



Converter Topologies (WP5)

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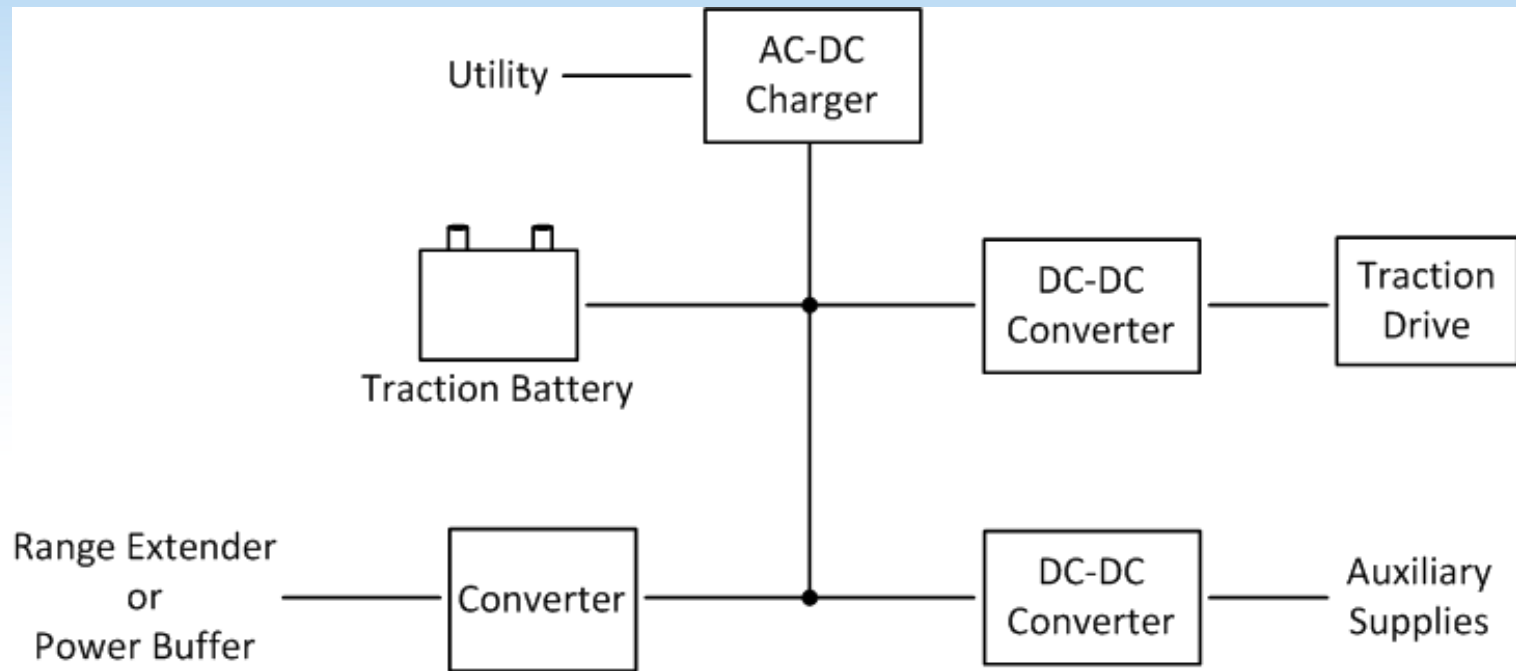
Research Team

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 - Nandor Bodo (RA), Ivan Subotic (PhD student)
- Prof Andrew Forsyth: Manchester University
 - Tom Ki (RA)
- Prof Volker Pickert: Newcastle University
 - Haimeng Wu (PhD student)



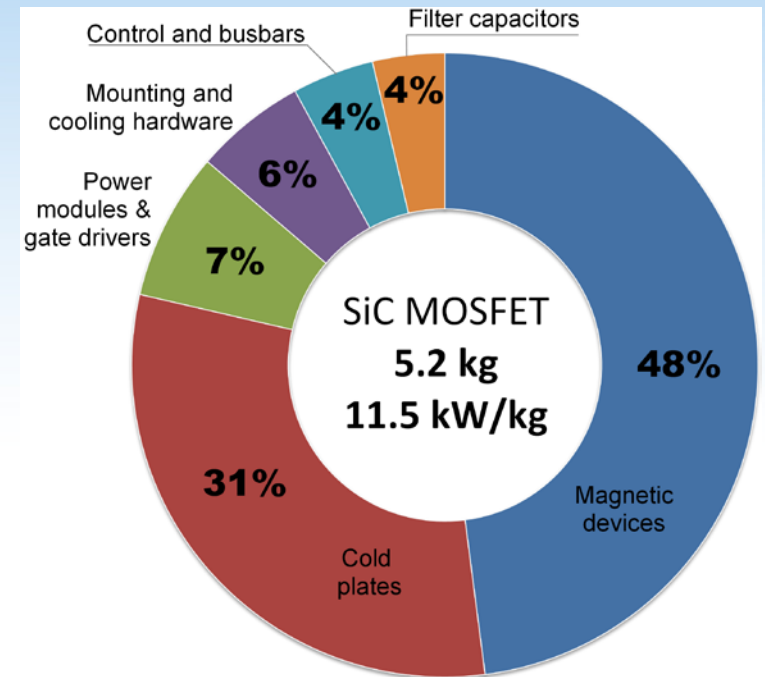
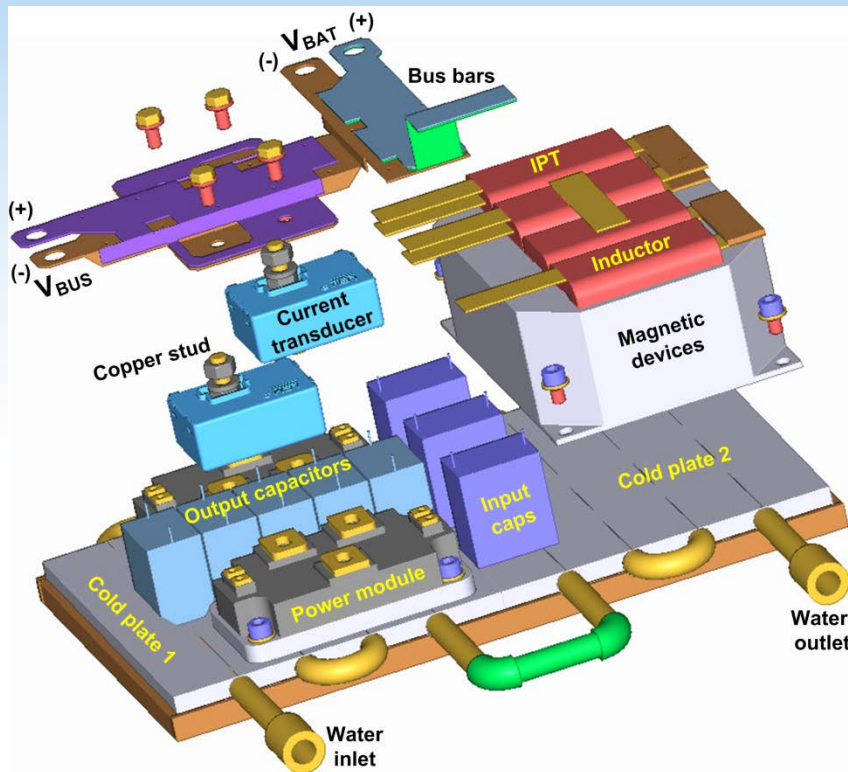
Introduction

- Typical on-board electric vehicle system



Introduction

- Mass audit of typical prototype



Overall Aims

- To reduce the size and cost of on board power electronics through new topologies, multi-use functionality and enhanced control
 - Traction system re-use for battery charging: LJM
 - Integrated converter for auxiliary supplies: Mcr
 - Non-linear control for inductor down-sizing: Ncl



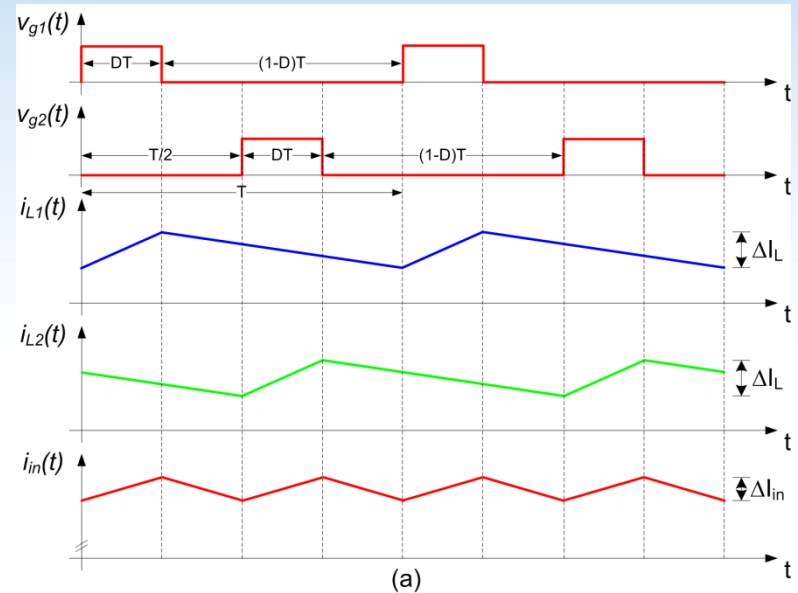
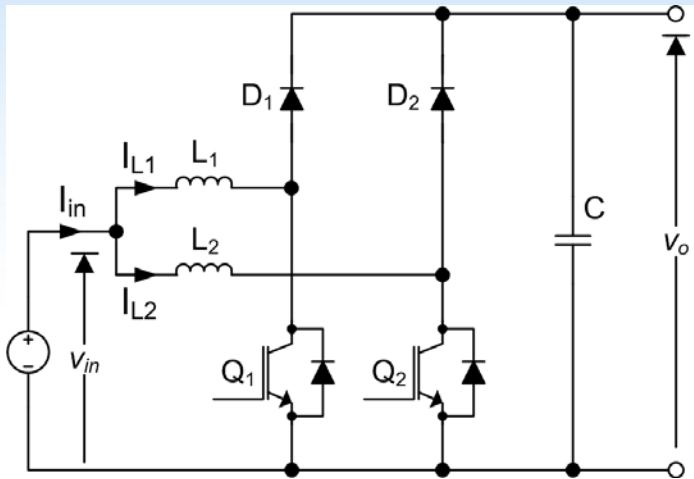
Contents

