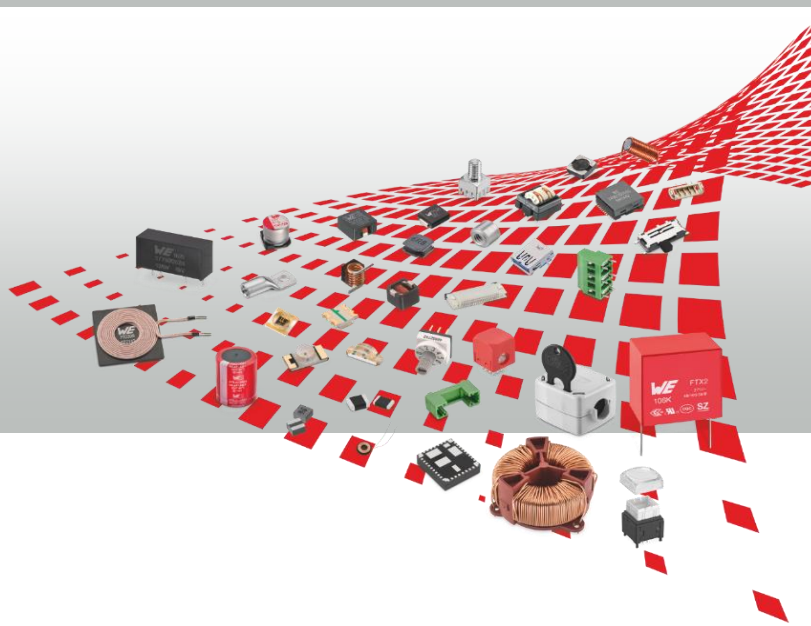


# Industrial Drive: EMC analysis



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# Würth Elektronik Line Card

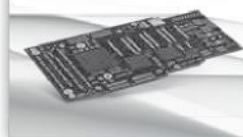


## The Würth Elektronik Group

### Electronic & Electromechanical Components



### Printed Circuit Boards



### Intelligent Power and Control Systems



### Standard

### Custom

#### Passive Components



#### Power Modules



#### LEDs



#### Electromechanical Components



#### Wireless Connectivity



#### Frequency Products



#### Connectors



#### Automotive



#### Magnetics





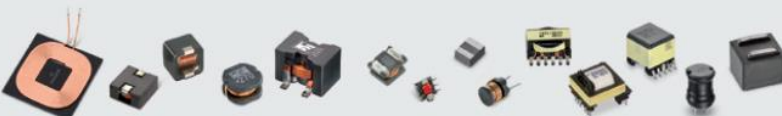
# Wurth Elektronik Line Card



**EMC Components**



**Capacitors**



**Power Magnetics**

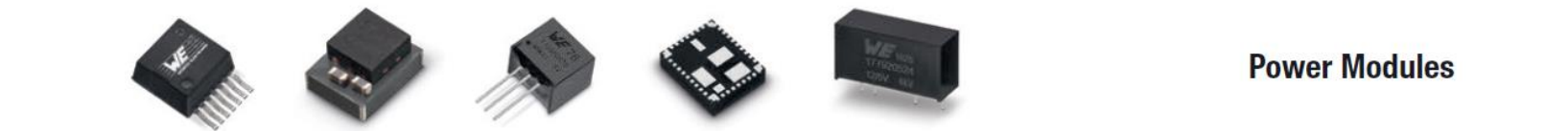


**Signal & Communications**

# Würth Elektronik Line Card



**LEDs**



**Power Modules**



**Wireless Connectivity**



**Connectors**



# Würth Elektronik Line Card



Fuseholders



Switches



Assembly Technique



REDCUBE Terminals

## Free Technical Support



- Possibility to agree on the presence of a FAE during the EMC tests in the laboratory
- Realization of free in-House seminars at your headquarters or in video-conference on different topics (EMC, ESD, DC / DC filtering, selection of inductors ...)
- Support in the selection of components for your application
- Sending of free samples for the prototyping phase and / or the EMC test phase
- Possibility to request on-site presence for project support

## Agenda

- DC Brushless
- Source of Interference
- Components for filtering
- More than Filter

## DC Motor (Brushless)

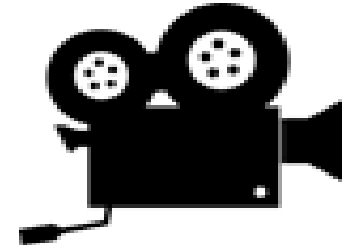
### Applications

- Fans
- Conveyers
- Pump
- Compressor
- Printer
- Automotive



### Stator

- Generate magnetic field



### Rotor

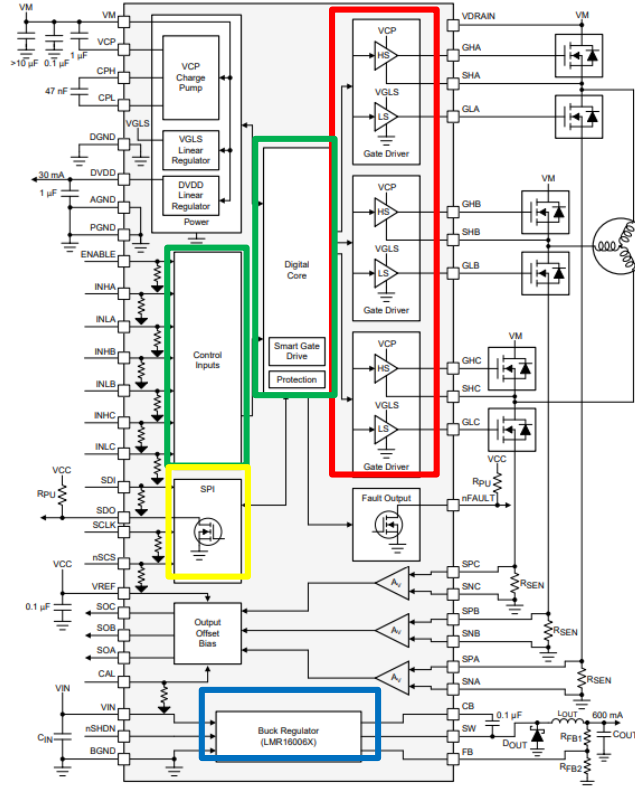
- Build by permanent magnet

**Dual construction  
of Brushed**



# Sources of Interference

- PWM Drive
- Control Logic and Oscillator
- Interfaces
- Switching Regulator
- Layout
- Wiring

