MACHone

Expertise Propels Excellence

Presents

EMC Design Considerations in DC-DC Converters for Automotive Application

Dr. Min Zhang

February, 2021

Visit: www.mach1design.co.uk

Email: info@mach1design.co.uk

This presentation outlines:

This Presentation outlines:

1. DC-DC converters in the automotive sector
2. DC-DC design challenges from an EMC perspective
3. EMC testing & trouble shooting

This Presentation is one of a series that include:

- 🚙 EMC in Electric Drive Unit - New Challenges for the Automotive Sector
- 🚙 Grounding & shielding technique for EV application
- 🚙 And More

The key element in managing power

MACHone
Expertise Propels Excellence

In electric vehicle application, DC-DC converters have now replaced alternators in internal combustion engine vehicles.

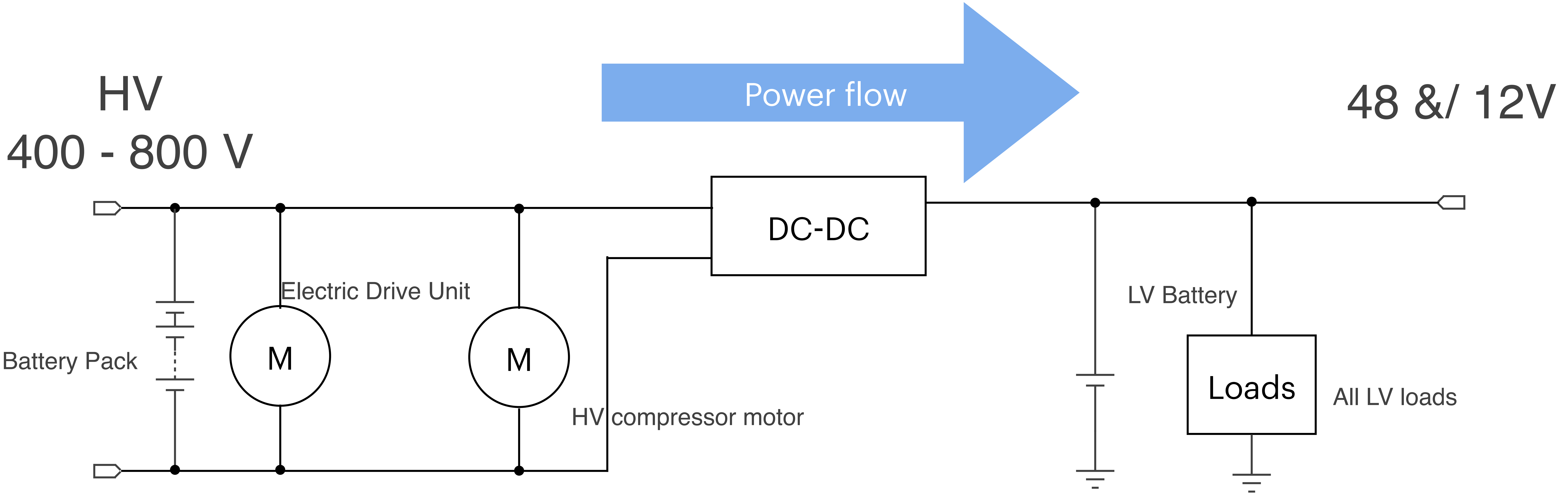
1. Key component in providing low voltage power
2. Functional safety critical
3. Safety critical
4. Supply instantaneous huge current demand