- DC-DC converter introduction
- Topologies for integrated auxiliary supplies: Mcr
- Non-linear control of DC-Dc converters: Ncl
- Integrated traction / charger systems: LJM



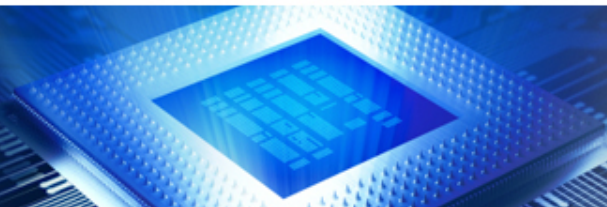
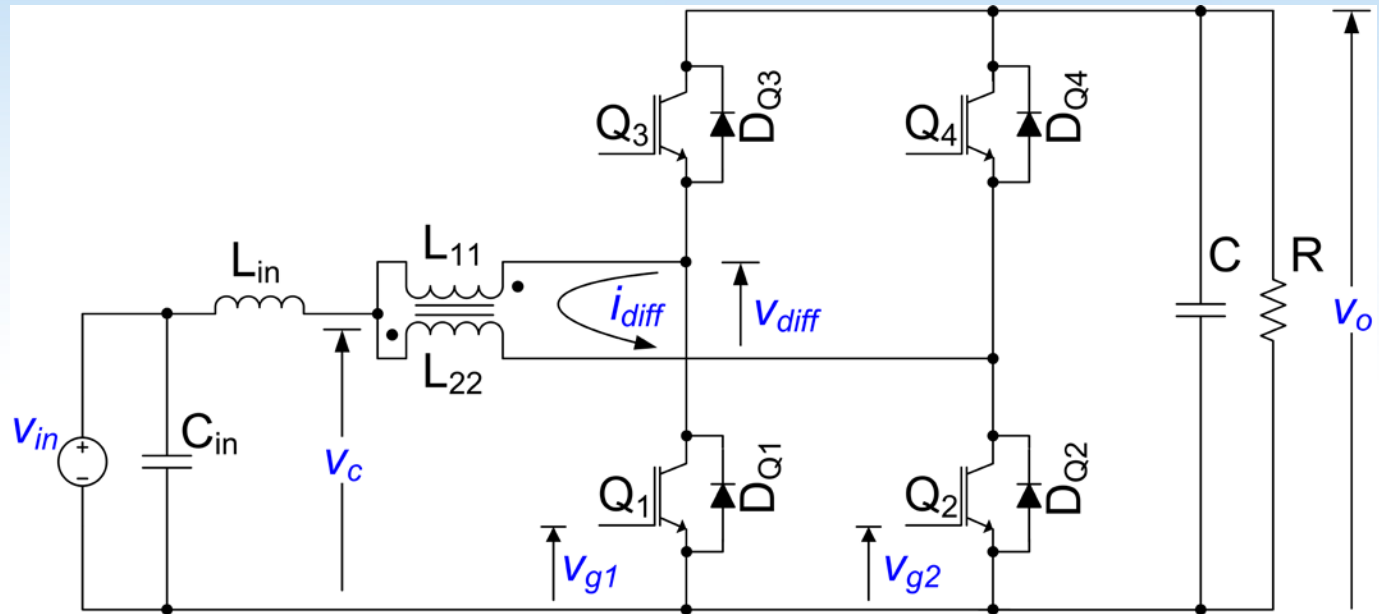
On-Board DC-DC Converter

- Interleaving to reduce passive component size and ease thermal design:



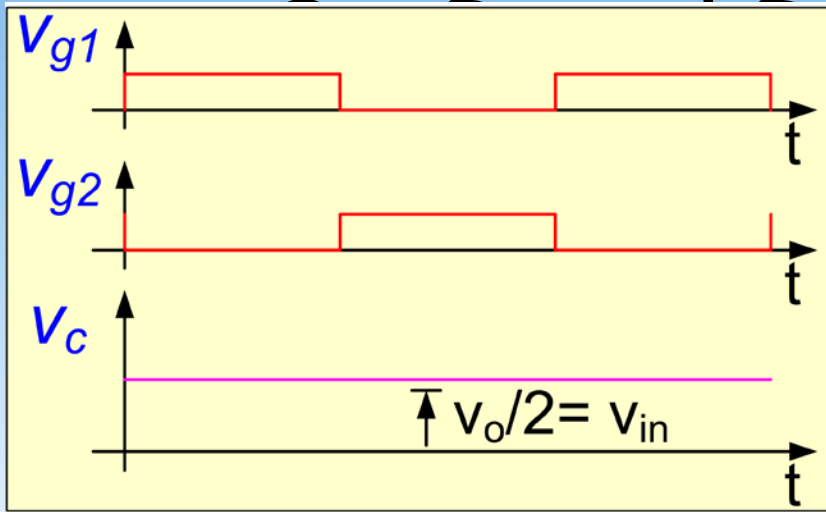
On-Board DC-DC Converter

- Use of interphase transformer to reduce magnetic weight:

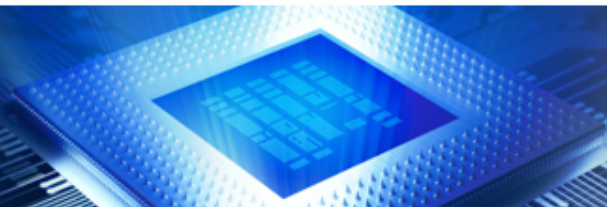
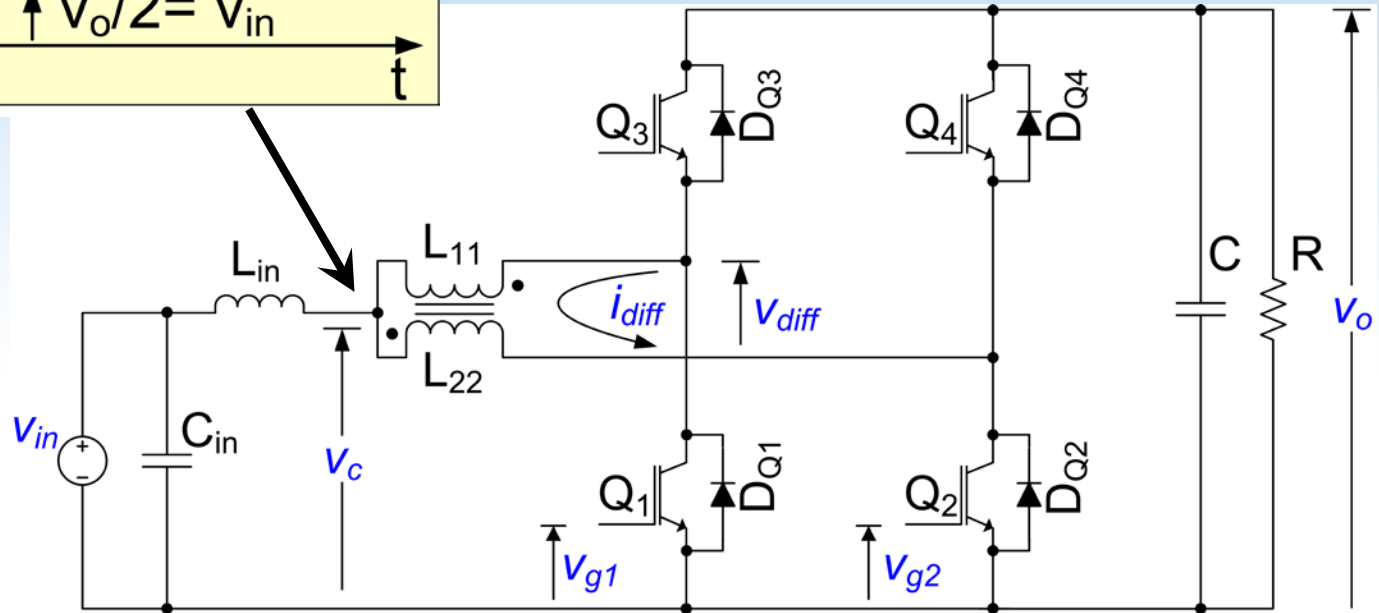