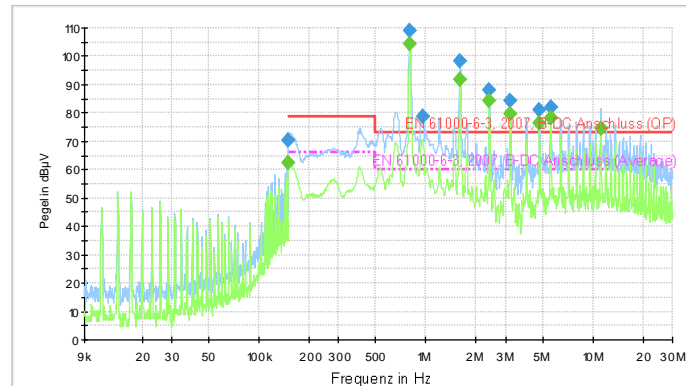


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# Wired interference - Conducted Emission

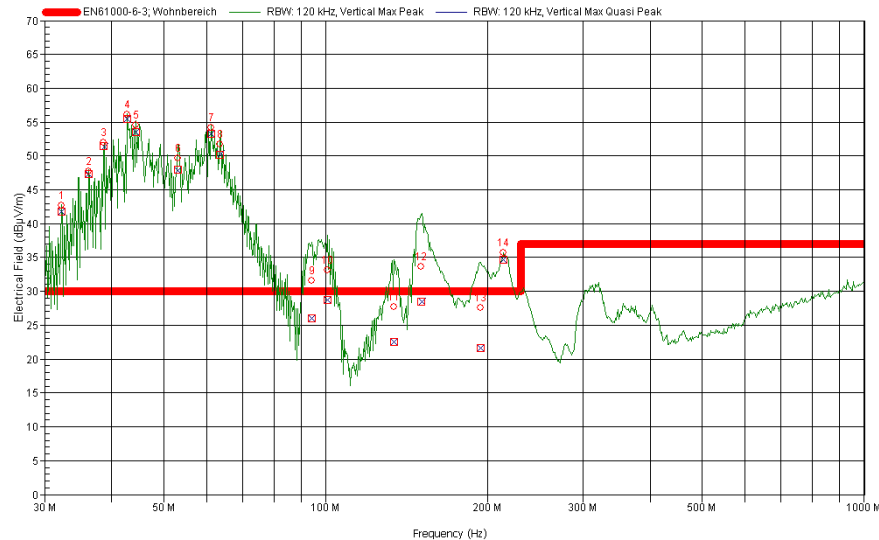
- Cause of the interference voltage of (9) 150kHz ... 30MHz:
  - Ripple current on the supply side
  - Rise/fall time controlled by gate drive
  - Interference current via parasitic coupling capacitances to ground (common mode)
- The unbalanced voltage sampled per phase contains symmetrical and asymmetrical components. .
- Limit value for the asymmetrical interference voltage, e.g. according to EN 61000-6-3

Emiss. 9kHz-30MHz ESIB26 ESH3-Z2 NNB-41 N



# Noise Emission - Radiated Emission

- Cause for the interference field strength of 30MHz ... 1 (6) GHz:
  - Noise current on conductor tracks or loops
  - Noise current on conductive housings
  - Interference current on lines connected to interfaces
- Limit value for the radio interference field strength e.g. according to EN 61000-6-3

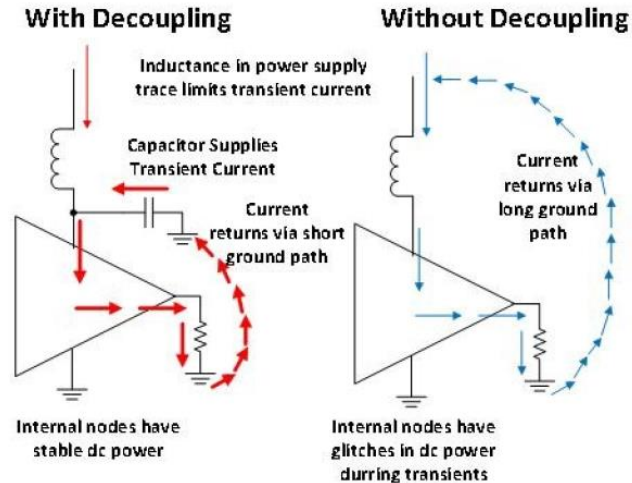
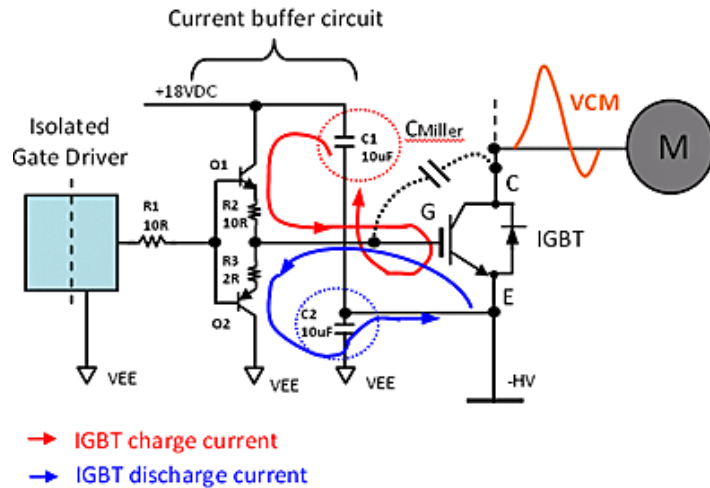


