GaN DC/AC Multilevel Converter for PV Application

Relatori:

Dr. Fabio Mandrile

Prof. Eric Giacomo Armando

Dr. Marco Palma

Candidato:

Francesco Emanuele Musumeci

Dipartimento Energia "Galileo Ferraris"

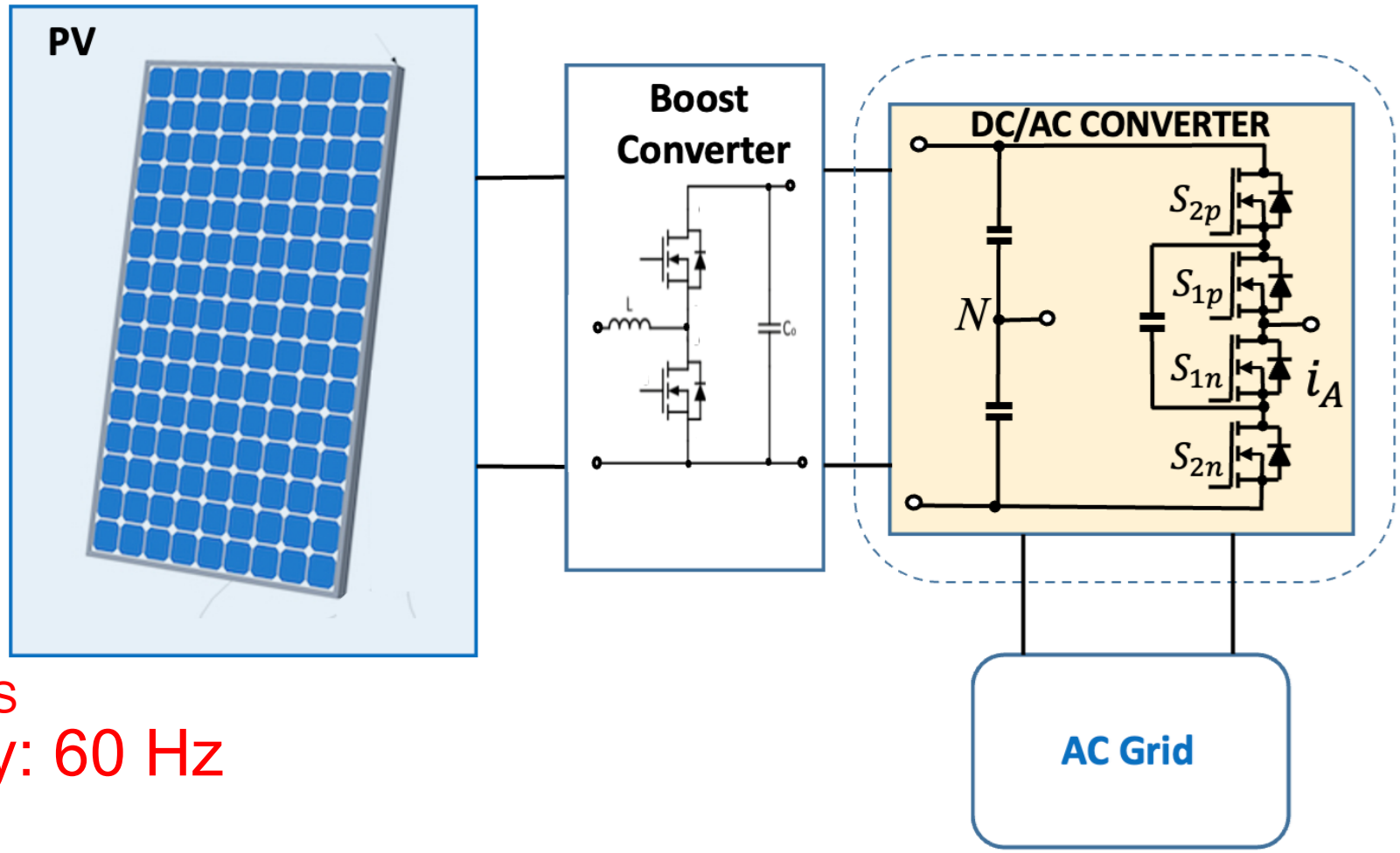
Politecnico di Torino, Italy

Index

- Introduction
- GaN Transistors
- Multilevel topologies comparision
- Application design
- Components and schematics
- Conclusions