C-DC Converter

transformer to reduce

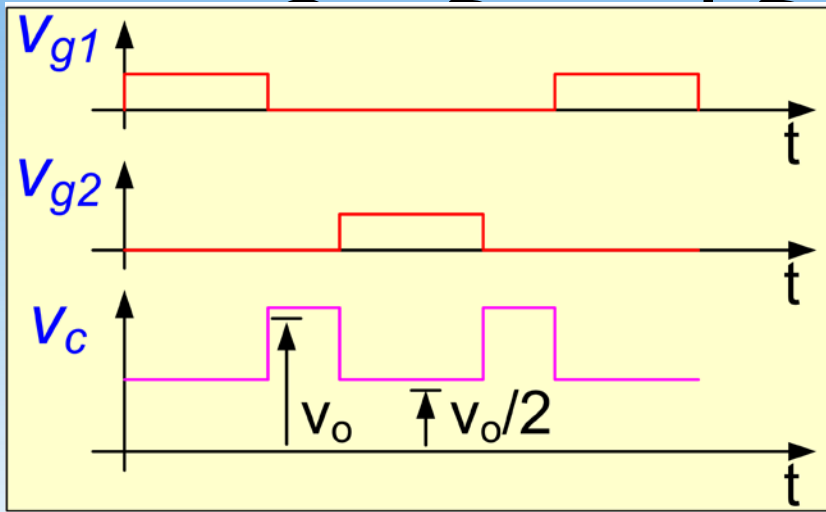


Duty-ratio
 $D=0.5$

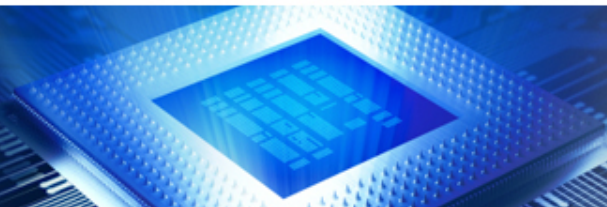
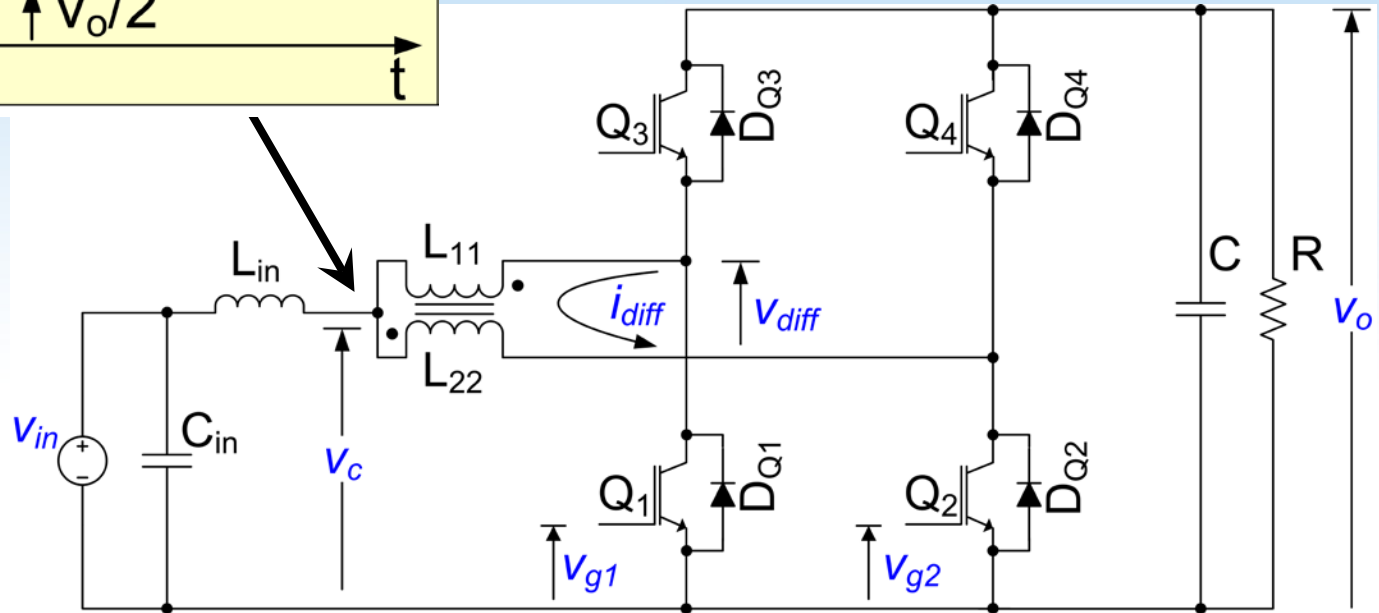