## Overview sources of interference

Type of Fault	Dominant Source	Frequency Range	Radiated or Conducted
Low Frequency Range	Fundamental and harmonics of the controller switching frequency	10kHz to 30MHz	Conducted
Broadband Interference	$dI / dt$ and $dU / dt$ of the FET (silicon) switching edges and parasitic resonant circuits	30MHz to 200MHz	Conducted and Radiated
High Frequency interference	Reverse Recovery of Schottky Diodes	Over 200MHz	Radiated

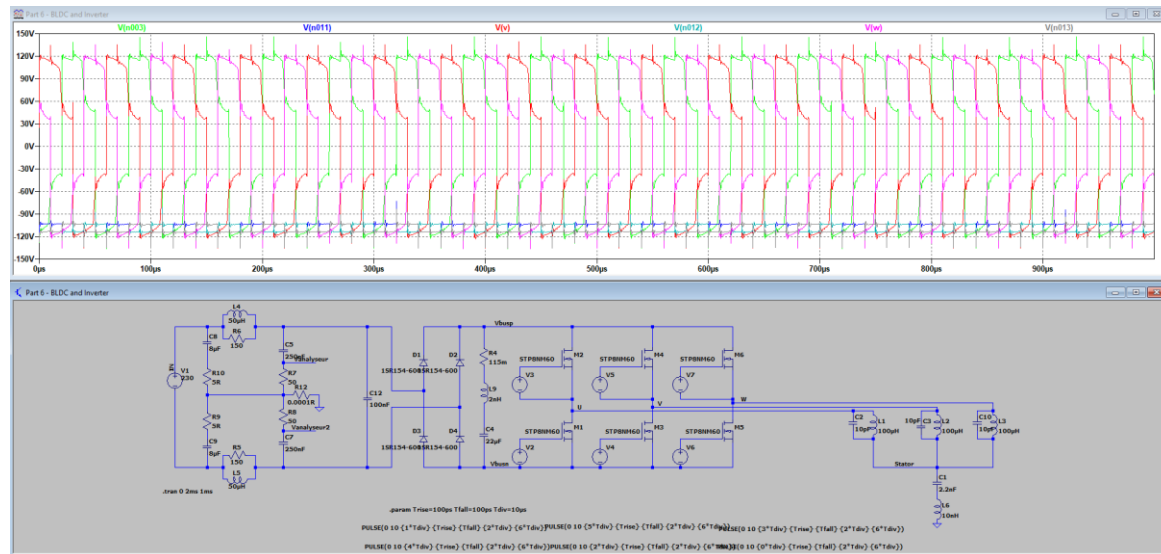
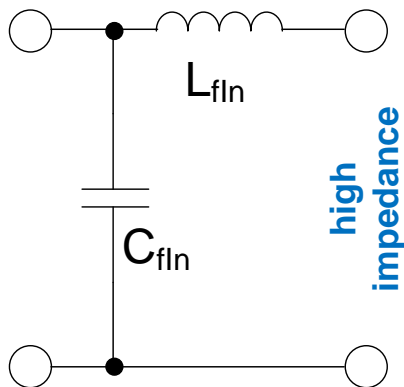
# Differential mode interference: Filtering

- Minimizing the differential mode interferers by :
  - Placing a RF decoupling "C" close to the switching node
  - Keep high  $\Delta I / \Delta t$  loops (loop antennas) compact → Minimization of H-fields
  - Use ferrite to filter HF differential noise generated by Oscillator



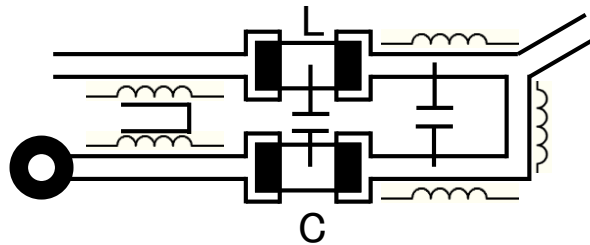
# Differential mode interference: Filtering

- DM Filtering:
- Input LC Filter to attenuate PWM signals (pulses)
- Place the correct way: input impedance of the transducer is very low, normally mainly dominated by the one or two capacitors
- The filter inductance thus represents a mismatch of impedance, and thus an effective DM filter

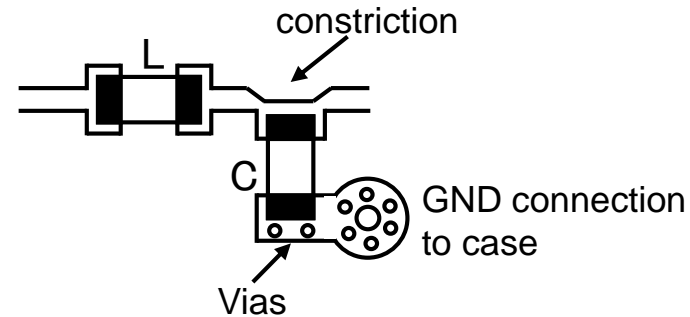


## Layout Suggestions on Drive Board : GND Reference for Filter

BAD



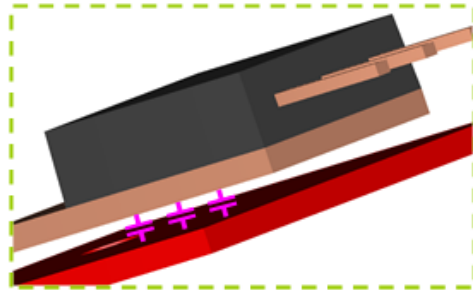
Optimal



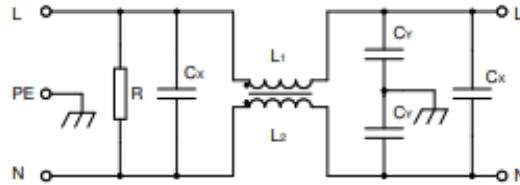
- Constriction reduces reflections (VSWR) in gigahertz range
- Right angle arrangement reduces capacitive coupling
- Vias and direct conductive board mounting enable low-impedance ground connection