Application system

- PV application
- DC/AC converter
- American grid application



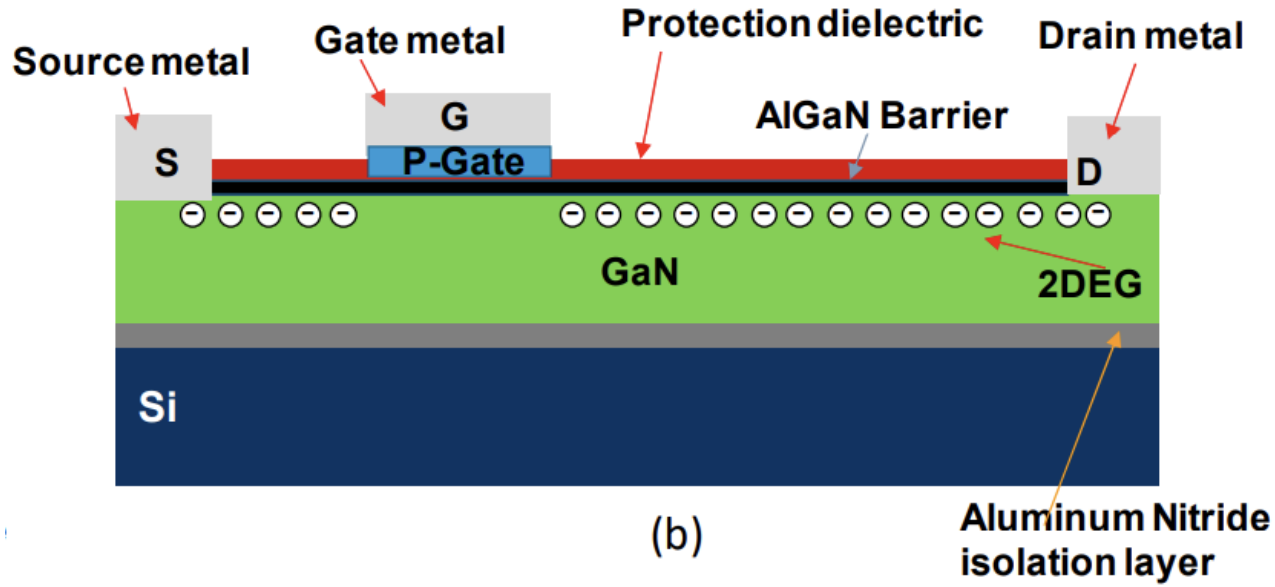
➢ Inverter dc-bus: 400 V

➢ Output Voltage: 110 V_{RMS}

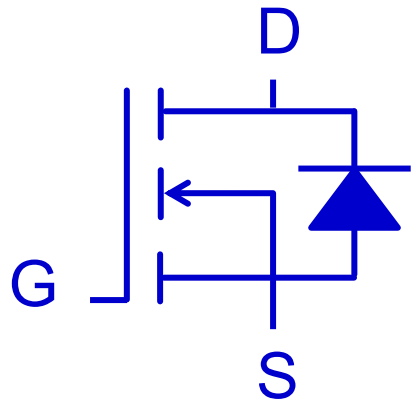
➢ Output voltage frequency: 60 Hz

Gan Transistors

- GaN power devices are high electron-mobility transistors (HEMTs) belonging to the wide-bandgap materials (WBG).
- 3-terminal transistor
- Voltage controlled



(b)



- Low on-resistance value
- Miller ratio <1
- Zero reverse recovery (Q_{RR})