A Tesla DC-DC module made by Delta Electronics

Bridging HV and LV systems in EVs

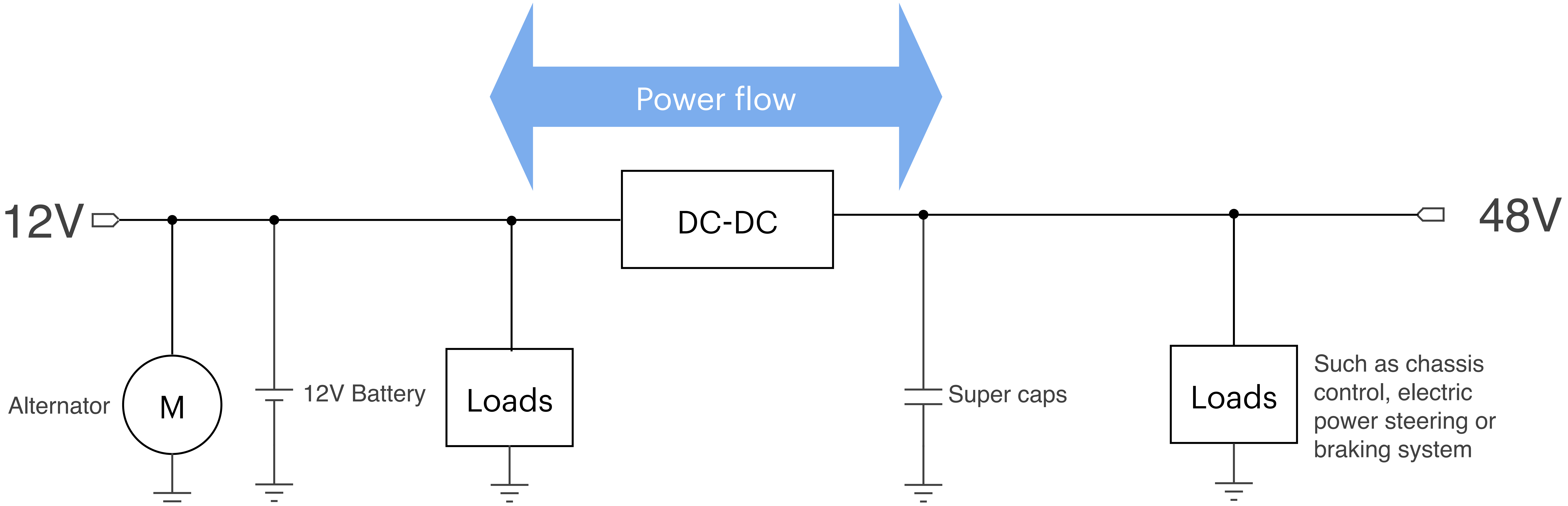
MACHone
Expertise Propels Excellence

Converter high voltage power to low voltage power



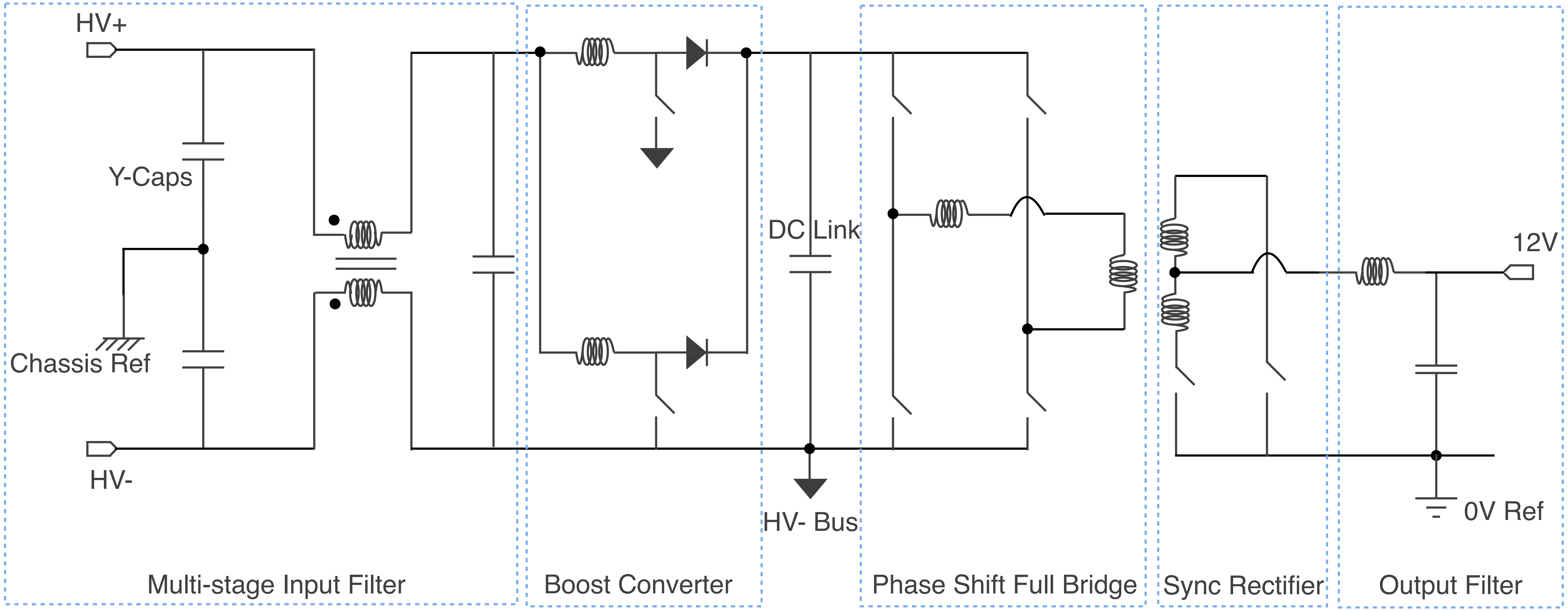
Also common in hybrids and PHEVs

Commonly seen in systems where both 12V and 48V power systems co-exist.