# Common mode interference: Common Mode Choke

- Large common mode current paths due to the heat sink formation of HF capacitance
- These leads to problems with the Conducted & Radiated Measurement!
- Use Common Mode Choke and X or Y caps

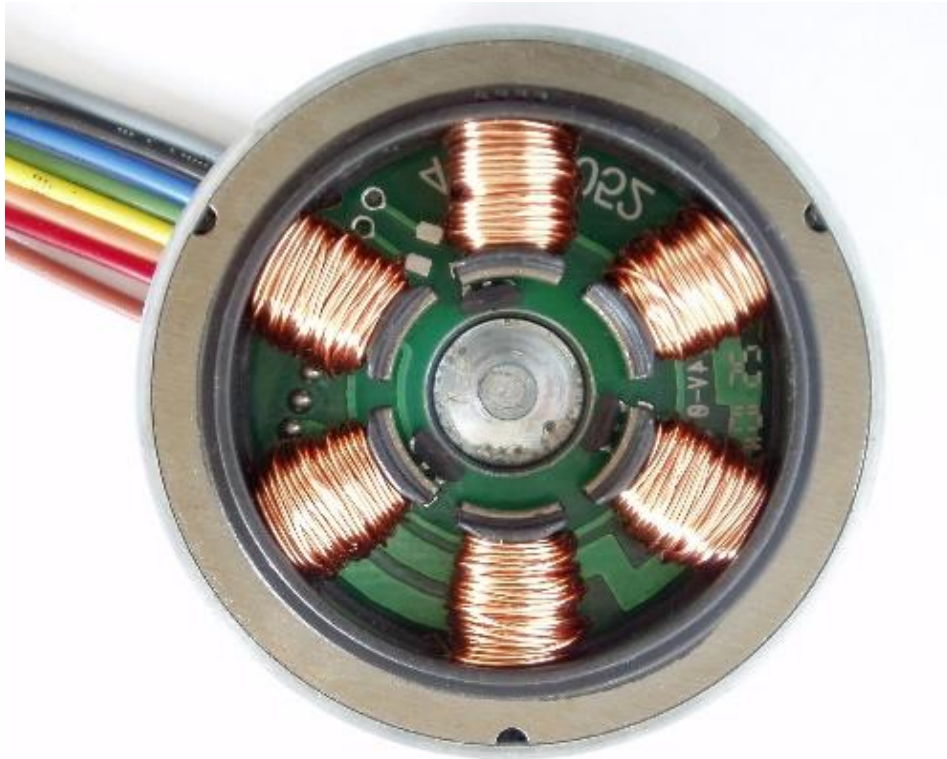


FET : fsw to 20MHz

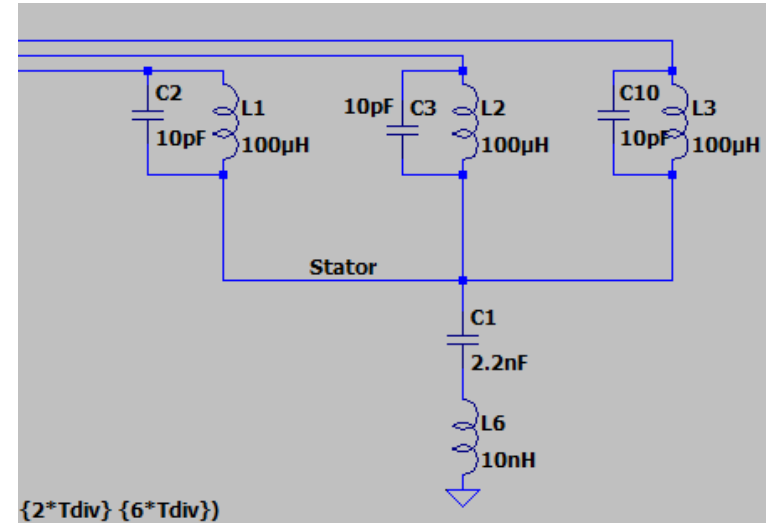




## Kind of Simulation

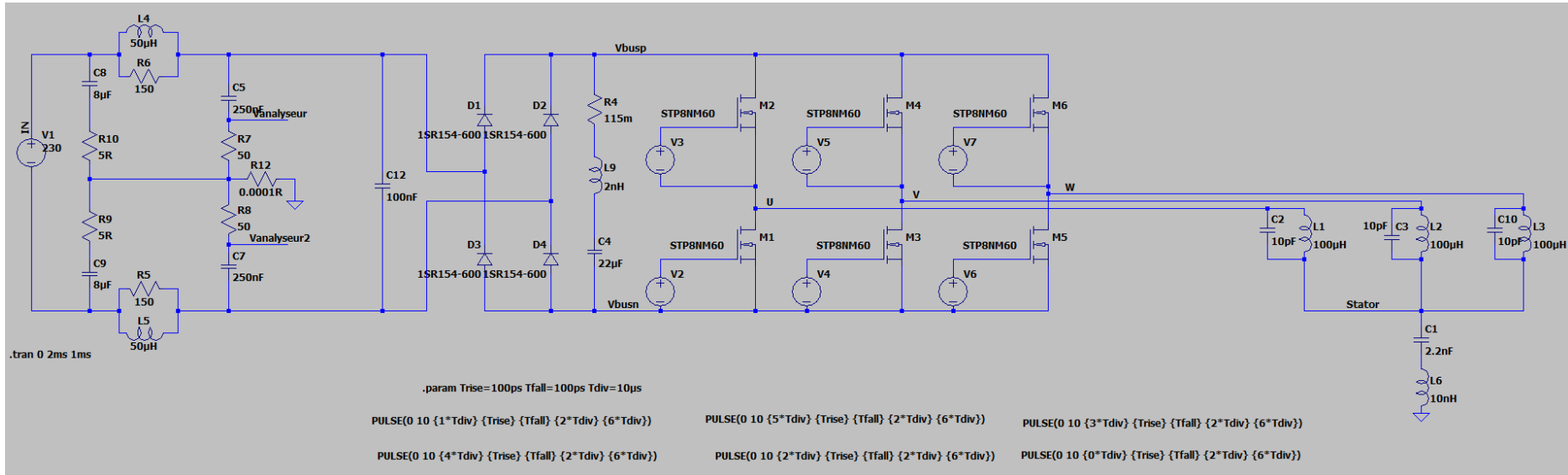


- Parasitic coupling to and through stator
- Influence of grounding (of stator)