$$Miller_{ratio} = \frac{Q_{GD}(V_{DS})}{Q_{GS\_Th}}$$

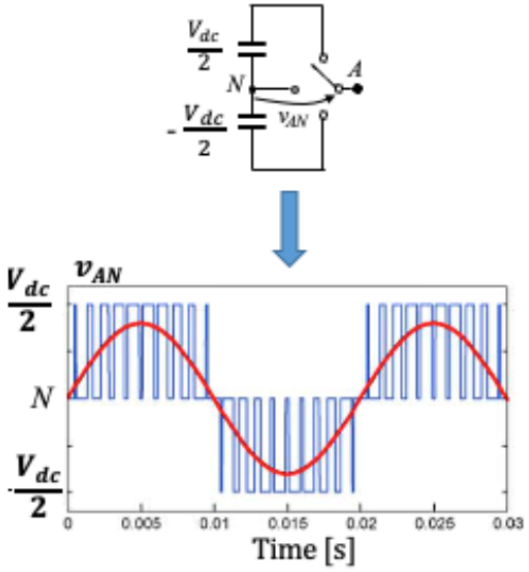
Multilevel topologies

- Multilevel converters stepped output voltage waveforms

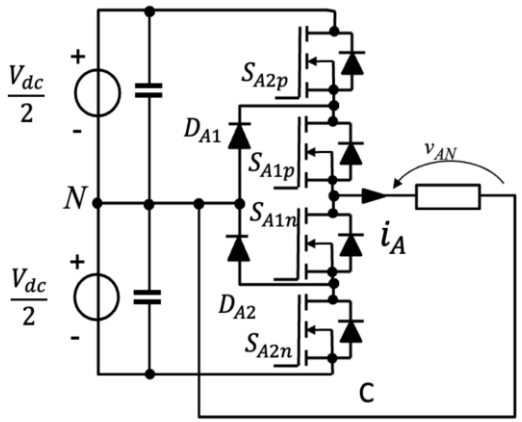
➢ Emulating sinusoidal waveform

➢ Total Harmonic Distortion (THD) reduction

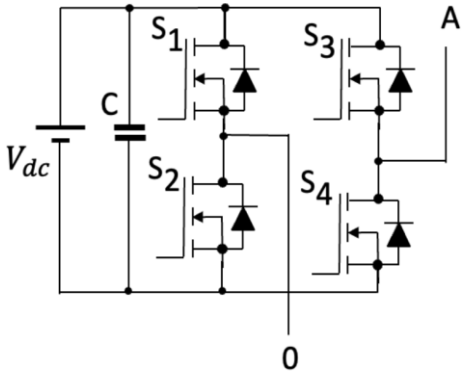
- Diode Clamped Inverter (NPC) Topology;
- T-Type Converter;
- Cascaded H-Bridge inverter;
- Cascaded Half Bridge inverter;
- MMC Converter;
- Heric Converter;
- Flying Capacitor Converter.



