EMI

Low EMI Design Techniques

FSG Academy – Main Workshop for FSG 2024
on 21st of October 2023 at Schaeffler in Herzogenaurach

EMI ?, EMC ?

- Electromagnetic interference (EMI)
  - Disturbance by an external source affecting electrical circuits

- Electromagnetic compatibility (EMC)
  - Ability of an electrical circuit to function in an “noisy” environment

„Black Magic“ – Based on Basic Equations

- Ohm's law: $V = I \cdot R$
- Kirchhoff's current law: $\sum_{k=1}^{n} I_k = 0$
- Kirchhoff's voltage law: $\sum_{k=1}^{n} V_k = 0$
- Gauss's law: $\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$
- Gauss's law for magnetism: $\nabla \cdot \mathbf{B} = 0$
- Faraday's law of induction: $\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$
- Ampère's circuital law: $\nabla \times \mathbf{B} = \mu_0 \left(\mathbf{J} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} \right)$

Thank you for your attention

EMI – Black Magic

- Modeling is difficult – simulation even more
- System must be simplified
  - But what can be removed?
- ➔ A lot experience is required for modelling

EMI – Simmulated Black Magic

- I used #1 tool from ??? for simulation
- got some Colorful Figures for Directors (CFD)
- Improve scales → everything blue
- ➔ EMI issues solved

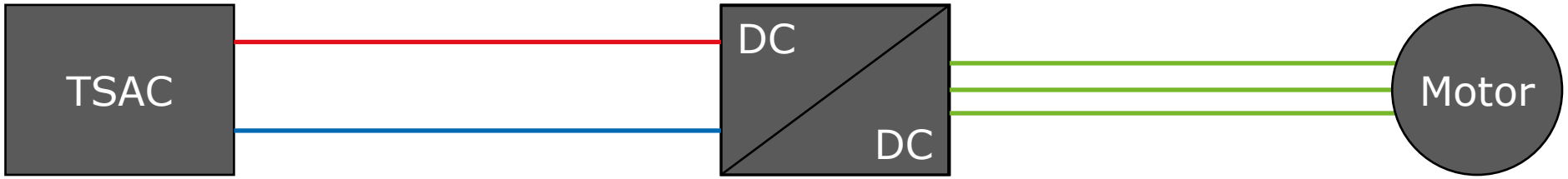
EMI – Simmulated Black Magic

- How to read such simulation results?
- And how to verify?
- Does the model fit realty?

- garbage in, garbage out!

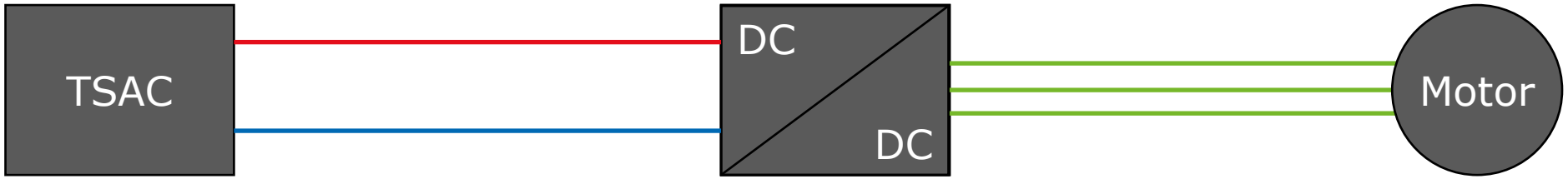
Back to the Roots

- Current flows if and only if the loop is closed
- Current flow generates a magnetic field
- Changing magnetic field inducts a current in a current loop
- Changing currents cause a changing magnetic field

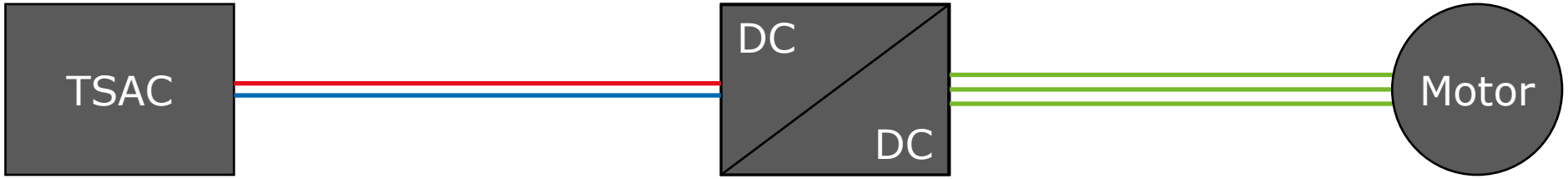


Parasitic Inductance

- Parasitic inductance is proportional to loop size
- Bad:

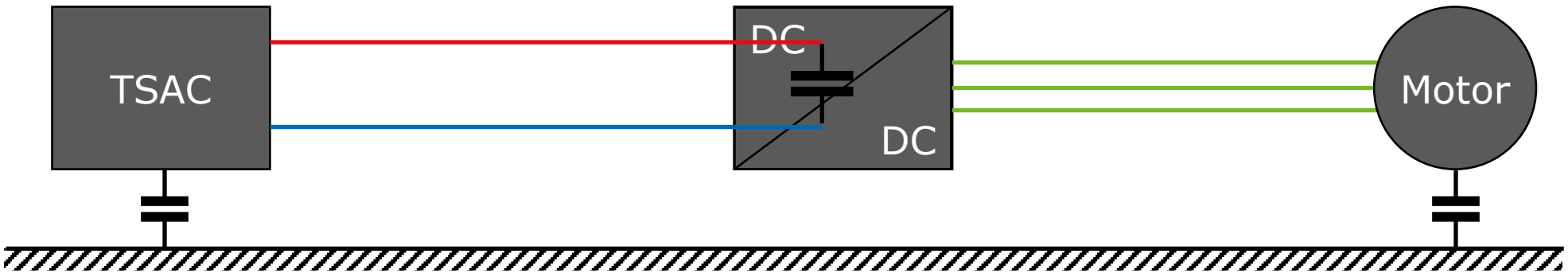


- Good:



Back to the Roots

- Commutation loop must be small → DC link capacitors
- Changing voltage causes current through (parasitic) capacitors
- Loop must/will be closed…



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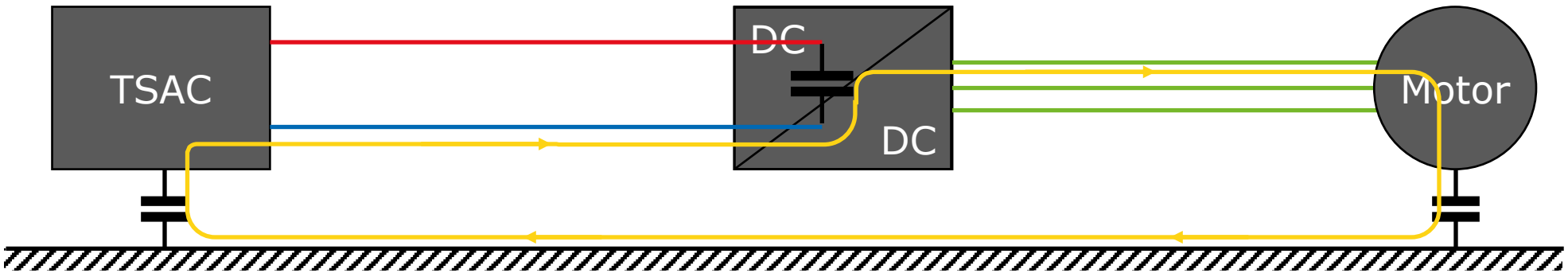
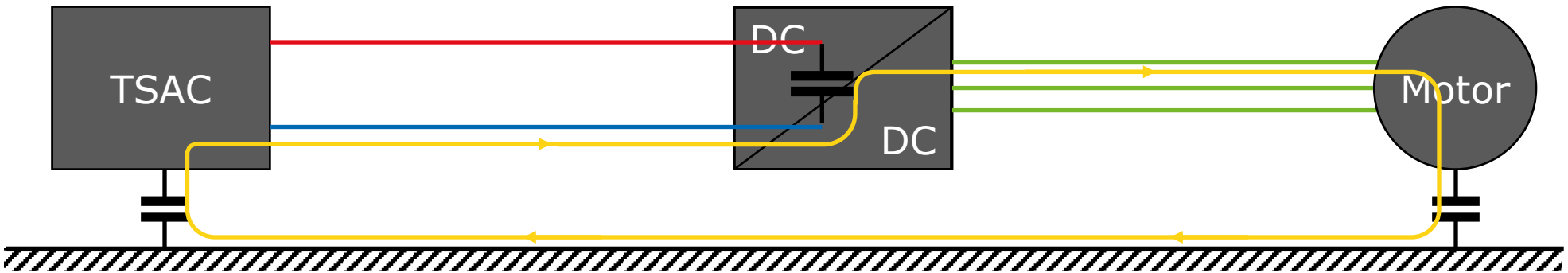