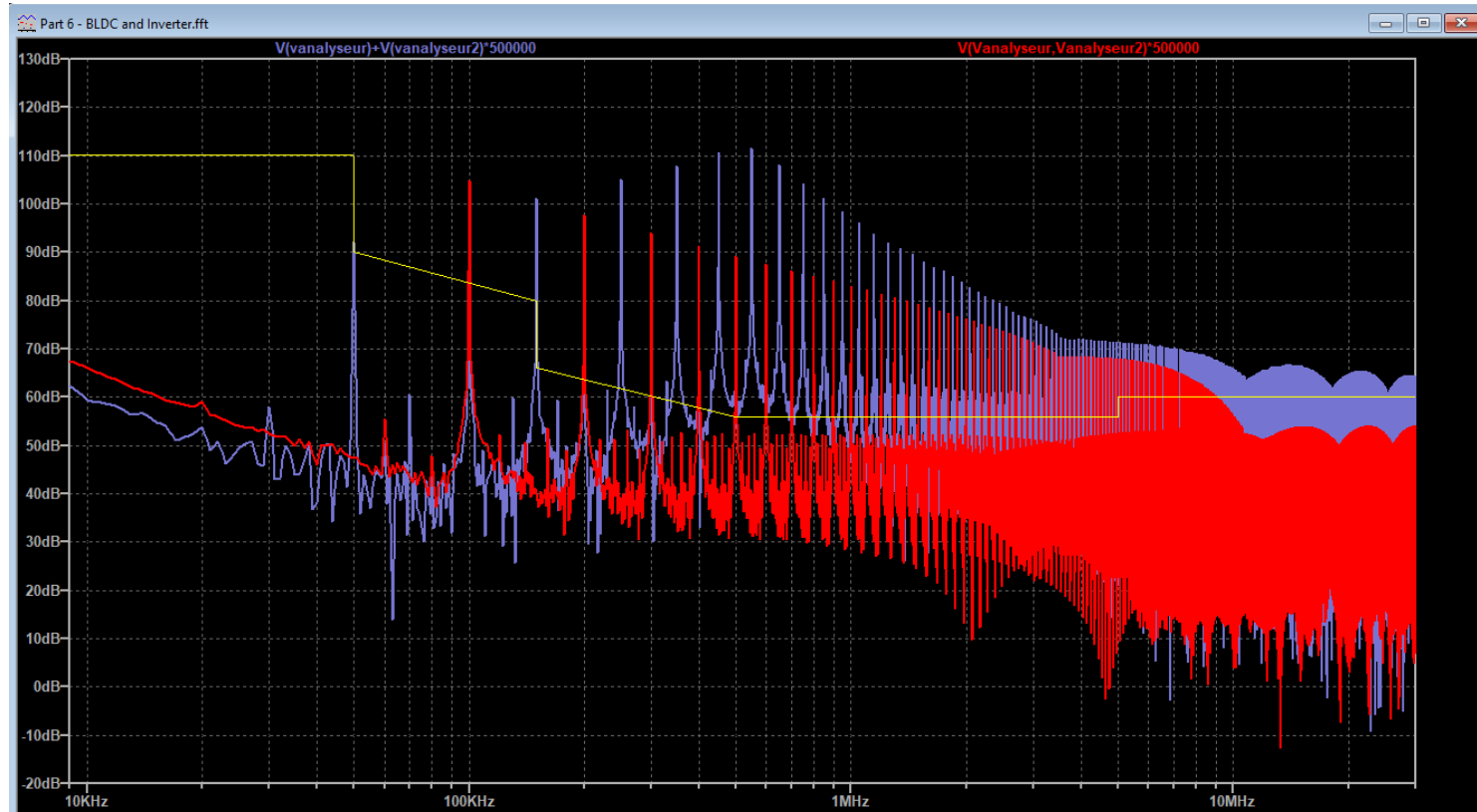


## Kind of Simulation

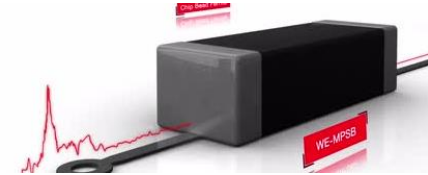
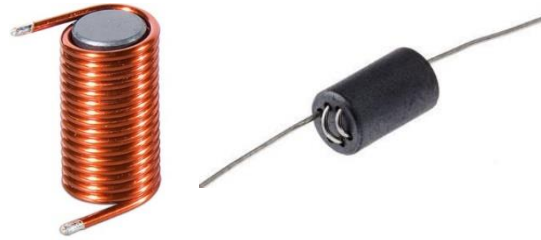
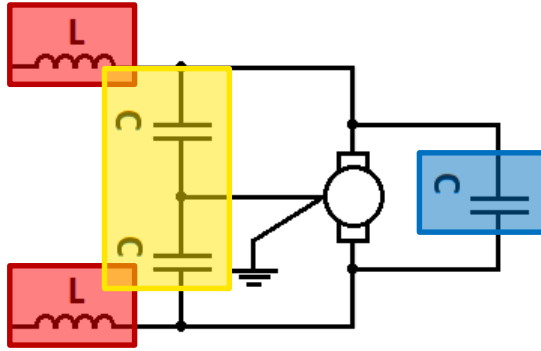
- Parasitic coupling to and through stator
- Influence of grounding
- Slew rate of driver
- Dead time impact