C-DC Converter

transformer to reduce

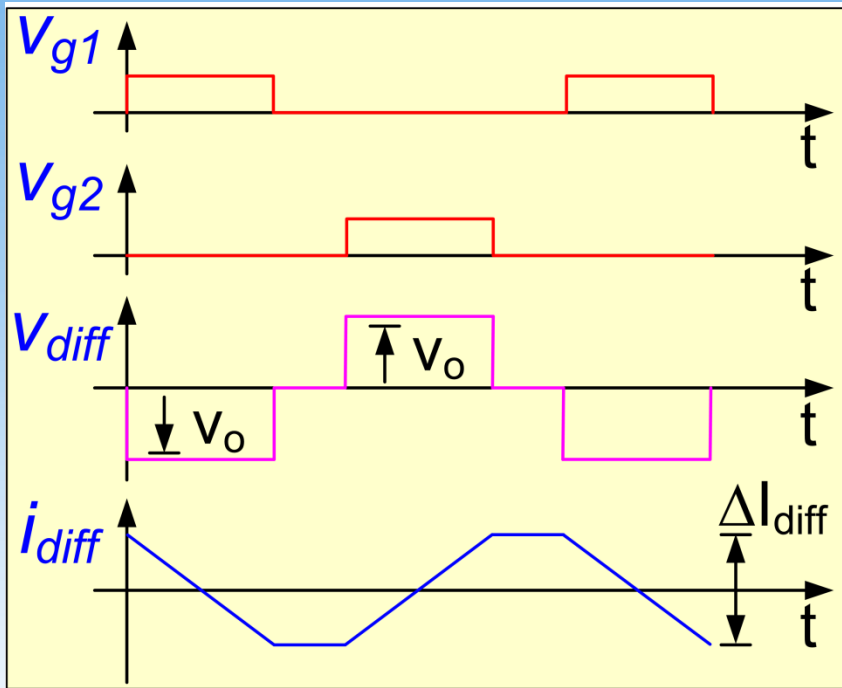


Duty-ratio
 $D < 0.5$

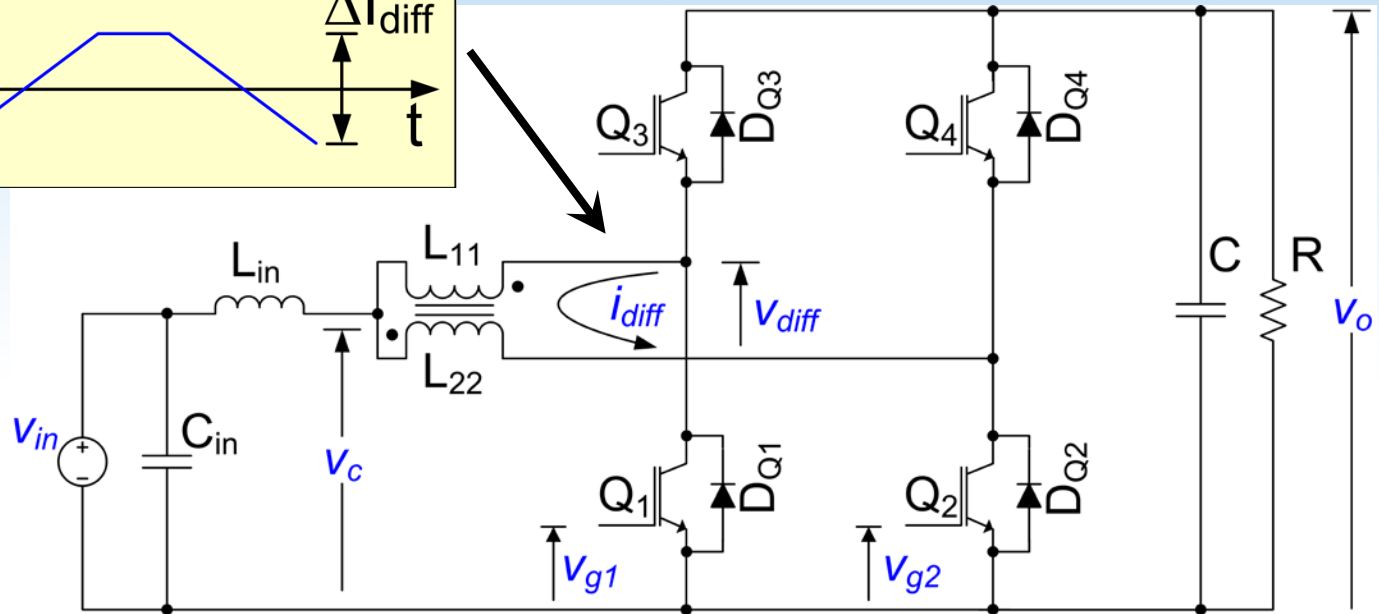


C-DC Converter

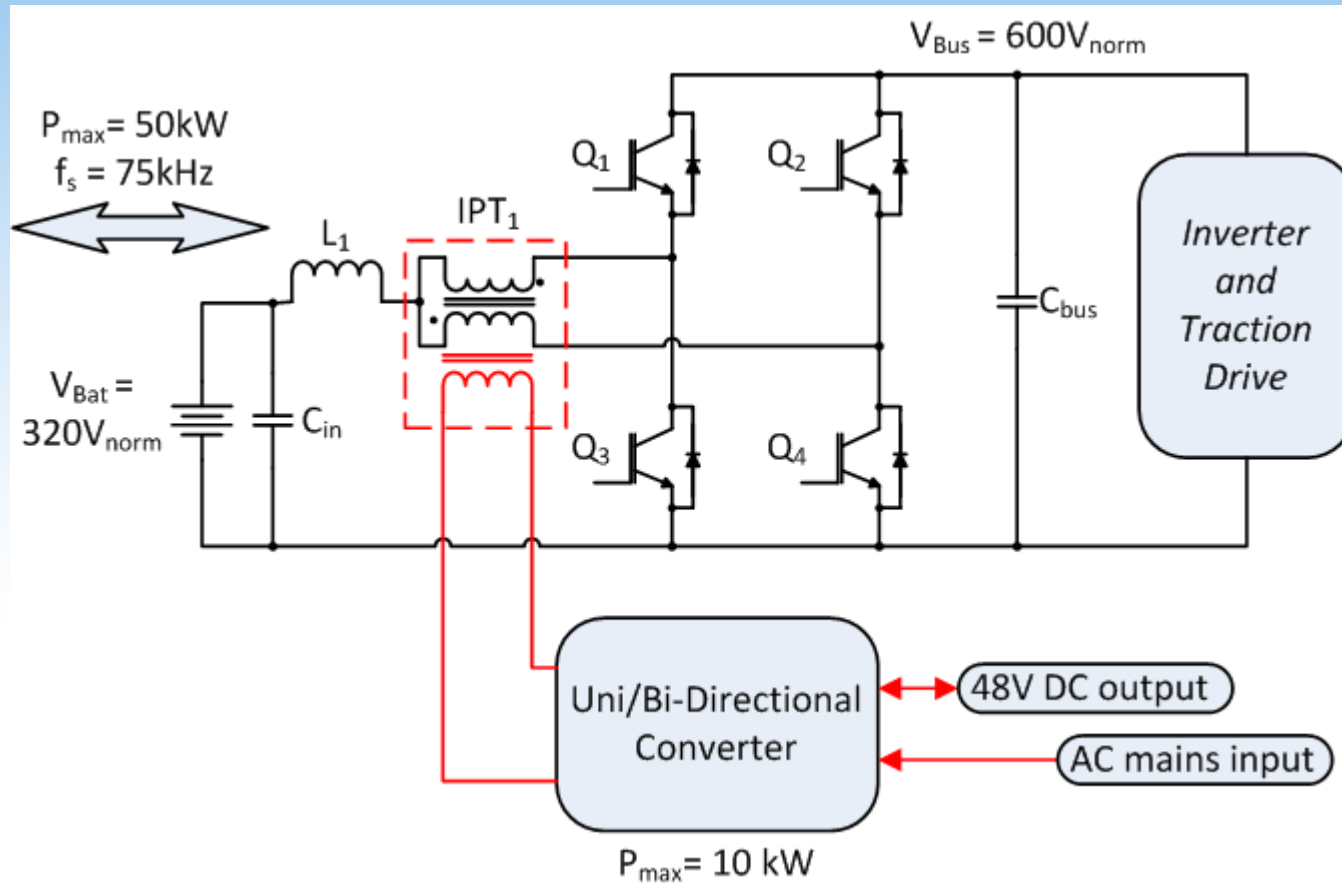
Transformer to reduce



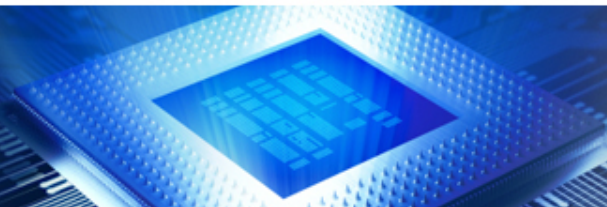
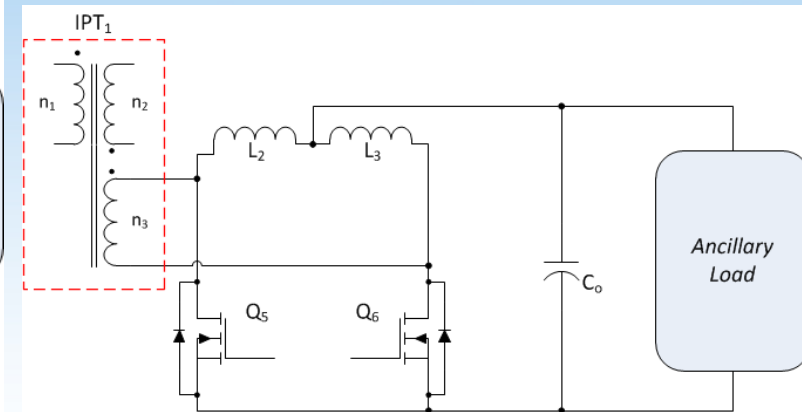
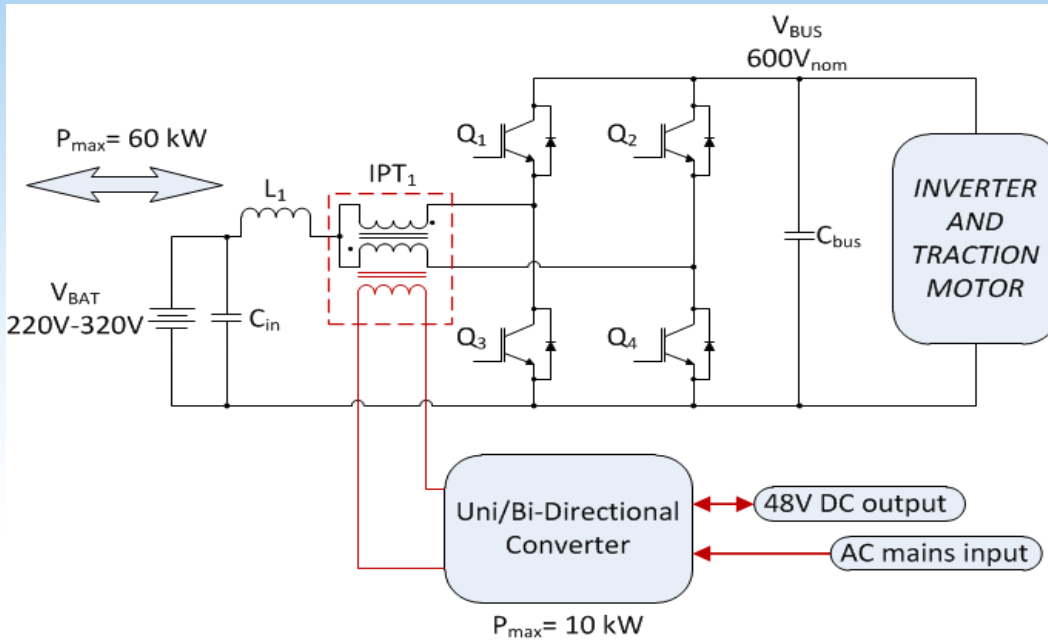
Duty-ratio
 $D < 0.5$



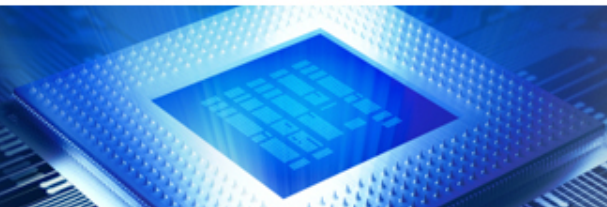
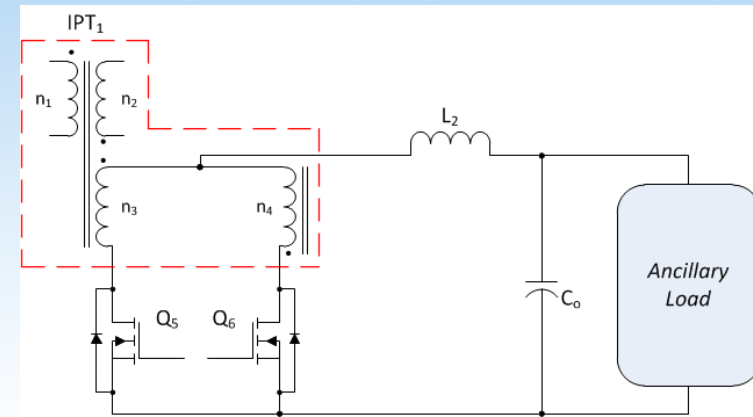
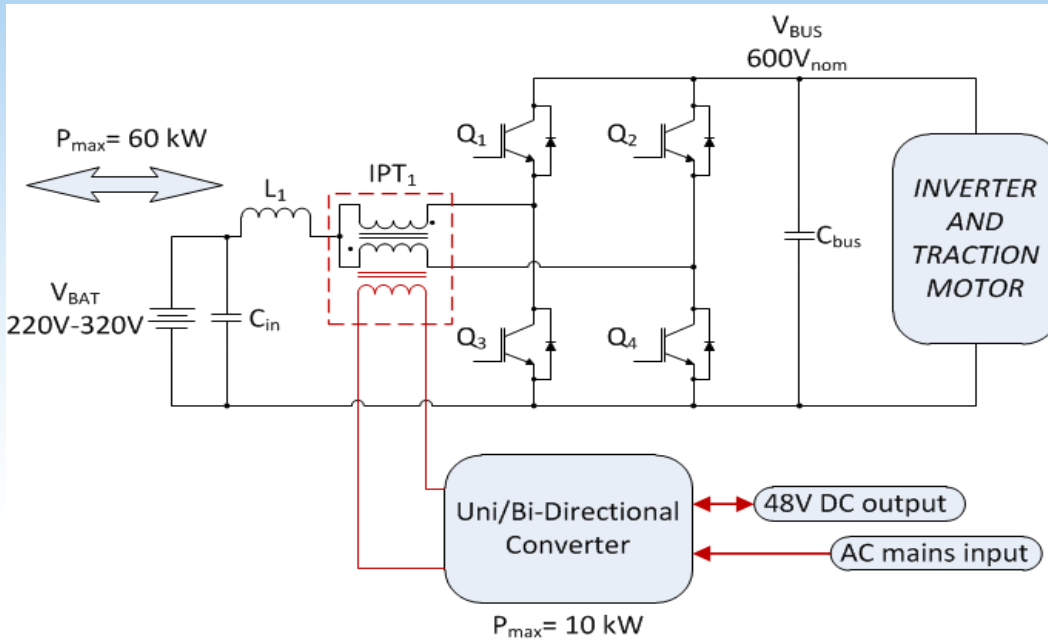
Integrated Auxiliary Supplies (Mcr)



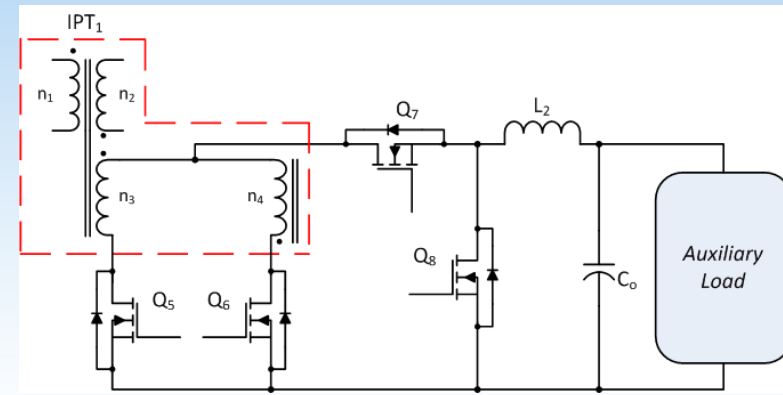
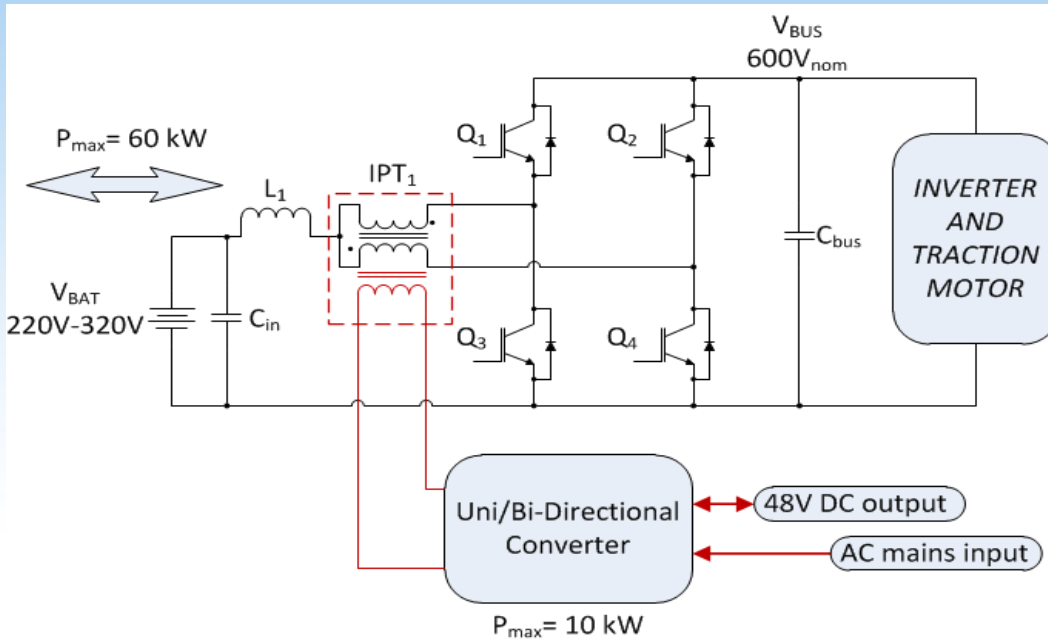
Topologies for Auxiliary Supplies (Mcr)