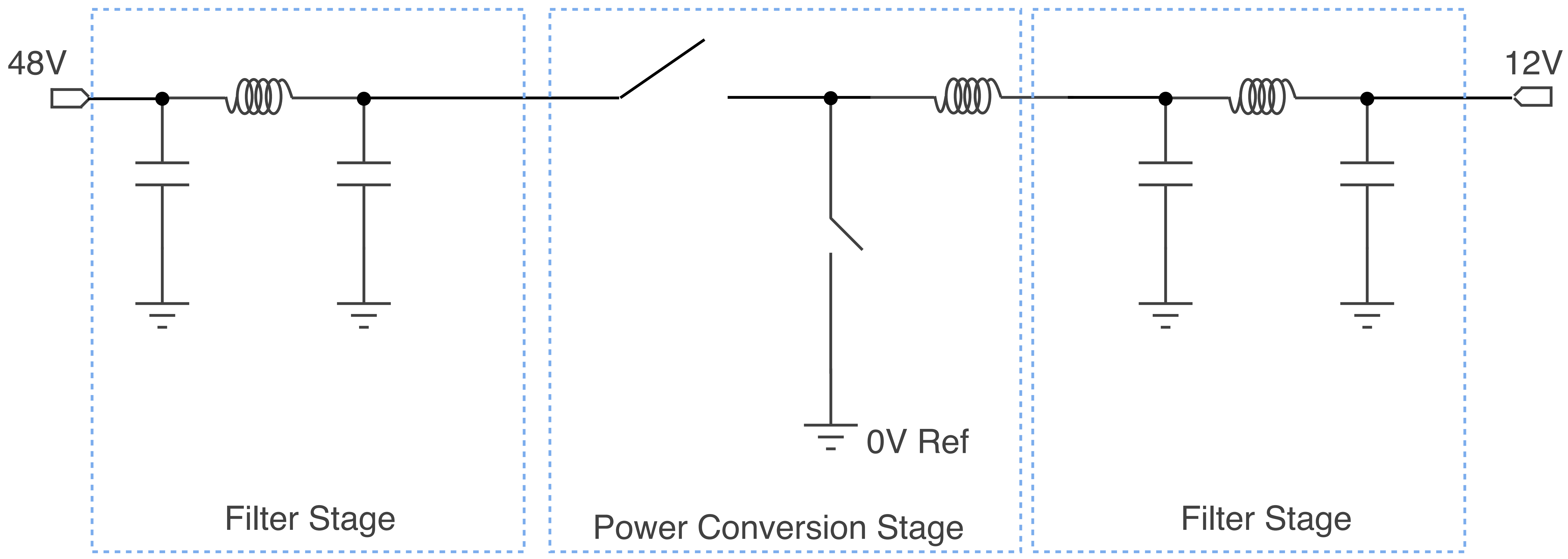


Simplified schematics of HV LV DC-DC

MACHone
Expertise Propels Excellence



Simplified schematics of LV DC-DC



The end game is to achieve the highest power density, which means:

🚀. High switching frequency - so as to keep passive components small

⚡. Fast switching speed - to minimise loss, hence improve thermal. GaN and Sic MOSFETs are the design of choices

🧊. Advanced thermal materials and design - new materials together with system thermal solution