# Kind of Simulation



## Motor Side



- **Filtering Choke (L):**
  - Several micro Henry
    - Rode choke (WE-SD)
    - Ferrite Bead (WE-UKW, WE-PF, WE MPSB)
- **Cx Capacitor:**
  - Several nano Farad
    - WCAP-FTXX, WCAP-FTX2)
- **Cy Capacitors**
  - Several nano Farad



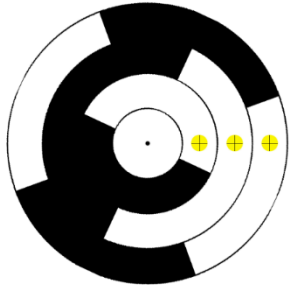
## Sensors (Encoder/Resolver)



Encoder  
(Digital)

Sensor

Resolver  
(Analog)

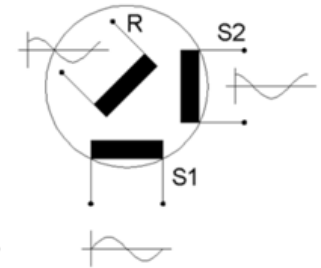


### Applications:

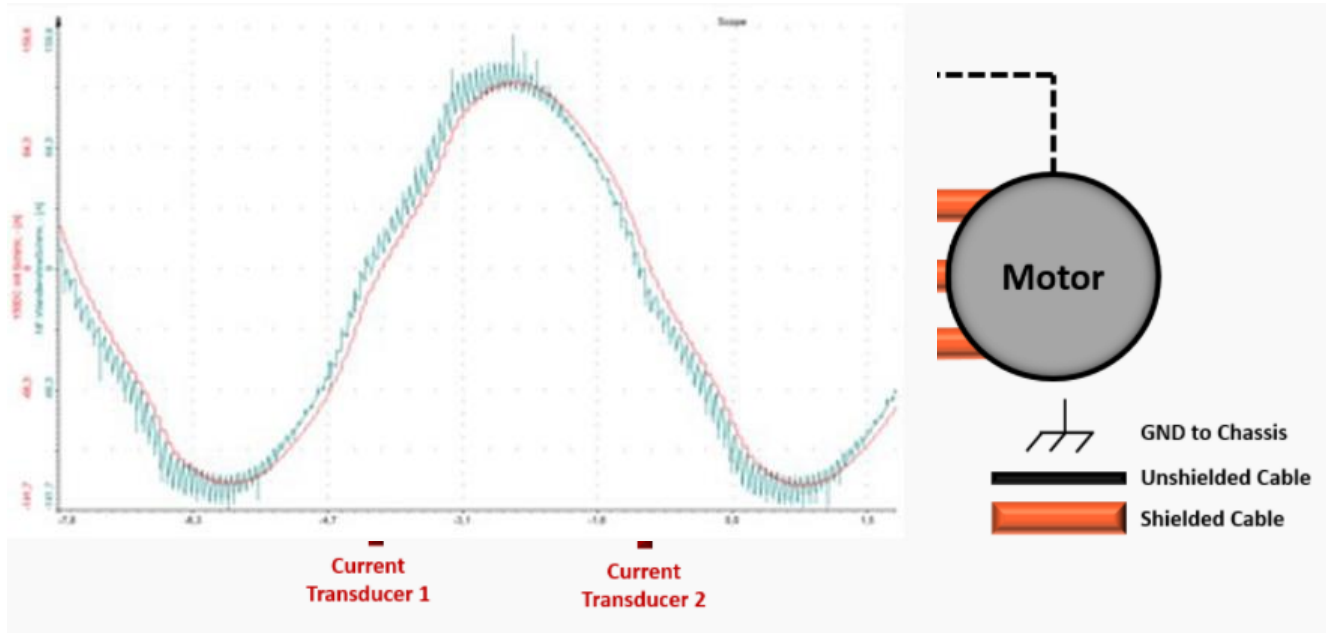
- Motor Speed Control
- Servo Motors
- ABS

### Filtering Digital Interface:

- **Can Bus**  
[https://www.we-online.com/applicationguide/en/applicationguide\\_can](https://www.we-online.com/applicationguide/en/applicationguide_can)
- **RS485**  
[https://www.we-online.com/applicationguide/en/applicationguide\\_rs485-rs422](https://www.we-online.com/applicationguide/en/applicationguide_rs485-rs422)

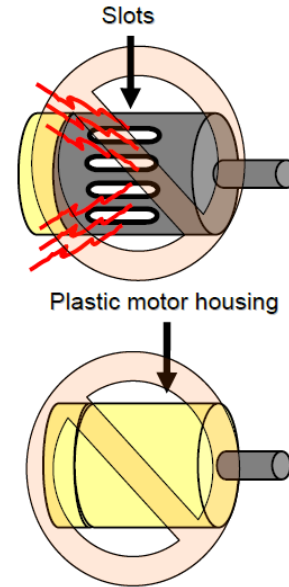


## More Than Filter: Shielding

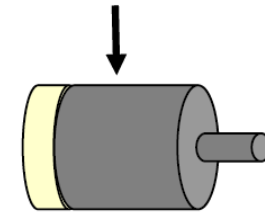


## More Than Filter: Shielding

- Housing should be metal or metalized to provide shielding.
- Slots should be eliminated or minimized to keep from making them “slot antenna”