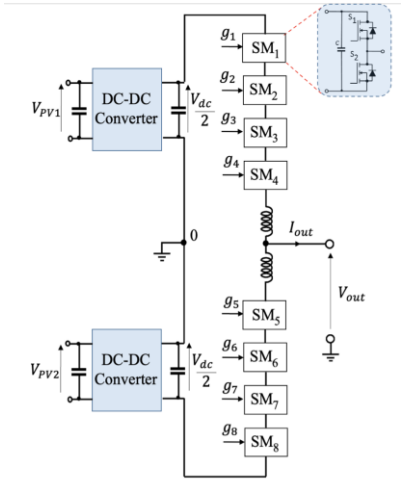
3L-NPC VSC



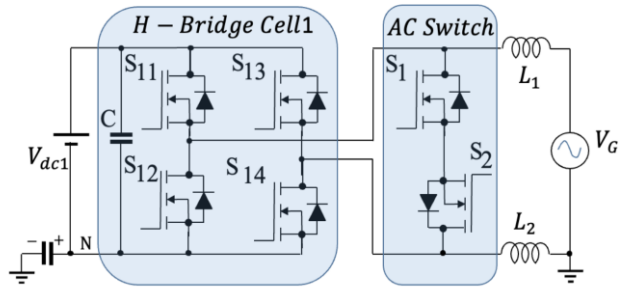
3L-Cascaded H-Bridge Inverter



MMC converter

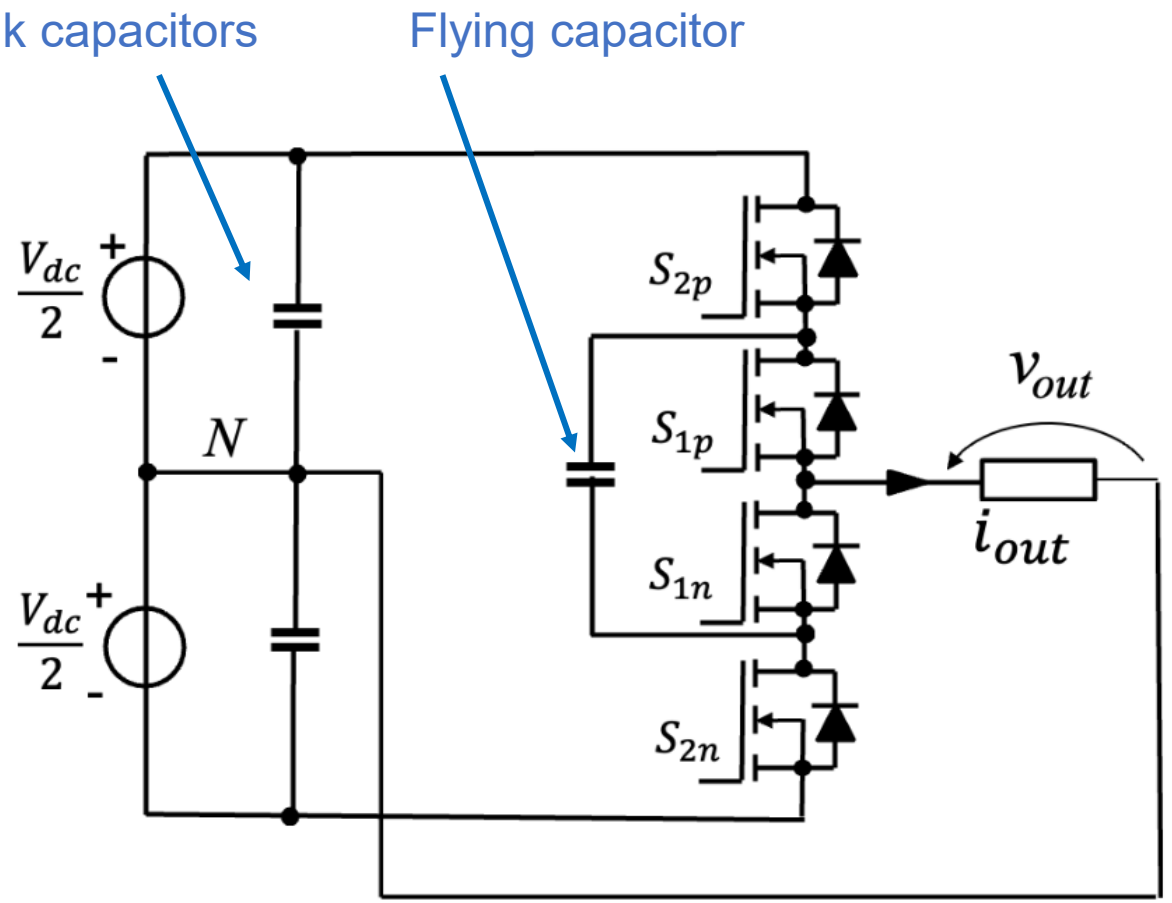


Heric converter



3-L Flying Capacitors converter design

- Gan transistor selection
- Modulation technique
- Power losses analysis
- Thermal analysis
- Capacitors design