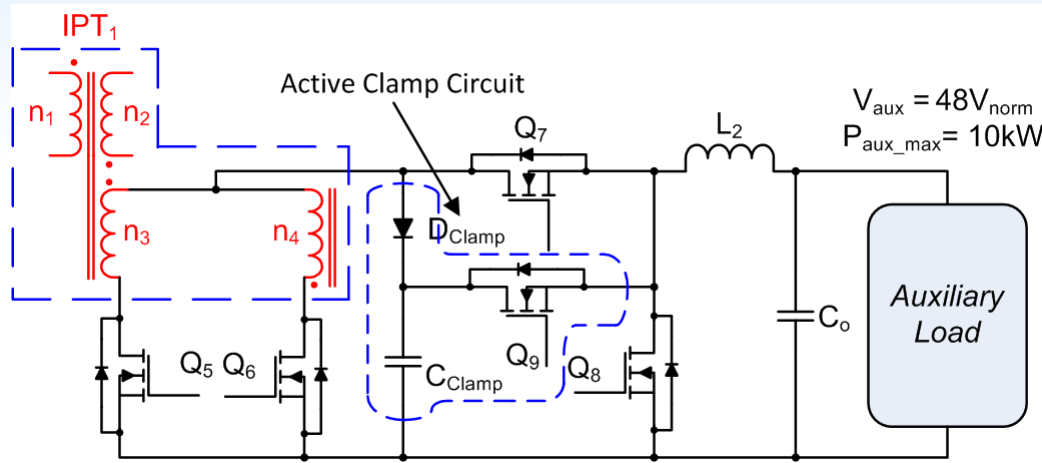
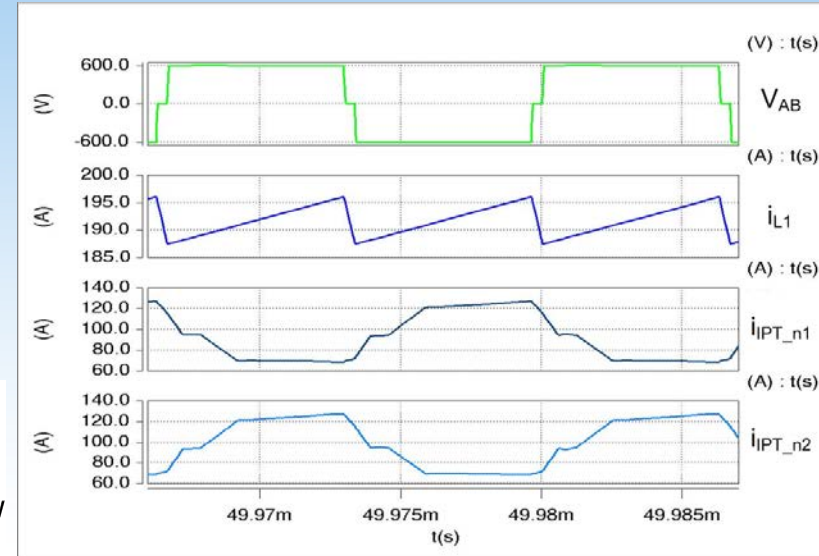
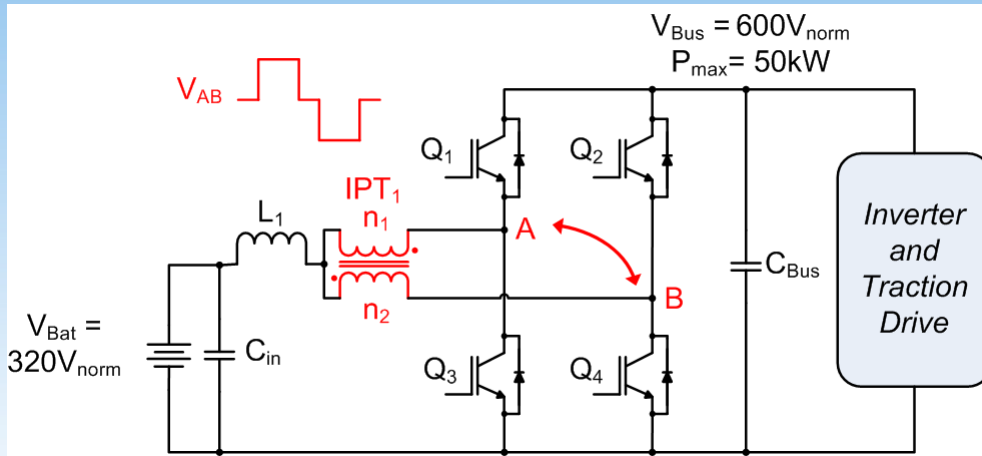
Topologies for Auxiliary Supplies (Mcr)



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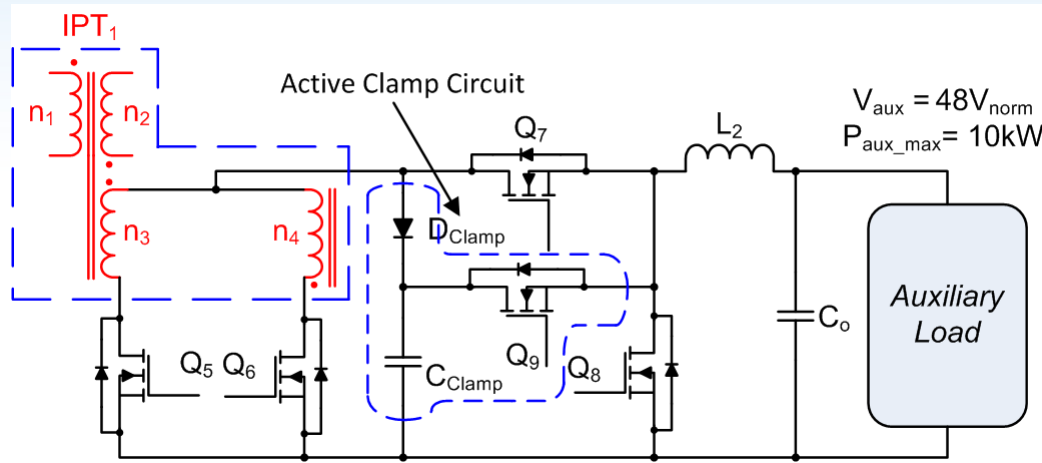
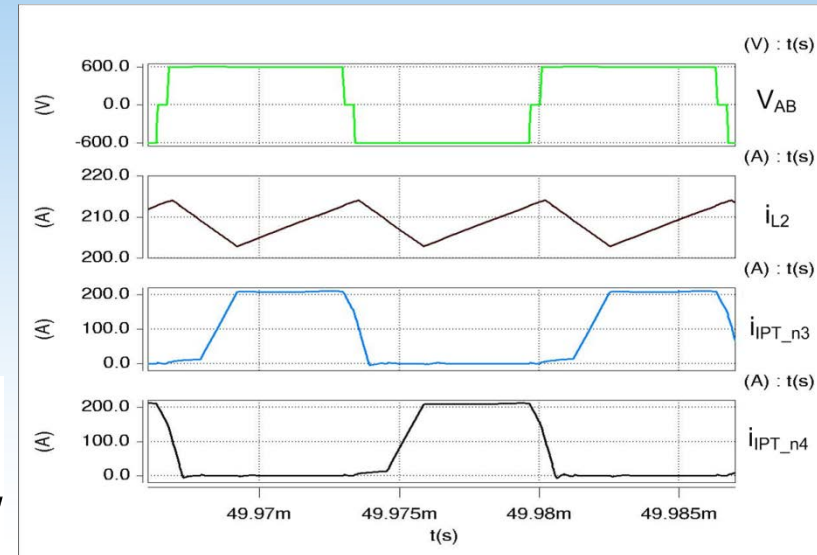
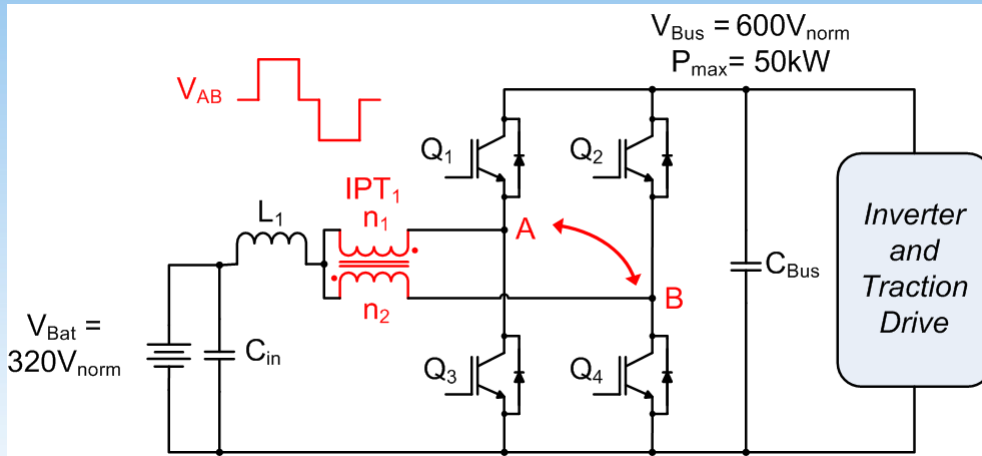
Topologies for Auxiliary Supplies (Mcr)



Simulated primary waveforms



Topologies for Auxiliary Supplies (Mcr)

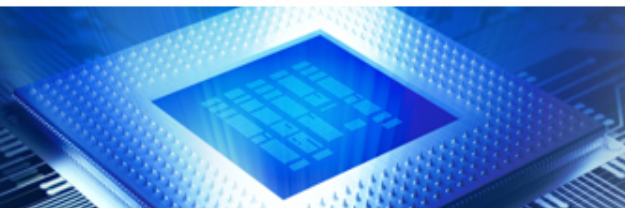


Simulated secondary waveforms



Topologies for Auxiliary Supplies (Mcr)

- On-going simulation and analysis to identify optimum solution and operating mode
- Experimental validation