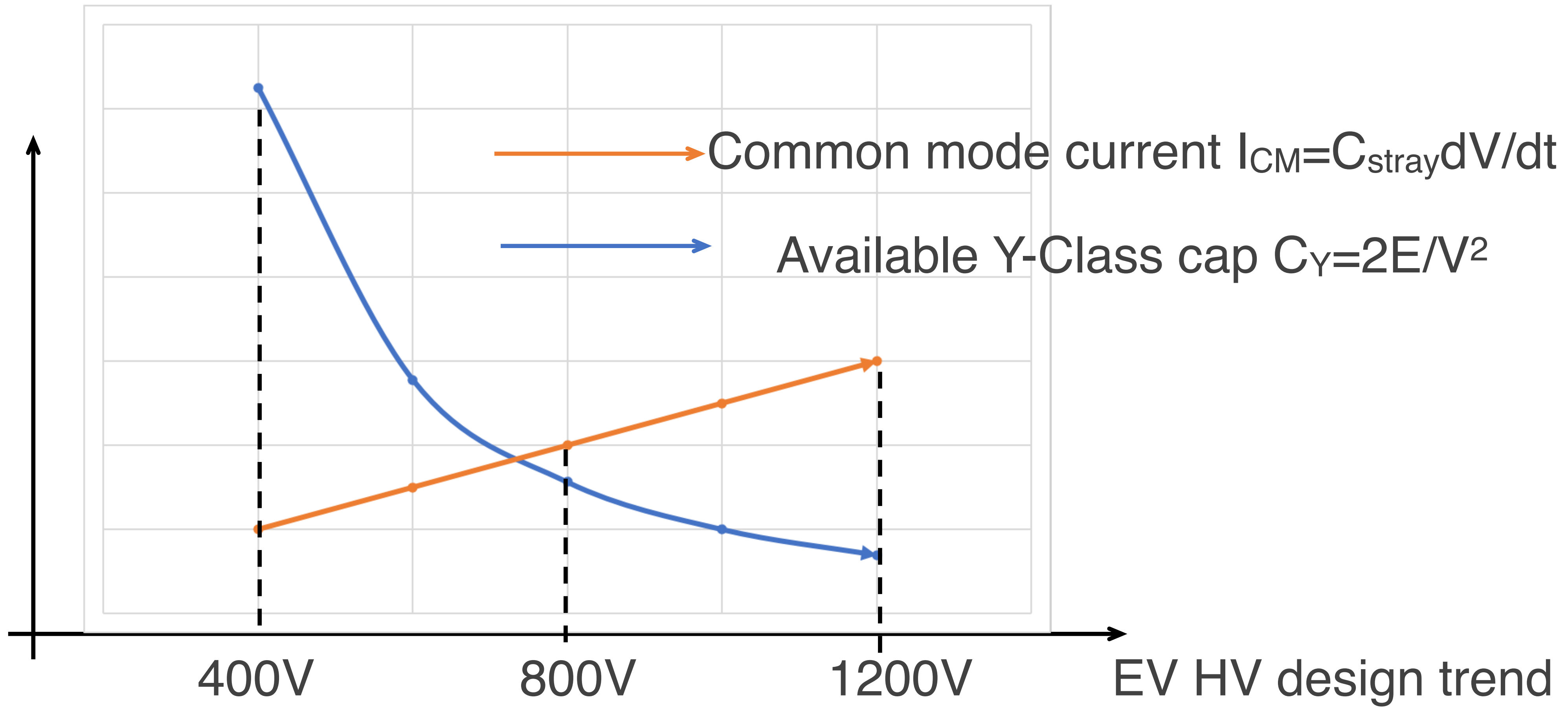
🧲. Enhanced electromagnetic design - to reduce eddy current loss, avoid using large and bulky EMC filter components

💱. State-of-the-art PCB design - to achieve small size and good EMC performance

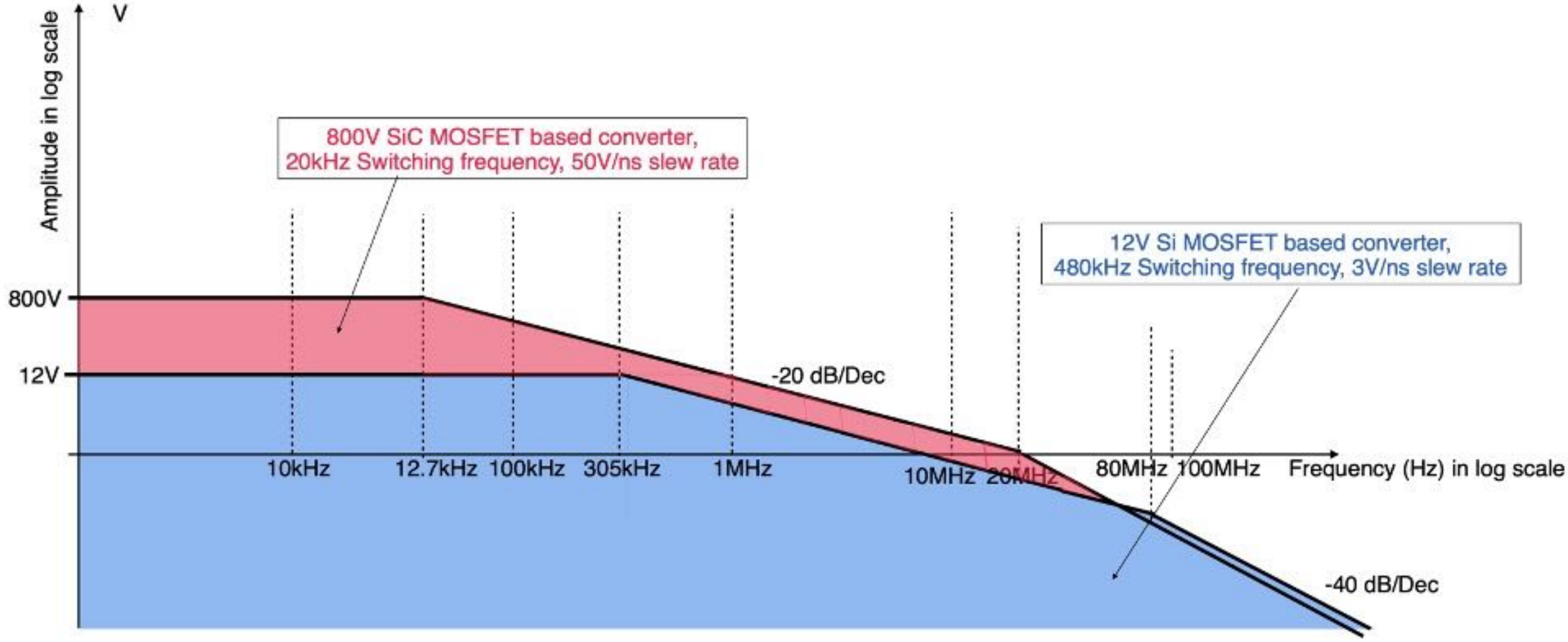
💰. And to keep the whole module at low cost - this really should be put as rule NO.1 !