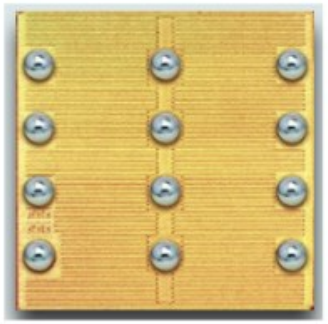
plexim plecs

LTspice®

GaN FET

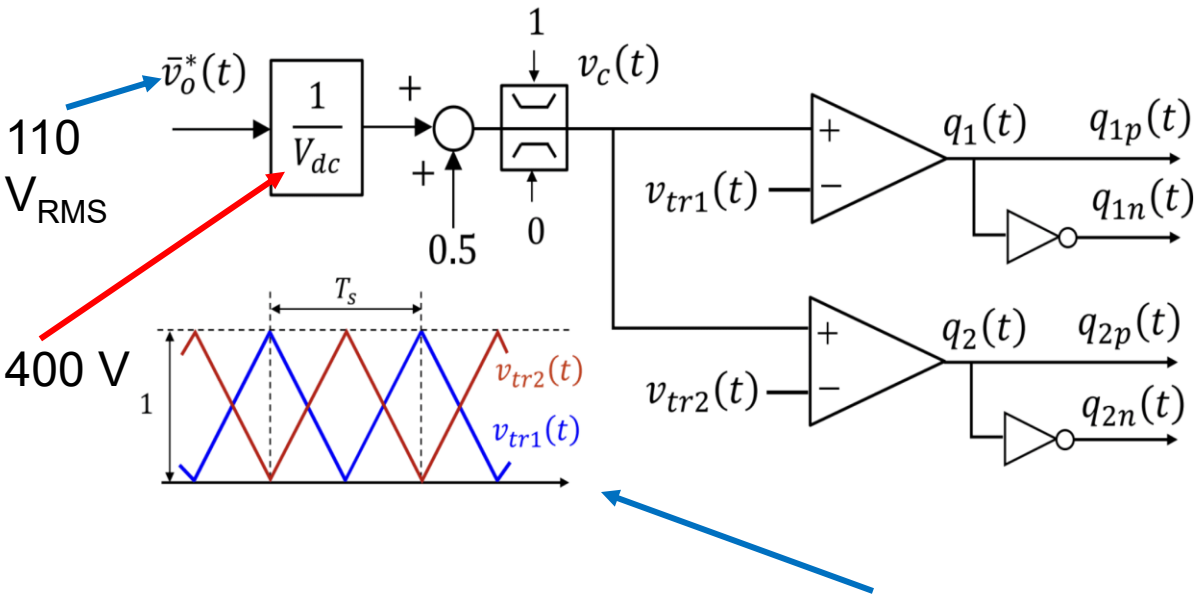
Modulation Technique

EPC2050



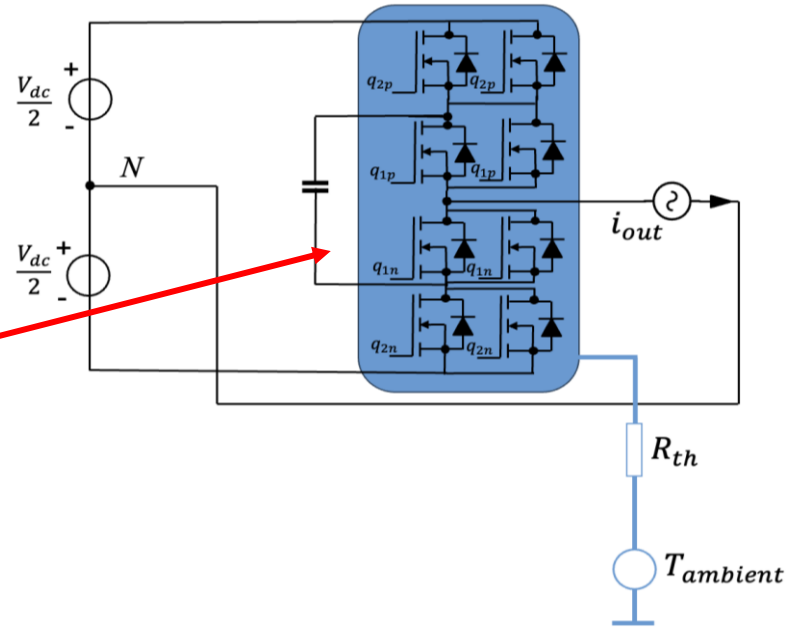
- $R_{DS,on}$ = 80 mΩ MAX
- V_{DS} = 350 V MAX
- Size=1.95mmx1.95mm