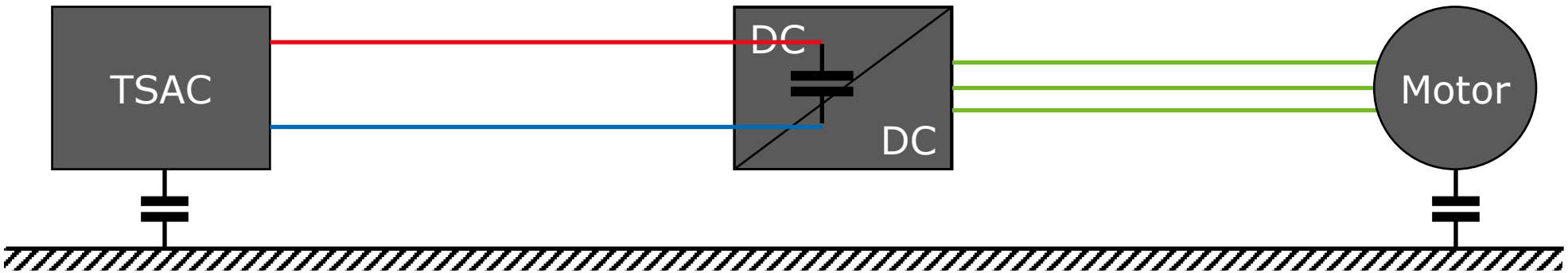
Back to the Roots

- Current through a resistor causes a voltage drop
- Digital single ended interfaces do not like jumping GND
  - Signal is referenced to “GND”



Mitigation

- Know your current paths
- Mind the ground currents
- Provide a ground current path back to DC link capacitors



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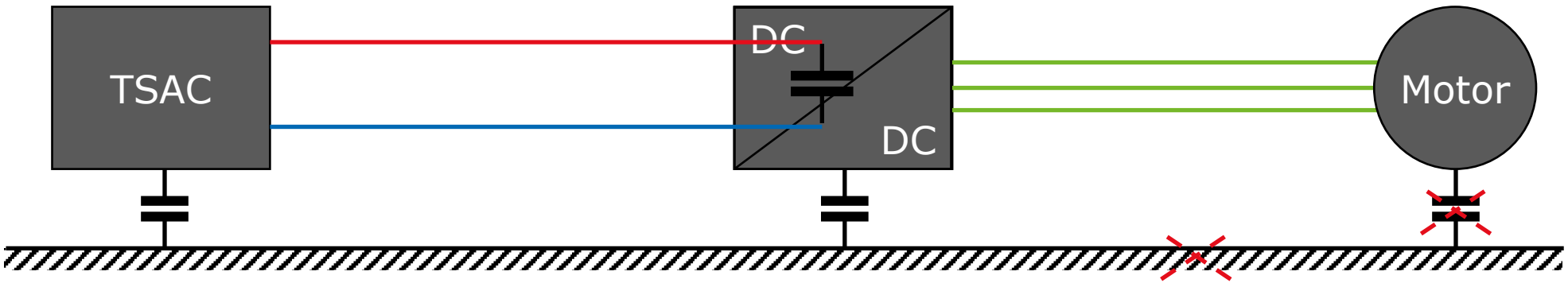
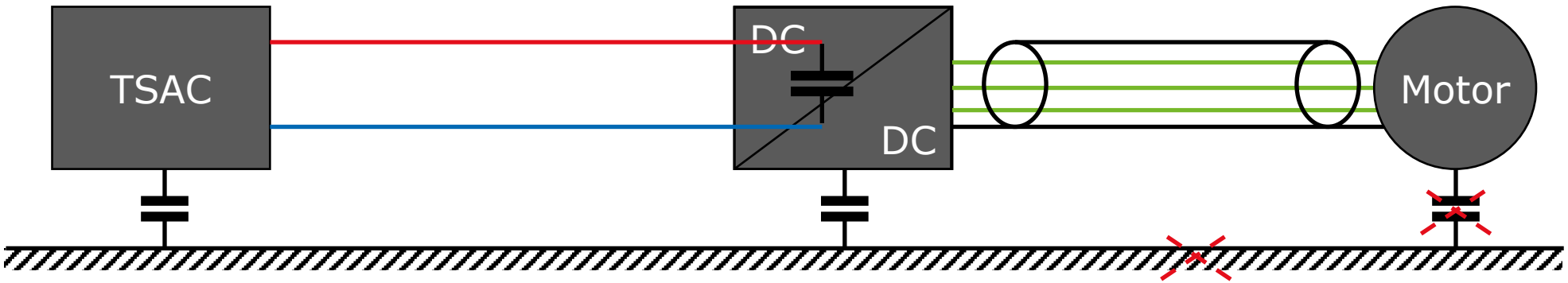
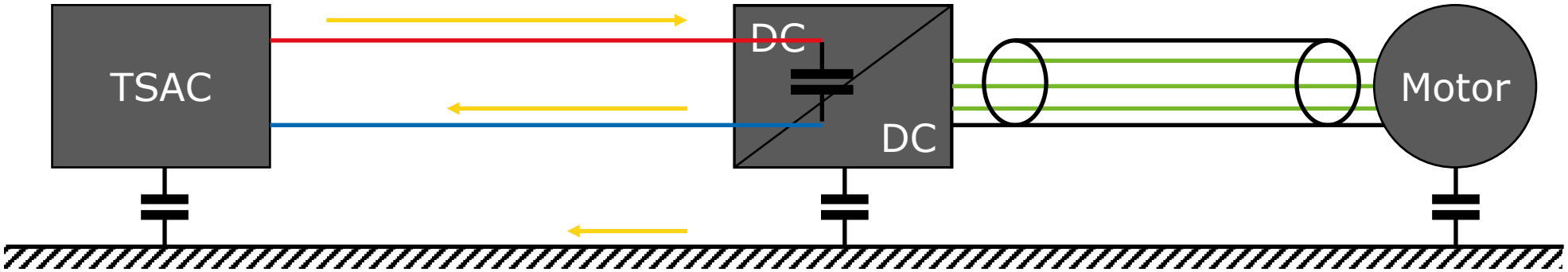