MACHone
Expertise Propels Excellence

⚠️. A high voltage challenge



🚀. Problem of being fast



DC-DC EMC design challenges - Continued

MACHone
Expertise Propels Excellence

In fact, all the electronics design requirements are EMC design constraints in one way or another! Why?

- High switching frequency means more EMI energy
- Fast switching speed indicates it hurts more (noise wise) every time a switching event occurs
- Thermal requirement will require high switching frequency and fast switching speed (to minimise switching loss), but as the points made above, it is bad for EMC. Thermal paste also means no direct electric connection.
- Most of the time, electromagnetic design only focuses on power conversion function without taking care of the leakage flux.
- And you want to apply 6 layer or 12 layer PCB? No no no, that’s way too expensive!

DC-DC EMC design challenges - Continued

MACHone
Expertise Propels Excellence

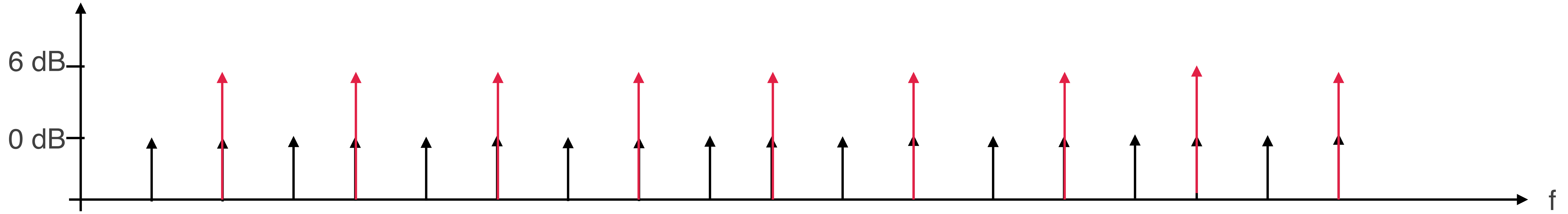
On top of those challenges, we have

- More stringent EMC requirements - worldwide
- Safety critical requirement and functional safety requirement
- Communication circuit evolution, used to be CAN, now CAN FD, Flexray, automotive ethernet in future
- New EMC requirements such as HV/LV attenuation, HV transient, etc