Doubling frequency effect



PWM with two 180° shifted carriers

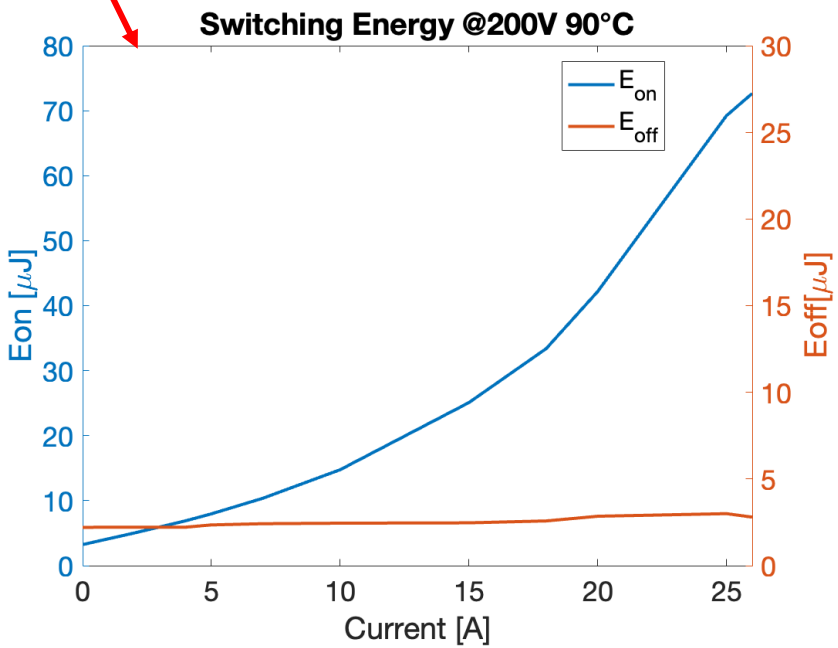
Power Losses



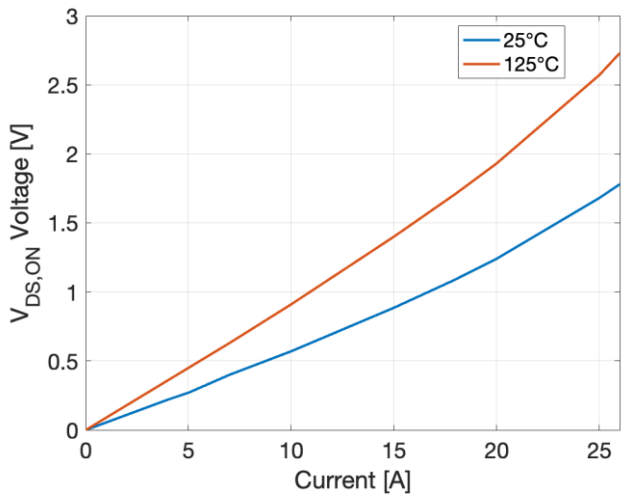
Parallel devices configuration

Switching Losses

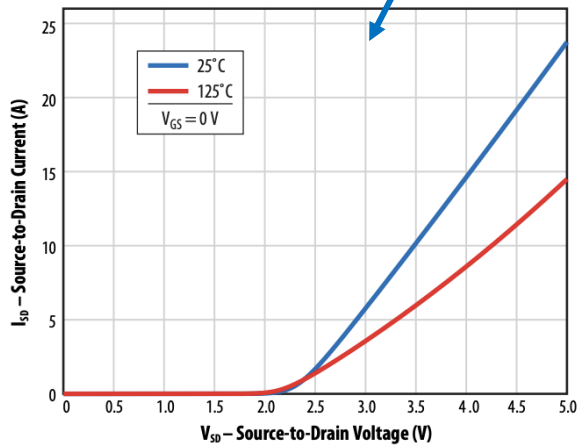