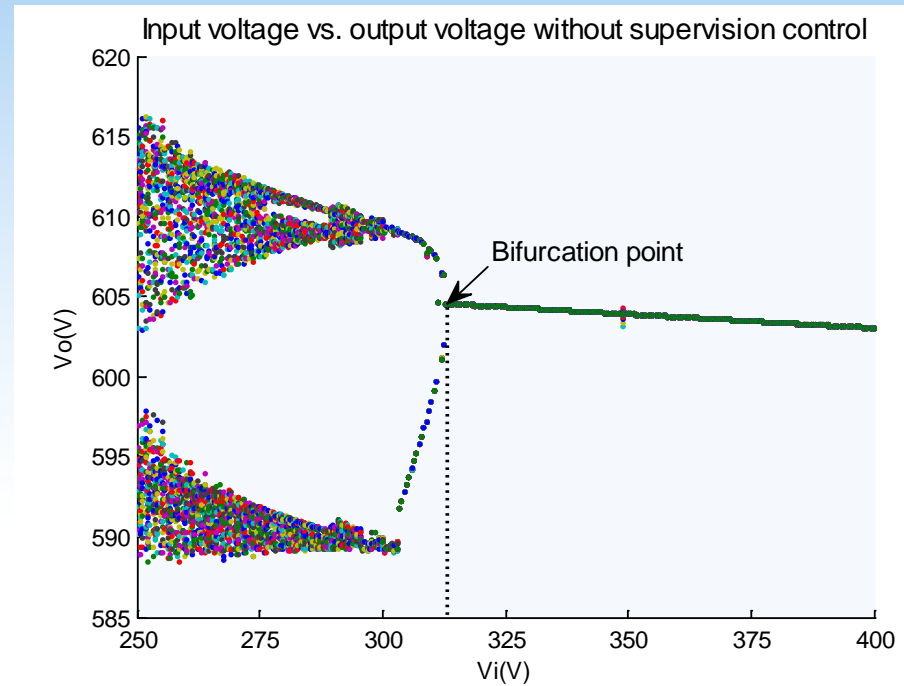
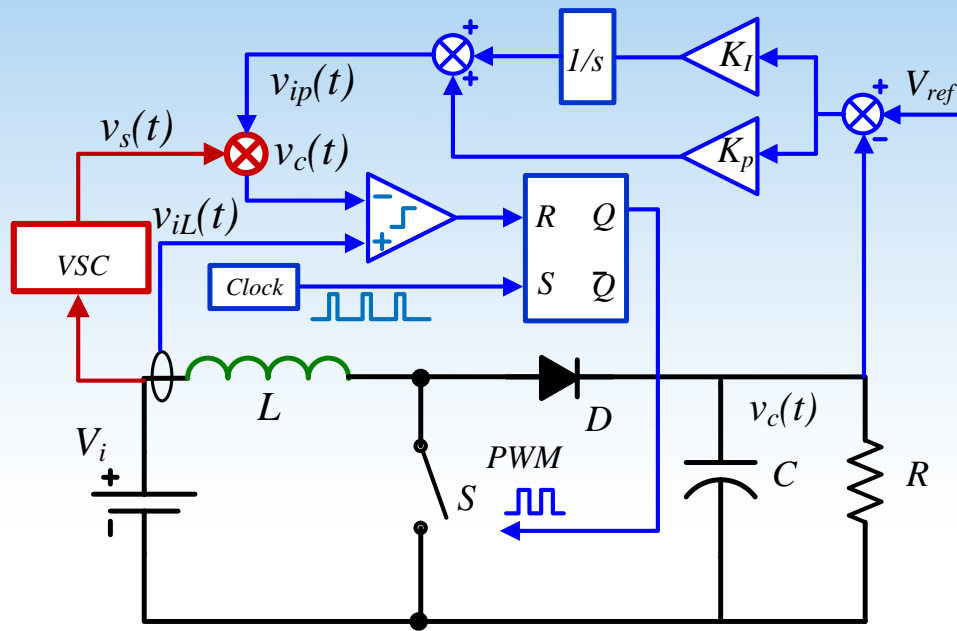


Non-Linear Converter Control (Ncl)

- Reducing the inductor value in simple DC-DC converters can lead to instability when using current mode control
- Non-linear analysis based on the Monodromy matrix has lead to stabilising controller

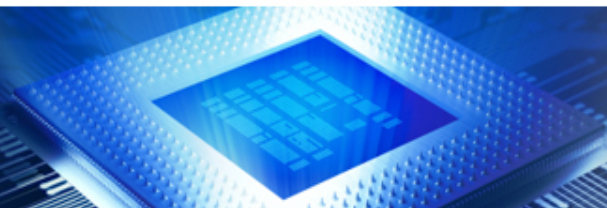
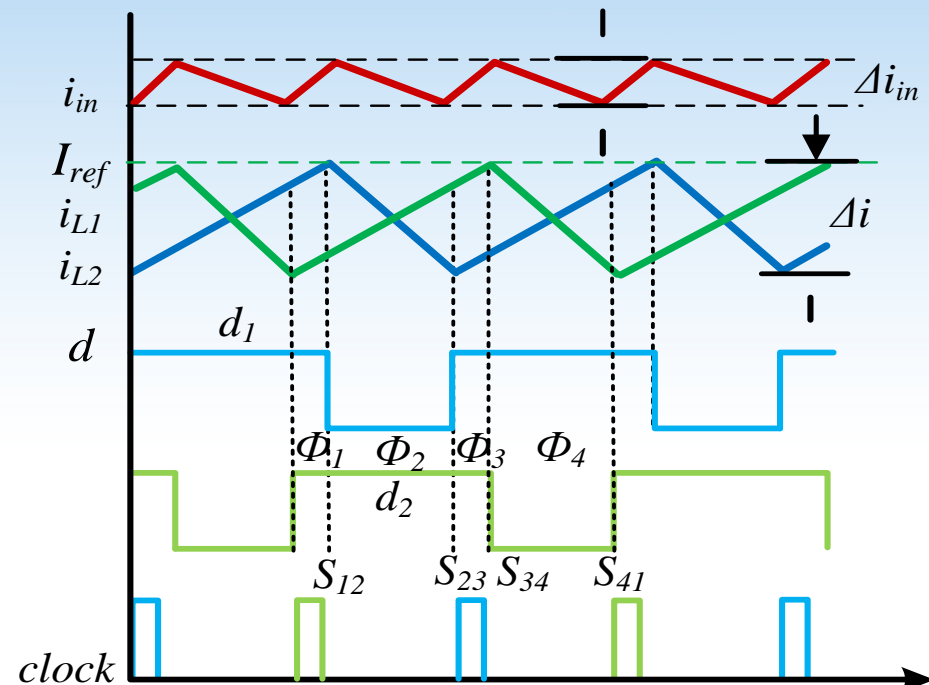
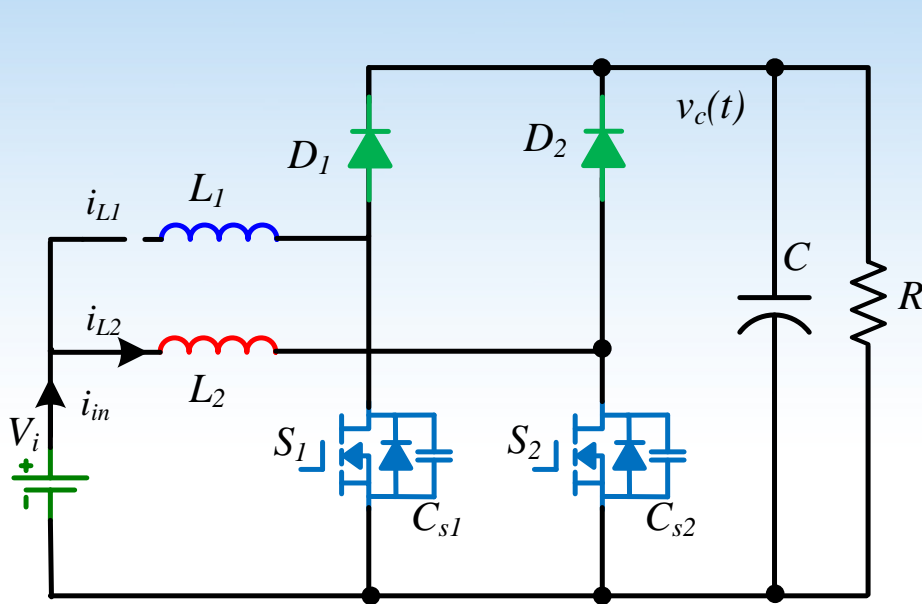


Non-Linear Converter Control (Ncl)



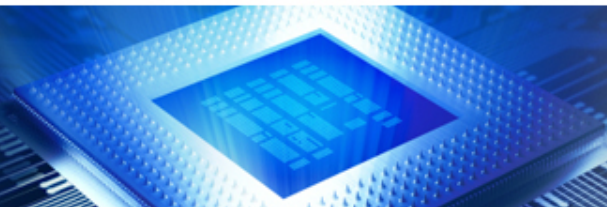
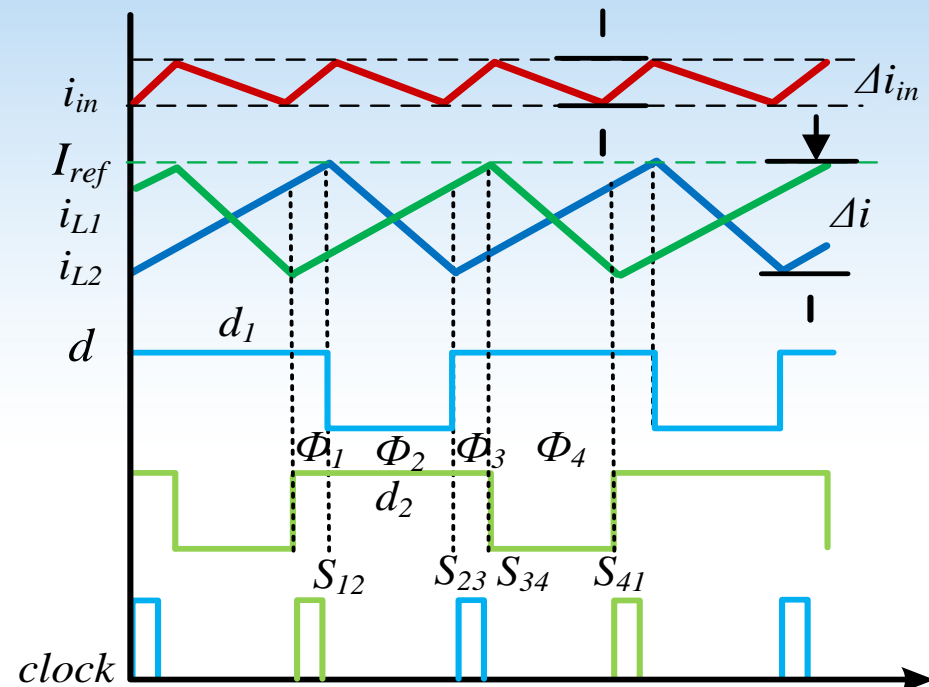
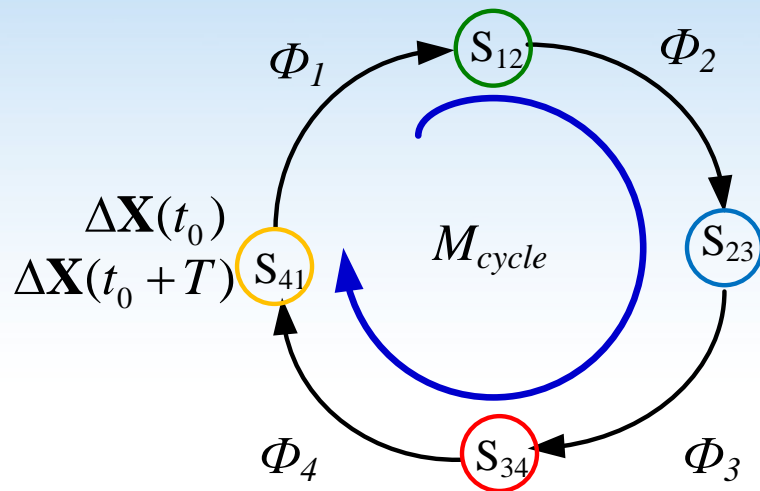
Non-Linear Converter Control (Ncl)