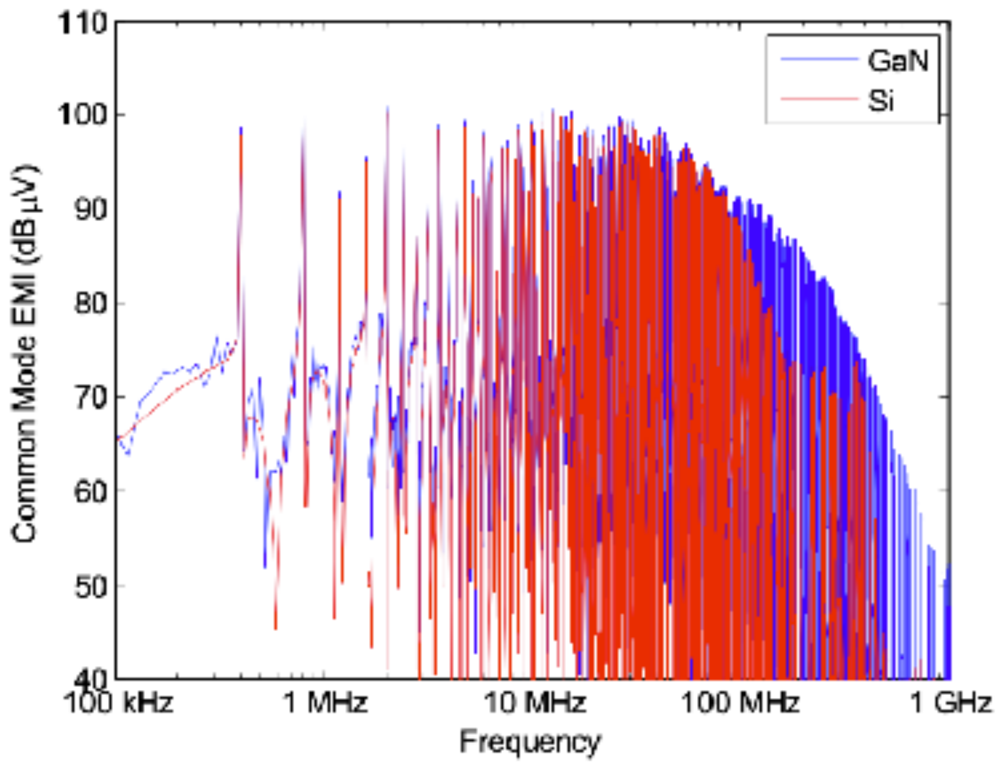
Dr Min Zhang - February 2021

Switching frequency and speed effect

When doubling the switching frequency, generally we end up being 6dB worse



When doubling the switching speed, we get at least another 3dB increase in high frequency of EMI spectrum



On chassis, 0V, ground, or earth?

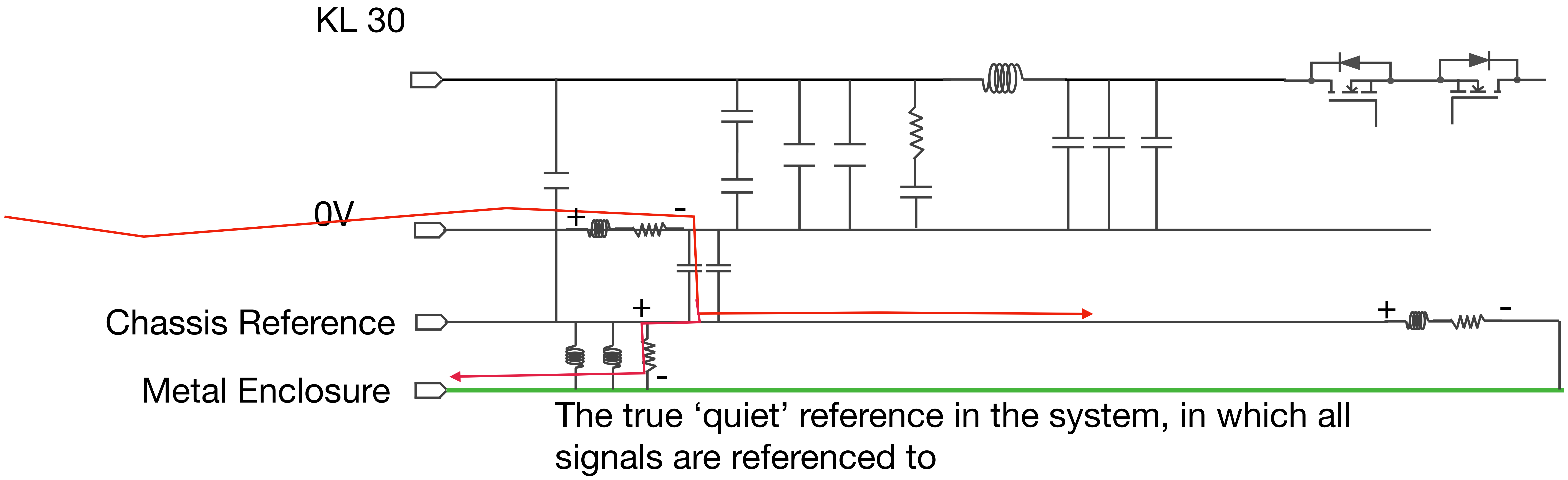
Have you found the ‘quiet ground’ yet? - It is a joke! There’s no such thing as a ‘quiet ground’!