E_{on} and E_{off}



Conduction losses

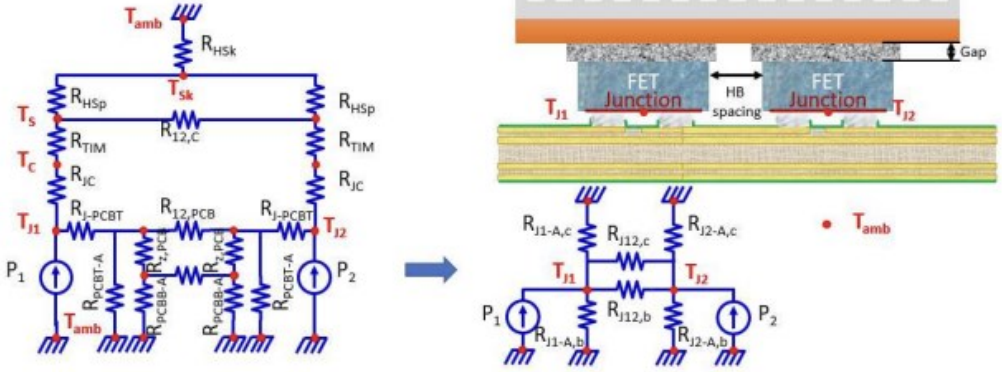


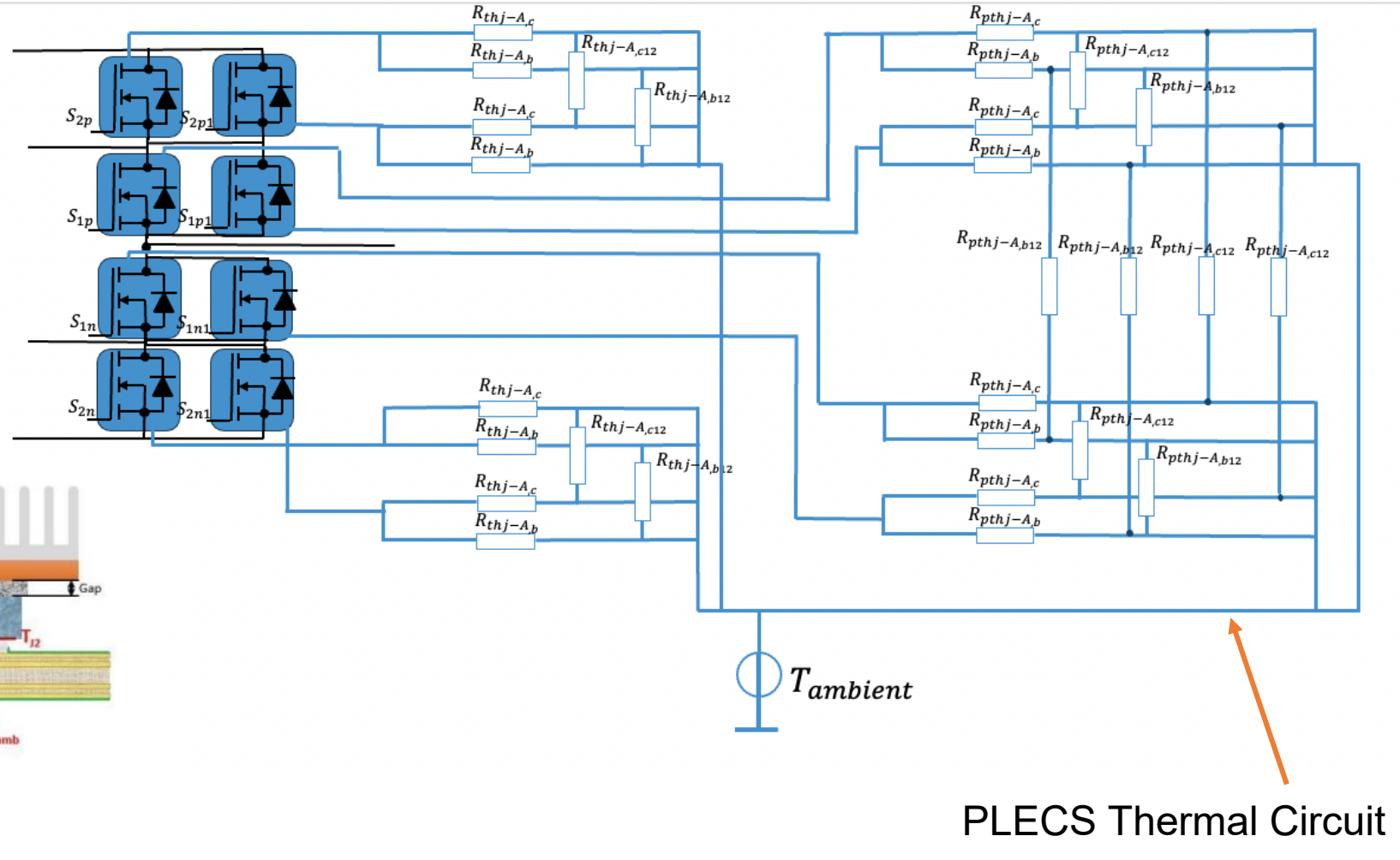
Reverse conduction



Thermal Analysis

GaN FET thermal model



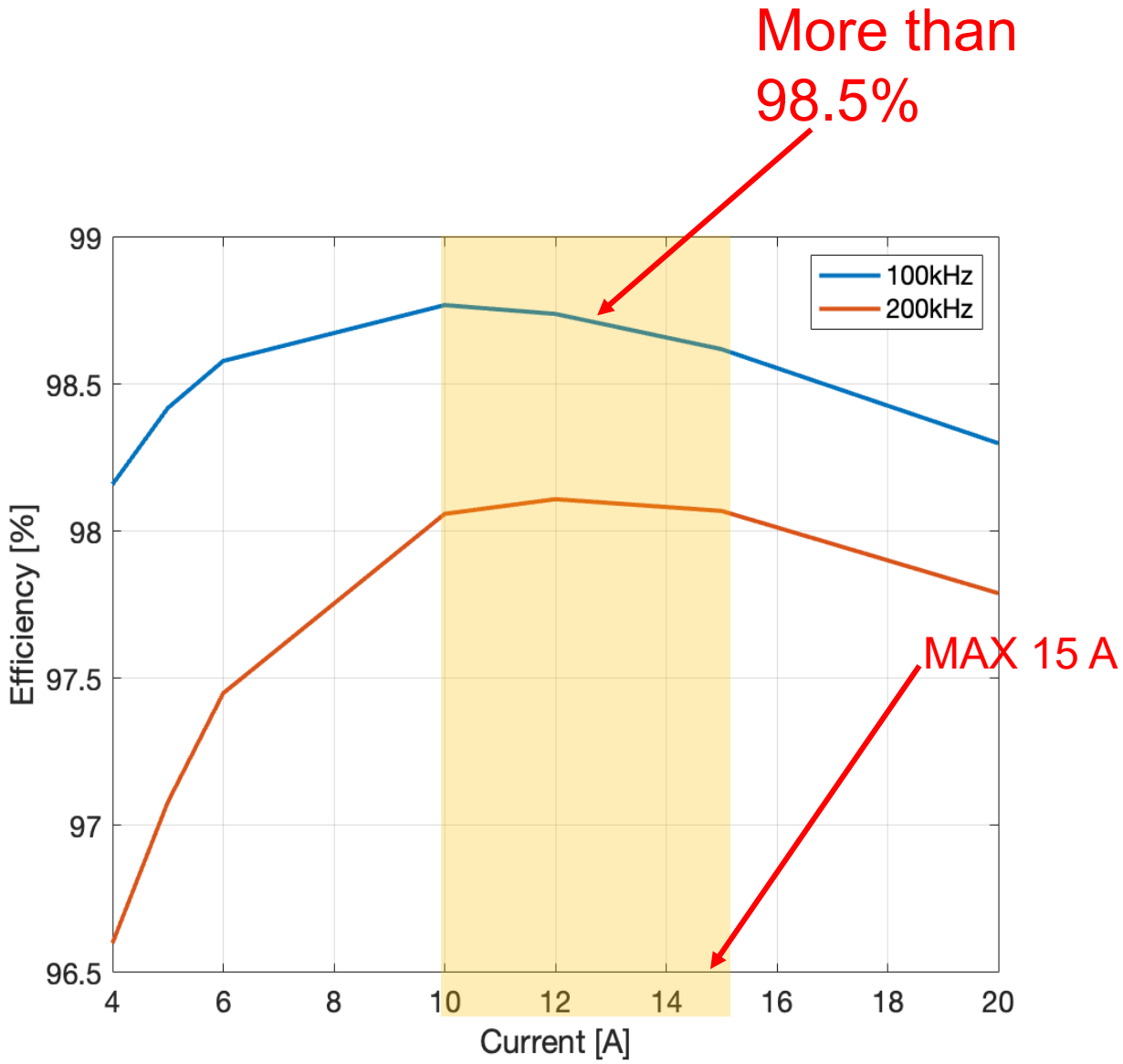