- Extension of analysis to interleaved converters



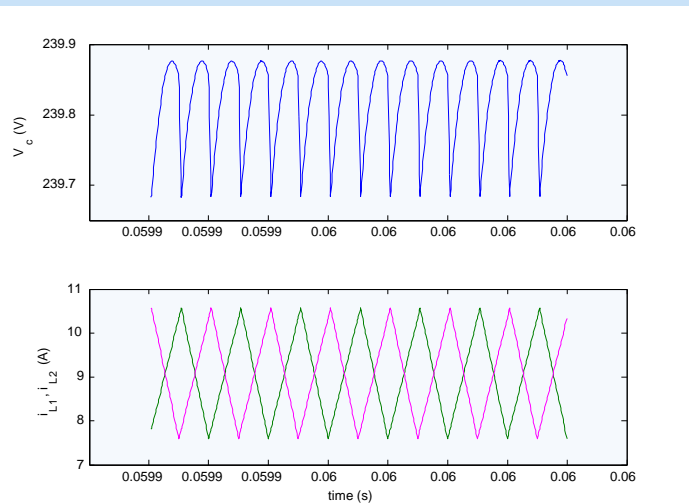
Non-Linear Converter Control (Ncl)

- Development of cyclic analysis

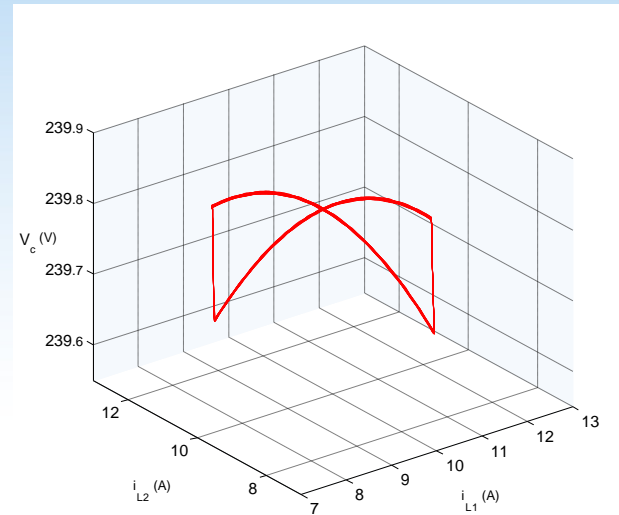


Non-Linear Converter Control (Ncl)

- Simulation of stable operation



Output voltage and inductor currents

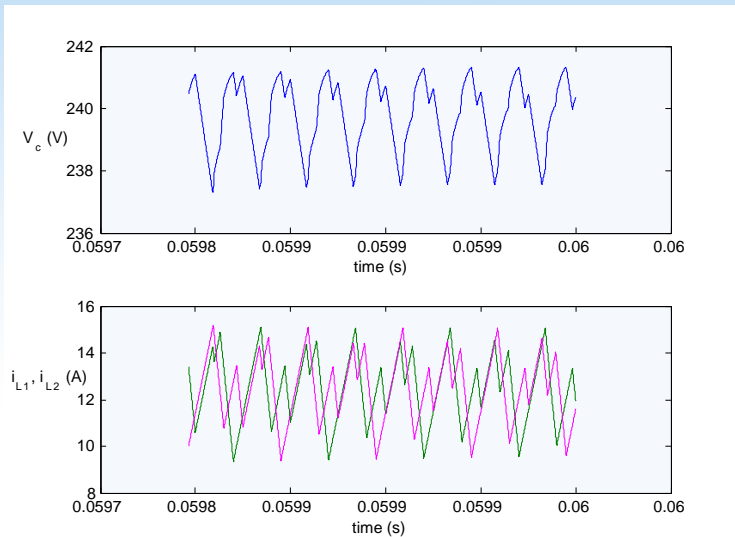


Phase portrait

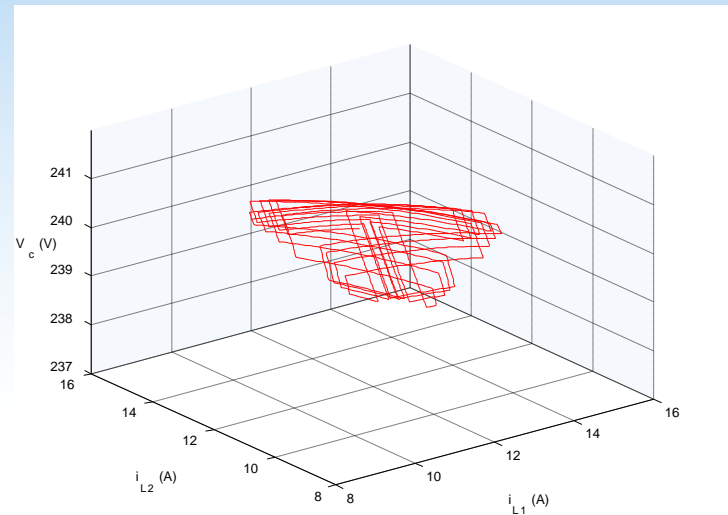


Non-Linear Converter Control

- Simulation of unstable operation



Output voltage and inductor currents

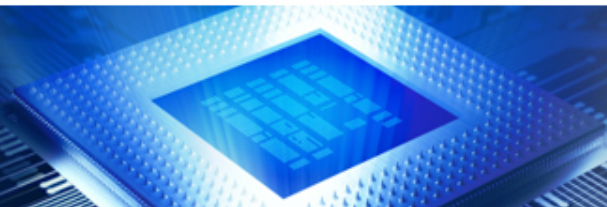
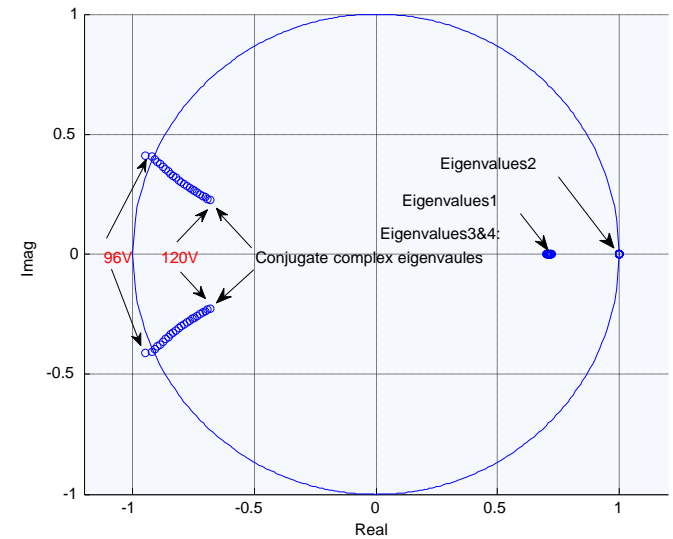
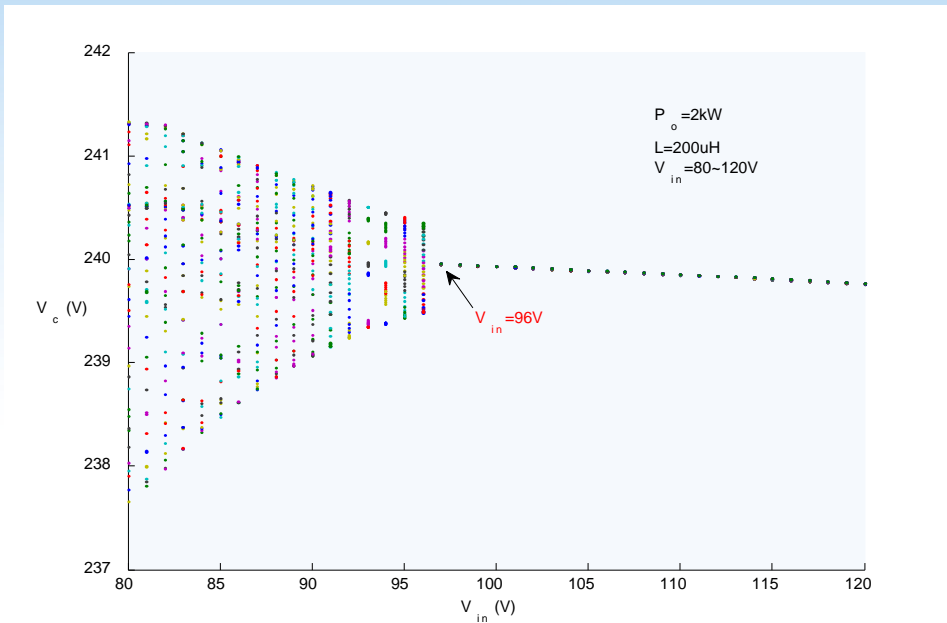