Metalized motor housing



**Improved**

## Be Careful With Oscillator

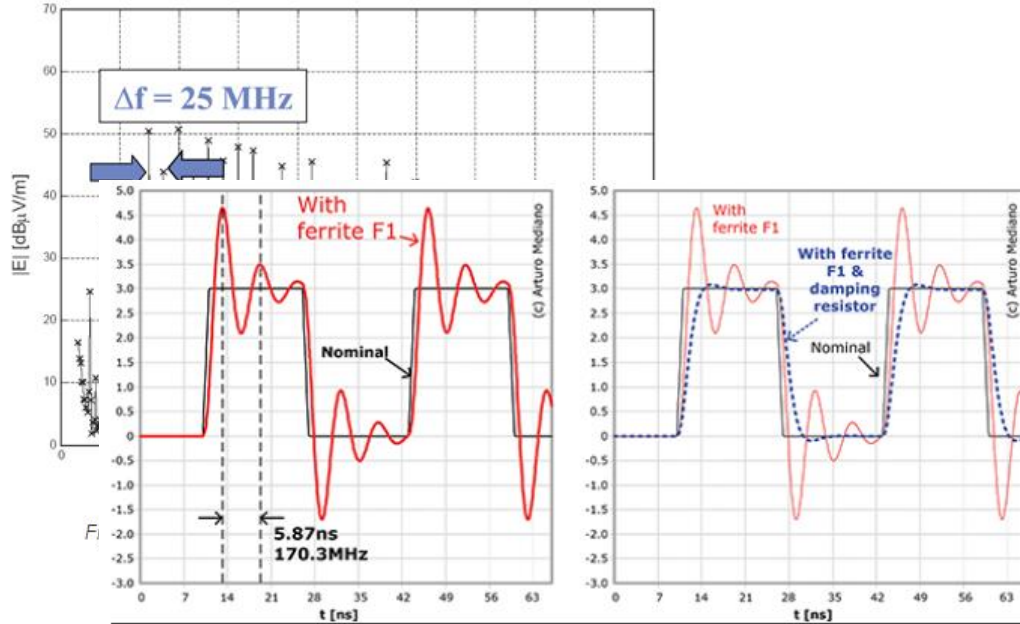


Figure 2: Nominal clock signal and effect of series ferrite (left). Ringing is damped with an additional series resistor (I do not like this solution).

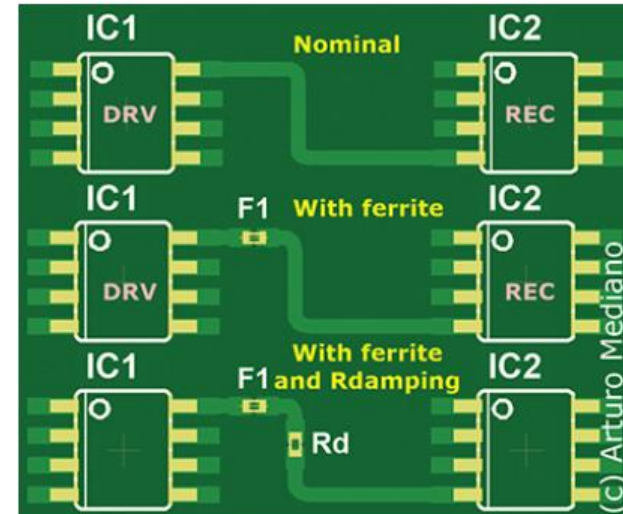
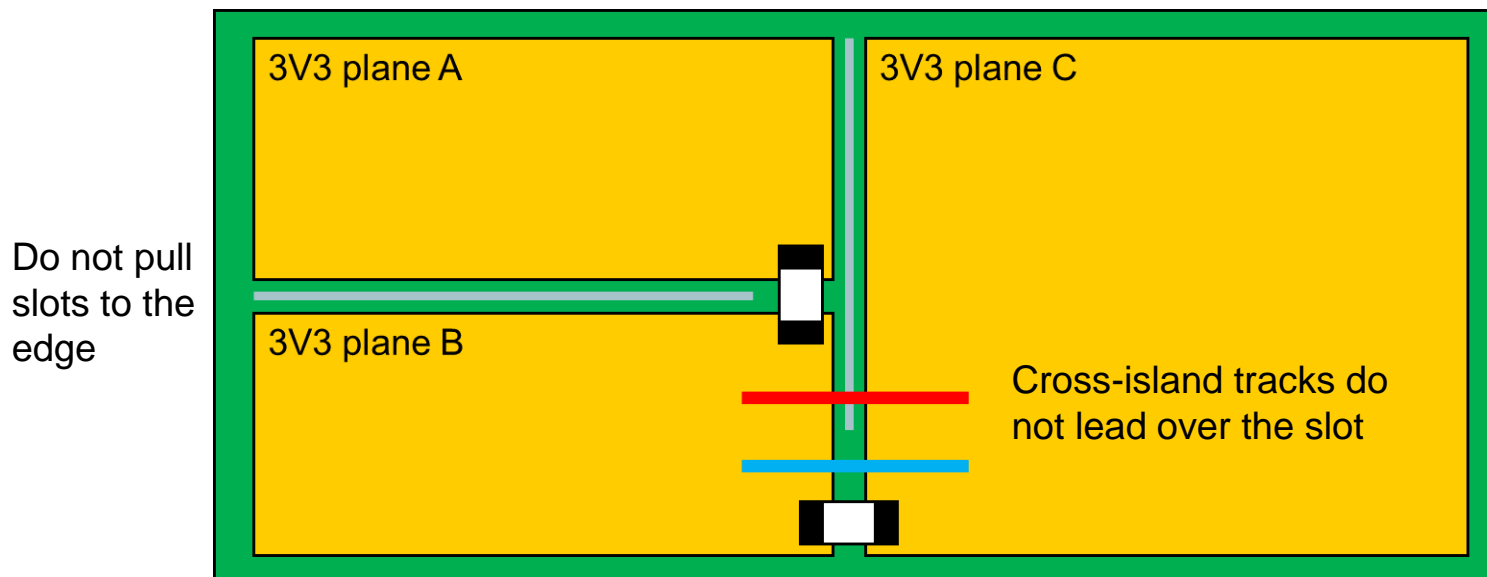


Figure 1: Original clock signal from IC1 to IC2 (top), with a ferrite in series (middle), and with ferrite and damping resistor (bottom).

