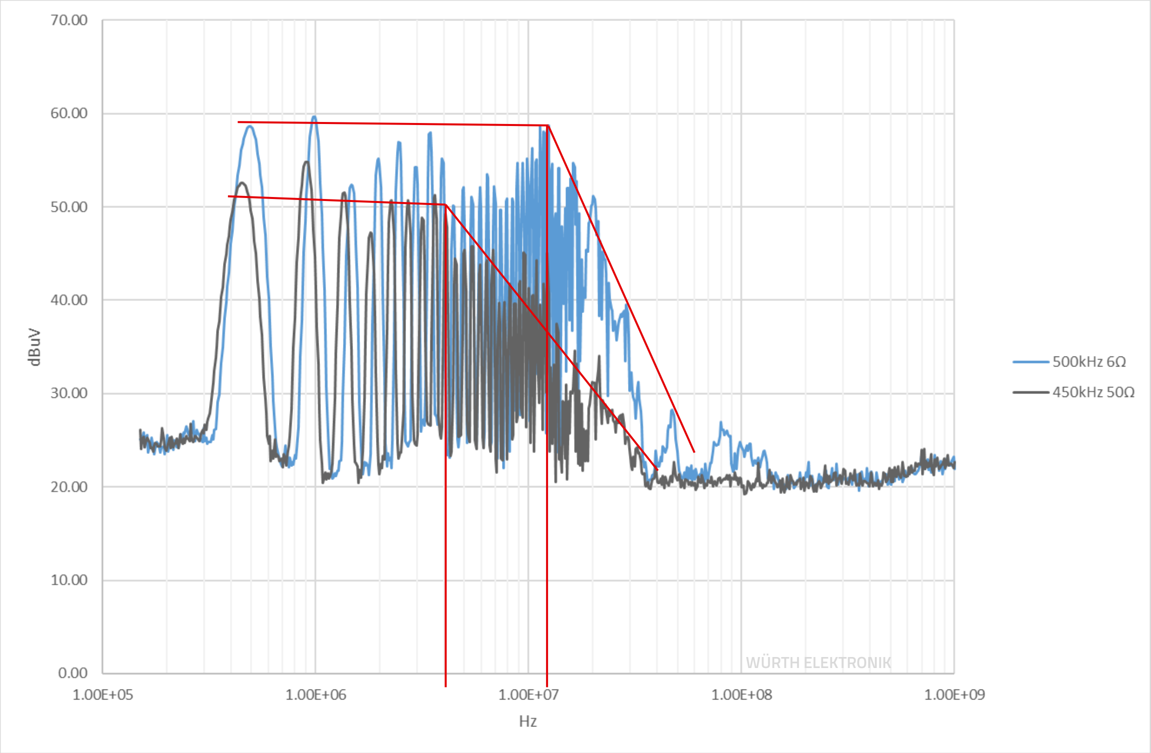




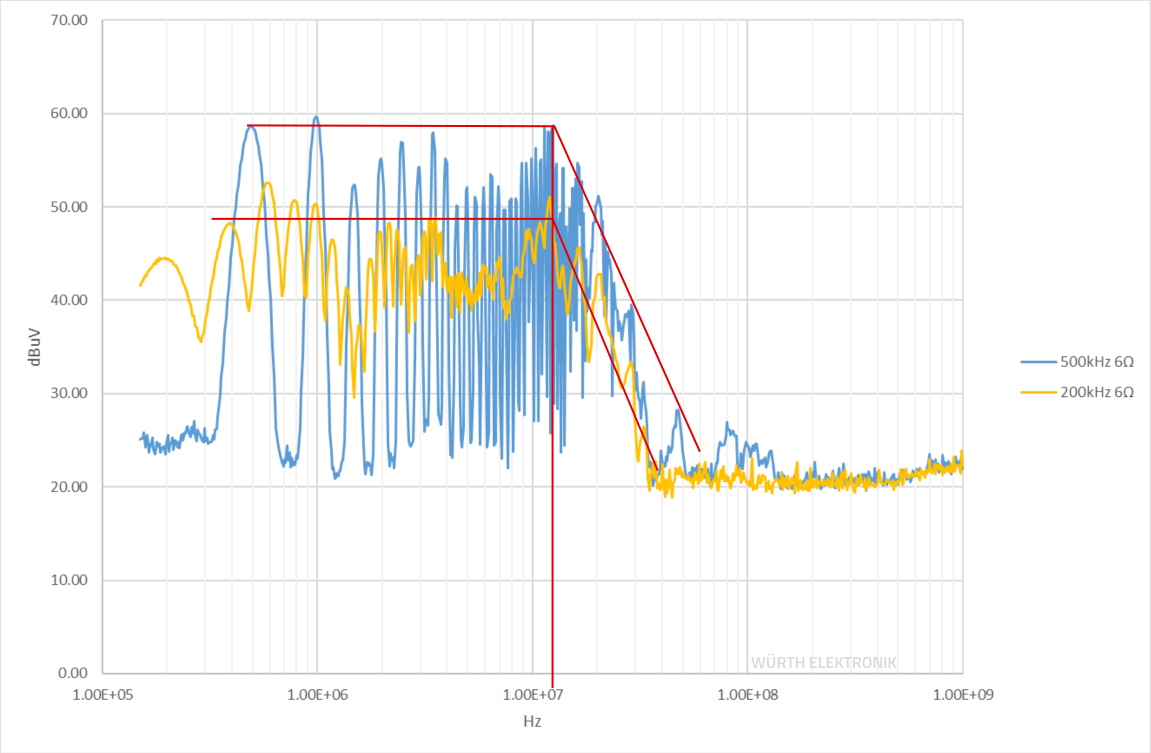


RISE TIME & FREQUENCY

- Increasing Rise Time

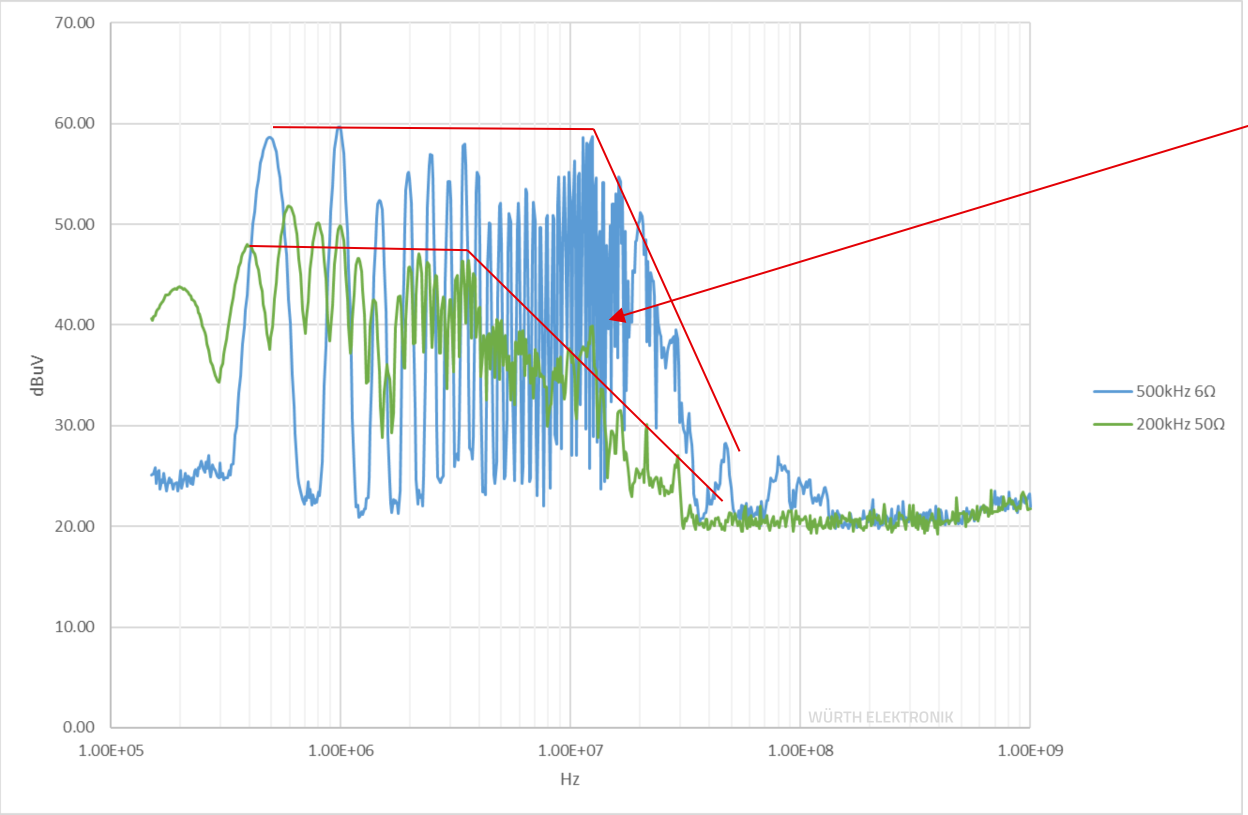


- Reducing Frequency



RISE TIME & FREQUENCY

- Increasing Rise Time & Reducing the Frequency

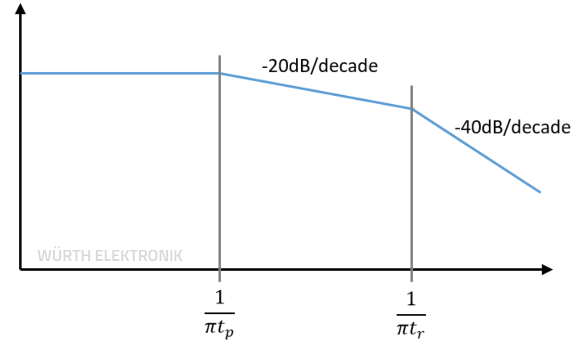


Almost 20dB reduction

in common mode

currents at 10 MHz!