Phase portrait



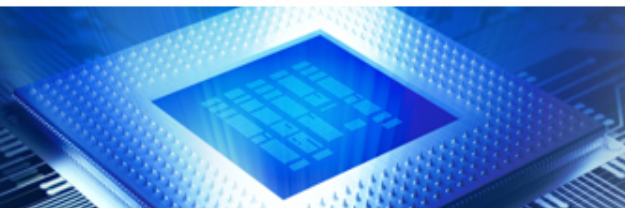
Non-Linear Converter Control

- Bifurcation diagram and root locus plot



Non-Linear Converter Control (Ncl)

- Analysis of dual interleaved converter completed
- Control techniques under development
- Publication of results at IEEE APEC 2014
- Planning experimental validation



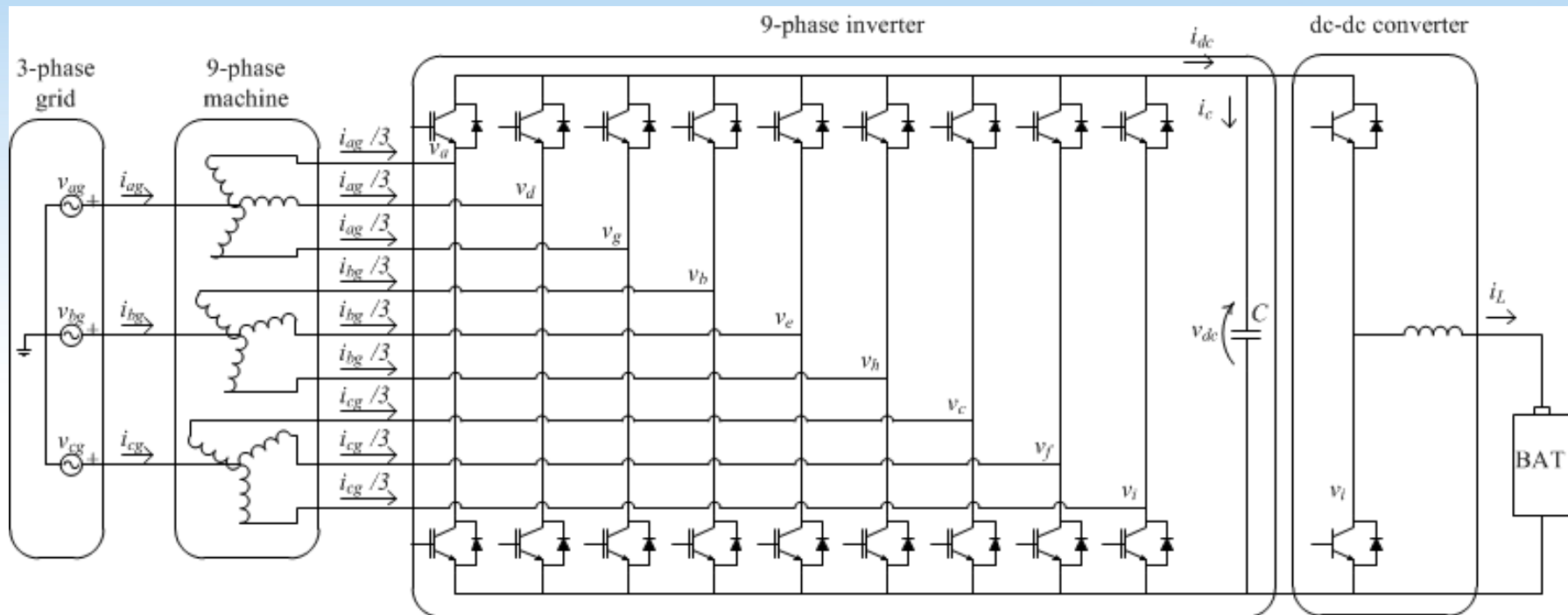
Integrated On-Board Chargers (LJM)

- To reduce system weight, utilise traction system hardware when stationary for charging
- Minimal or zero re-configuration of system
- Key challenge is ensuring zero machine torque
- Use of multi-phase drive systems due to flexibility and fault tolerance



Integrated On-Board Chargers (LJM)

- Nine-phase example



Integrated On-Board Chargers (LJM)

- Development of experimental system



Battery
emulation

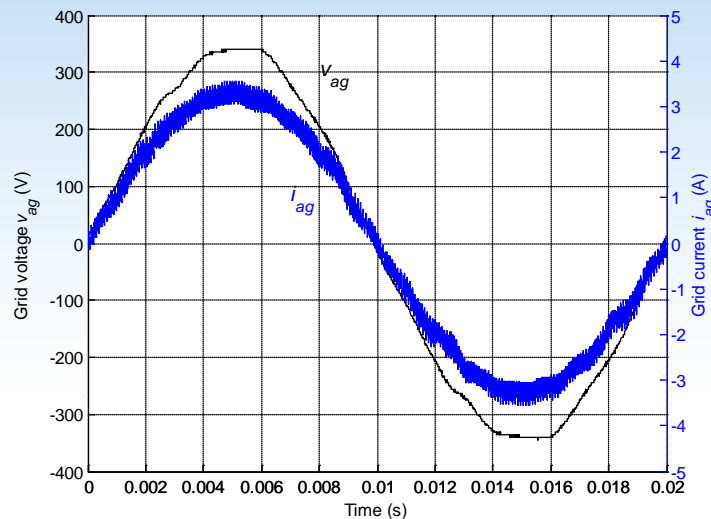
Multi-phase machine
and power electronics

Grid
connection

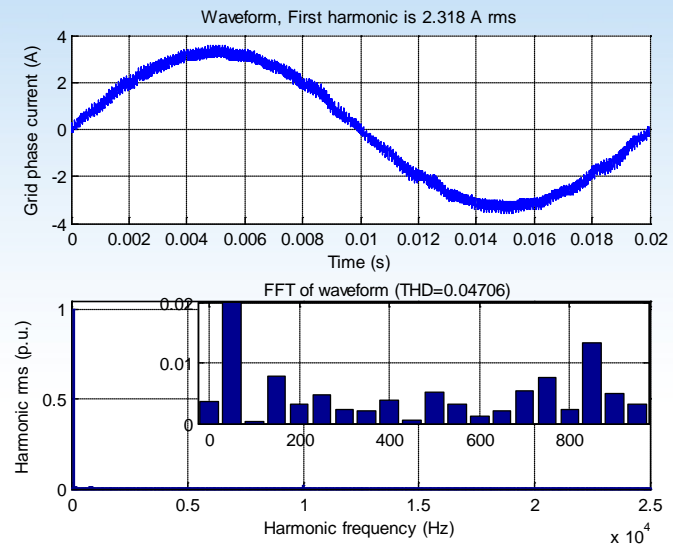


Integrated On-Board Chargers (LJM)

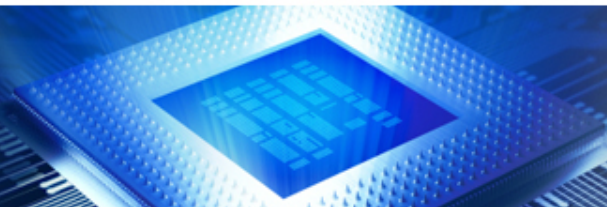
- Experimental results – single-phase charging



Grid voltage and current

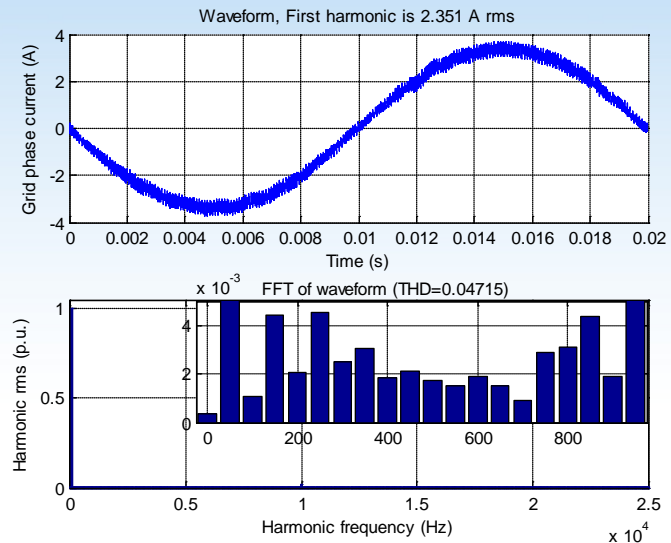
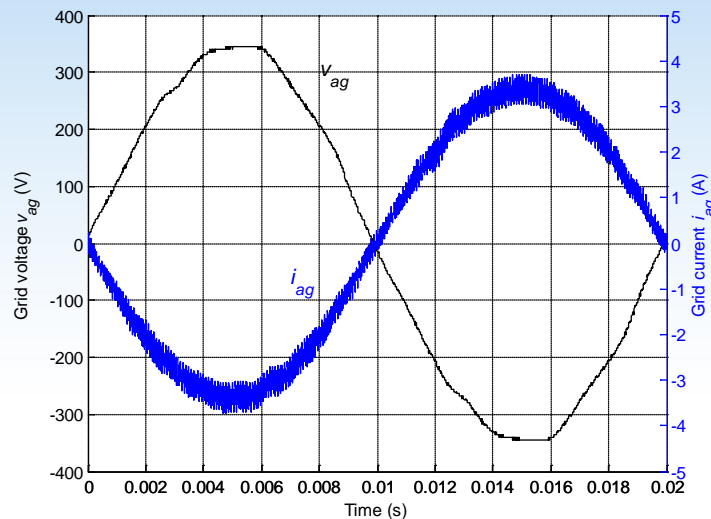


Current harmonics



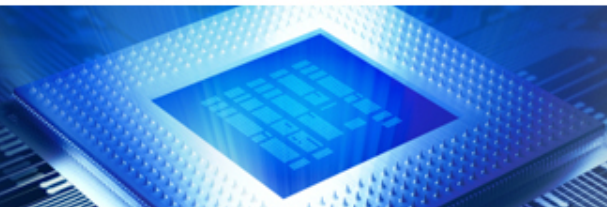
Integrated On-Board Chargers (LJM)

- Experimental results – single-phase V2G mode



Grid voltage and current

Current harmonics



Integrated On-Board Chargers (LJM)

- Exploitation of multi-phase drive for grid connection
- Multi-phase systems provided greater control flexibility to ensure zero torque production when grid connected
- On-going experimental work on different system configurations
- Incorporation into project demonstrator



Conclusion

- Three related strands of research to reduce weight of on-board electrical systems
 - Integrated auxiliary supplies (Mcr)
 - Enhanced converter control to reduce passive component size (Ncl)
 - Integrated charger / V2G connection and traction drive (LJM)