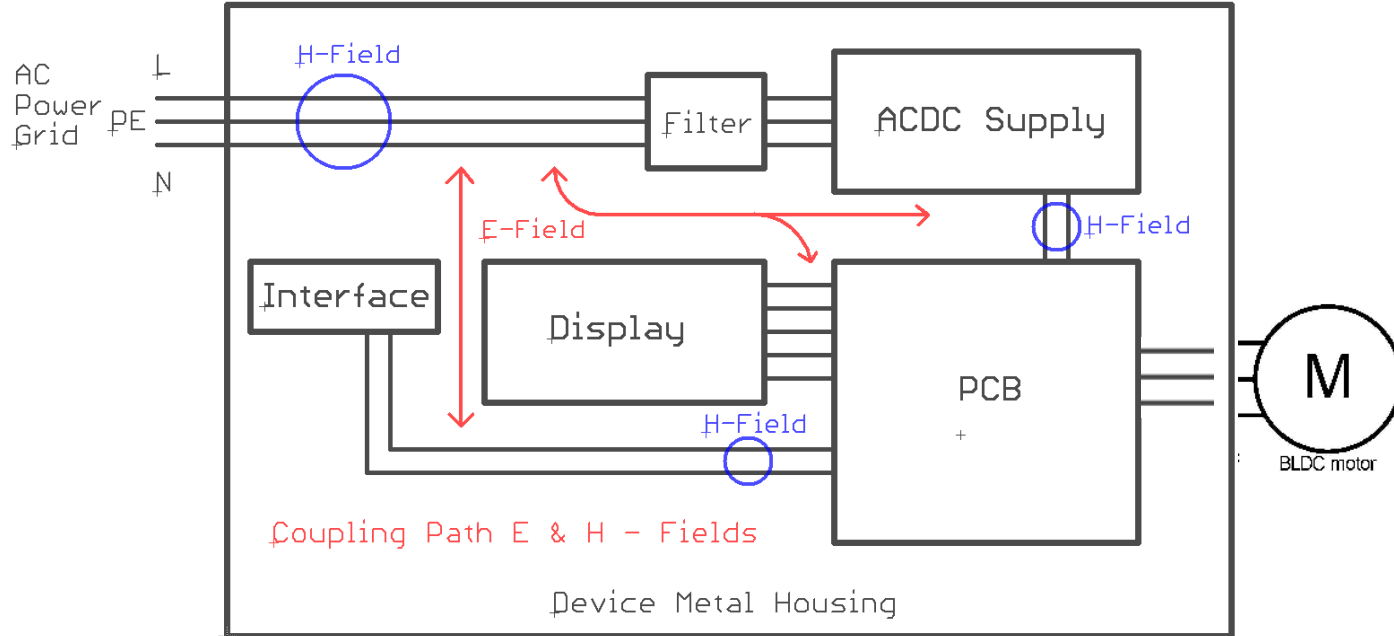


## Layout Suggestions: Segmentation for functional areas



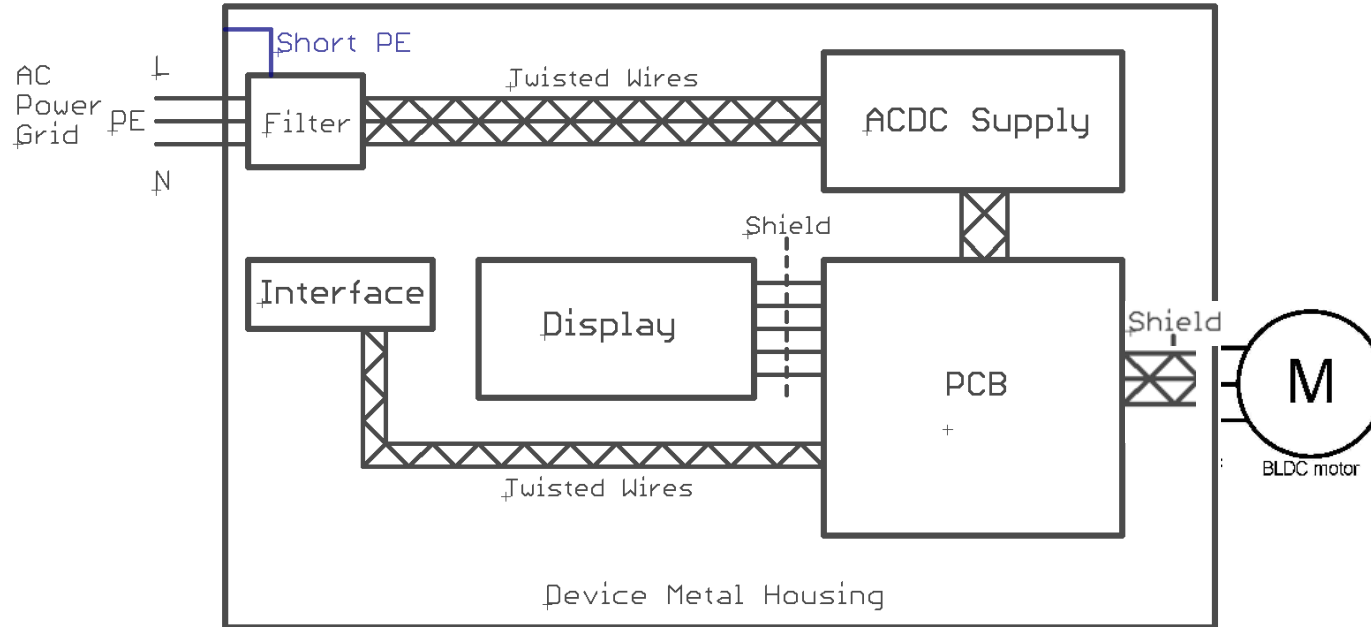
**Slicing the GND layer to form sub-grounds (AGND, DGND, PGND)**

## Placement of the filters in the device



- Cables between filter and appliance are too long
- Susceptible to interference emission and immunity to interference Capacitive coupling (E-field) and inductive coupling (H-field)

## Placement of the filters in the device



- Low-inductive and areal connection of the filter to housing / PE
- Twisted lines (not only differential signals!)
- Plan cable routing exactly! Star-shaped cover!



**Thank You For  
your Attention**