CONCLUSION – WIDE BANDGAP DEVICES



- WBDs have lower switching losses that allow for higher power density and higher efficiency.
- The fast rise times will cause more EMI above 10MHz, compared to silicon devices, which will need to be mitigated.
- EMI Mitigation Techniques
  - It is important to have a large toolbox of options since likely multiple techniques will be required to pass EMC.
  - Conducted – mostly differential, but also some common mode. LC filters and CMCs can be used.
  - Radiated – mostly common mode. CMCs, shielding materials, gaskets and cable ferrites might be needed even with good PCB design

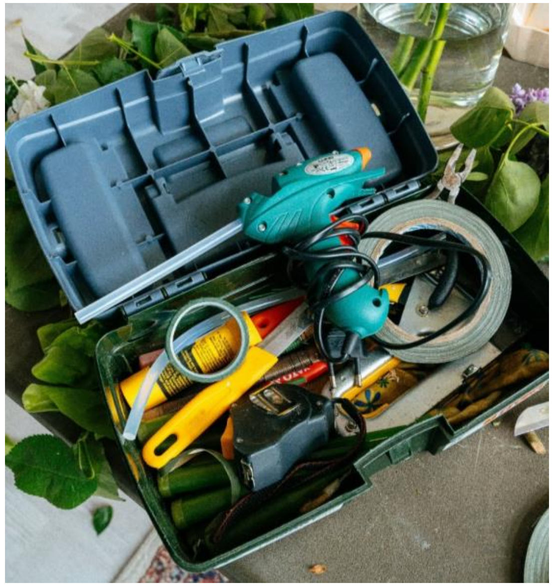
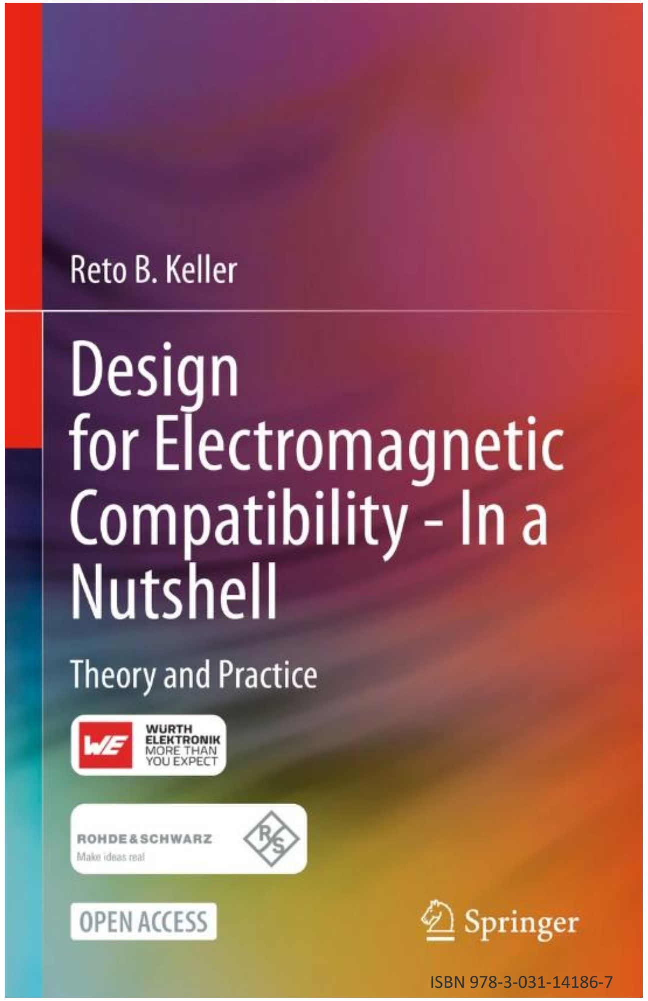


Photo by Antoni Shkraba: https://www.pexels.com/photo/glue-gun-in-the-toolbox-4612225/

FREE RESOURCES

- Free E-book
- Design for Electromagnetic Compatibility--In a Nutshell: Theory and Practice


Reto B. Keller

Design for Electromagnetic Compatibility - In a Nutshell

Theory and Practice

ISBN 978-3-031-14186-7

REFERENCES

[1] R. B. Keller, *Design for Electromagnetic Compatibility--In a Nutshell*. Springer, 2022.

[2] H. W. Ott, *Electromagnetic Compatibility Engineering*. Wiley, 2009.