Mitigation

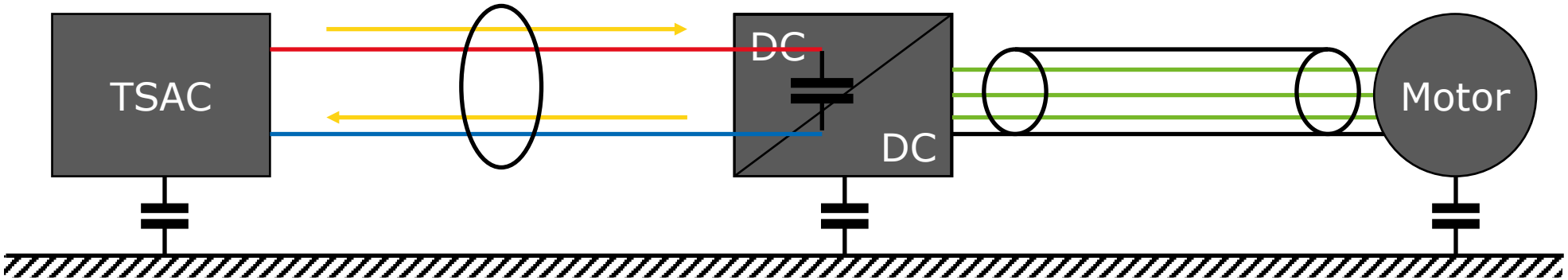
- Force the TS GND current to the TS cable shield
- Make other paths bad
- No AC current on sensor cable shield



Common Mode Chokes

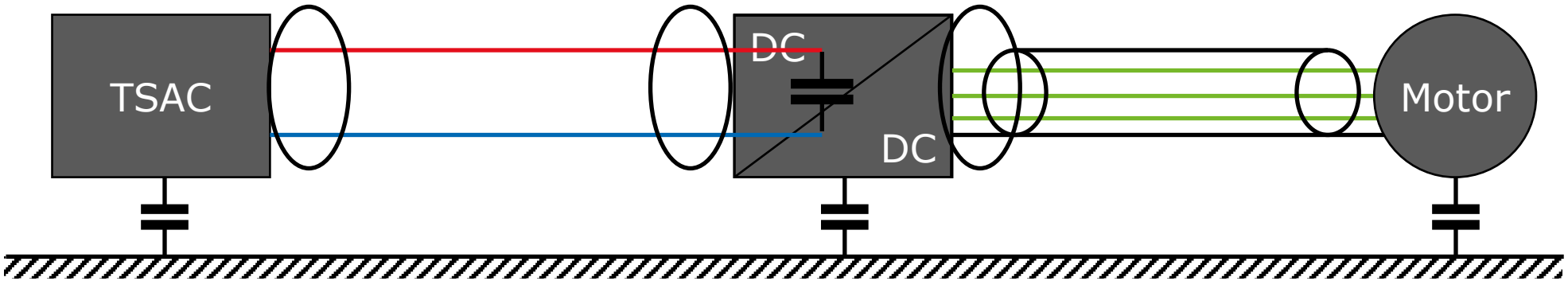


- Sum of currents through coke is 0 A



Summary

- Mind the AC ground path → design your return path
- Keep commutation loop small
- Common mode chokes
- No AC on TSAC to DC link
- Use differential interfaces



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