Instead, we often see:

- Too many different symbols on one schematic
- Ground plane is not a plane (often with track or gap on the plane)
- Connection between 0V reference and chassis reference is high impedance
- Connection between the ‘analogue ground’ and ‘digital ground’ is a think track

A commonly seen issue

A commonly seen issue is a high impedance connection between different references. This high impedance path could be a poor electrical connection, or lack of gasket, or oxidised metal structure, which means noise voltage developed cross it will help drive emissions.



How effective is your filter?

Expertise Propels Excellence

Most of the filters are somehow ineffective due to various reasons.

. Inductor is by passed by nearby conductors (could easily bypassed by a ground plane, for instance)

. Inductor is the wrong type (for instance, too many turns, use power conversion type in filter type application, etc)

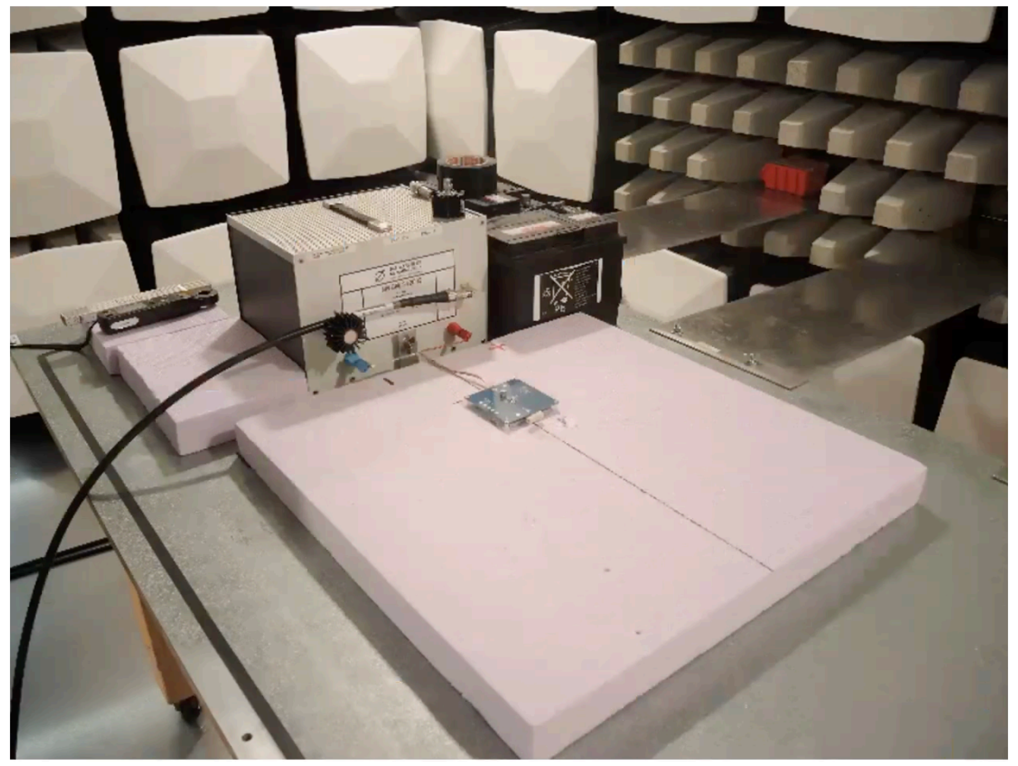
. L-C resonance (you might put a damping resistor in there, but is it in the right place?)

. Filter location is wrong (EMI filter should be placed near the connector not the power stage)

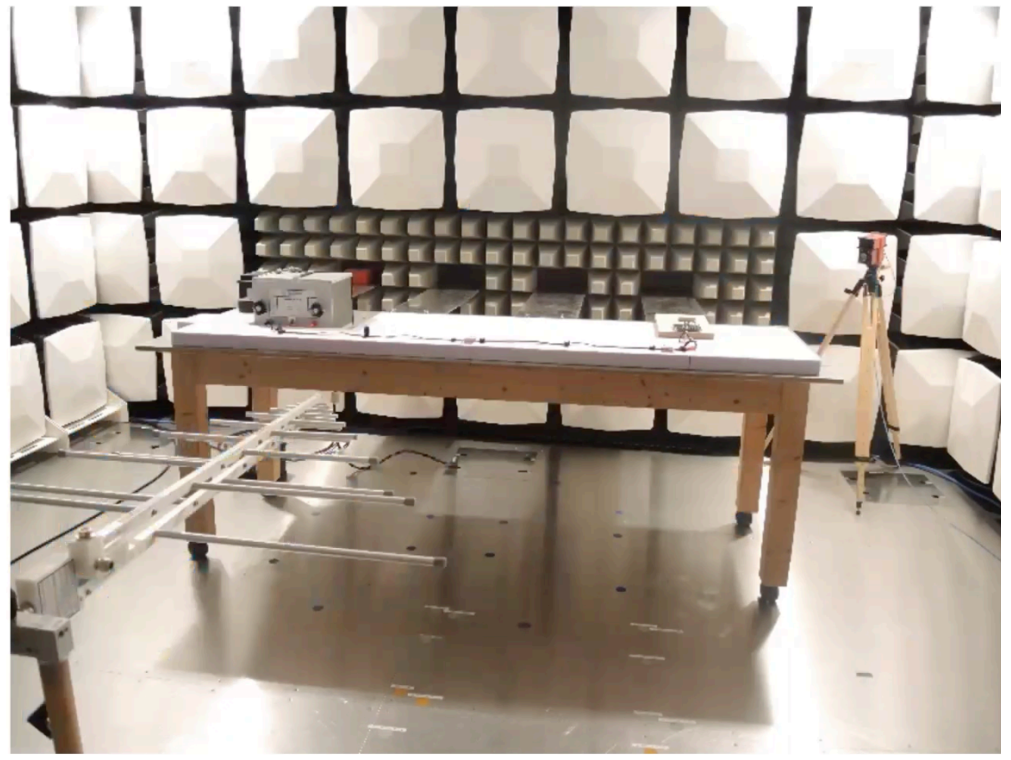
. Too many capacitors make filter performance worse (yes, surprising facts!)

. Should I put ground plane under the inductor or not? (A million dollar question!)

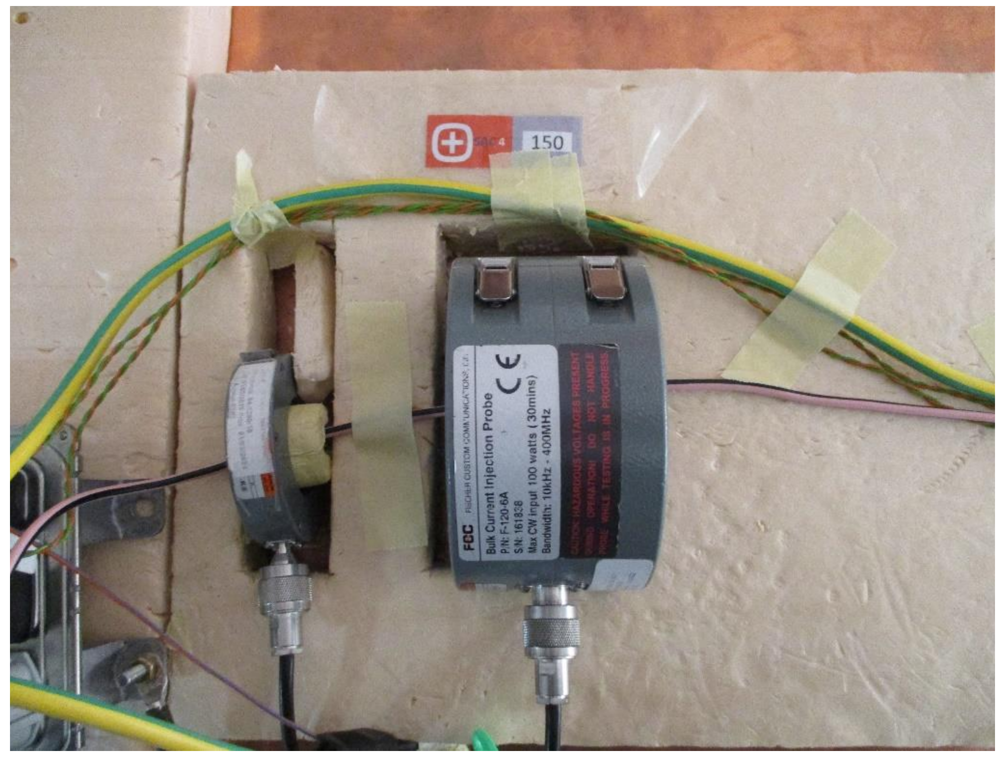
Generally speaking, if you failed conductive emission test, chances are that you will fail radiated emission test, together with radiated immunity tests.



Conducted emission



Radiated emission



Bulk current injection

HV/LV coupling

Contact us for the full-length detailed presentation

MACHone
Expertise Propels Excellence

🩺 Design Review and Diagnosis

📝 Compliance

📞 Consulting

📚 Training

Visit: www.mach1design.co.uk
Email: info@mach1design.co.uk