PLECS Thermal Circuit

Efficiency

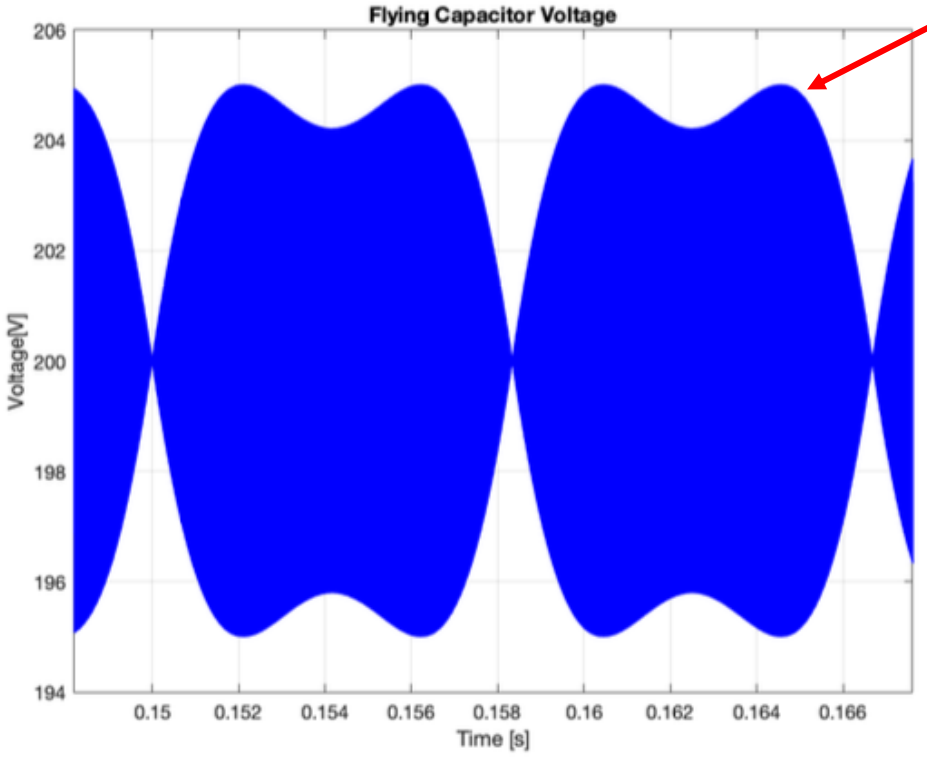
- Comparision between 100 kHz and 200 kHz efficiency

➢ Better efficiency at 100 kHz



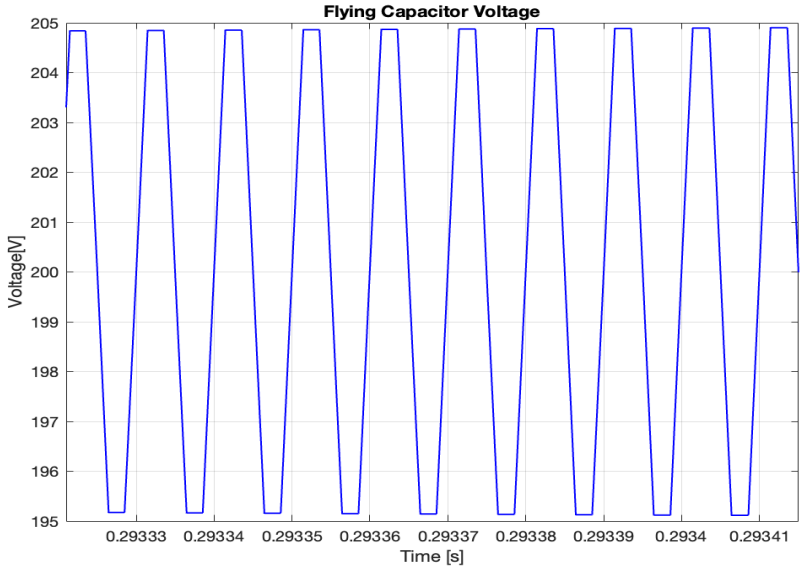
Flying Capacitor ripple

Peak ripple value

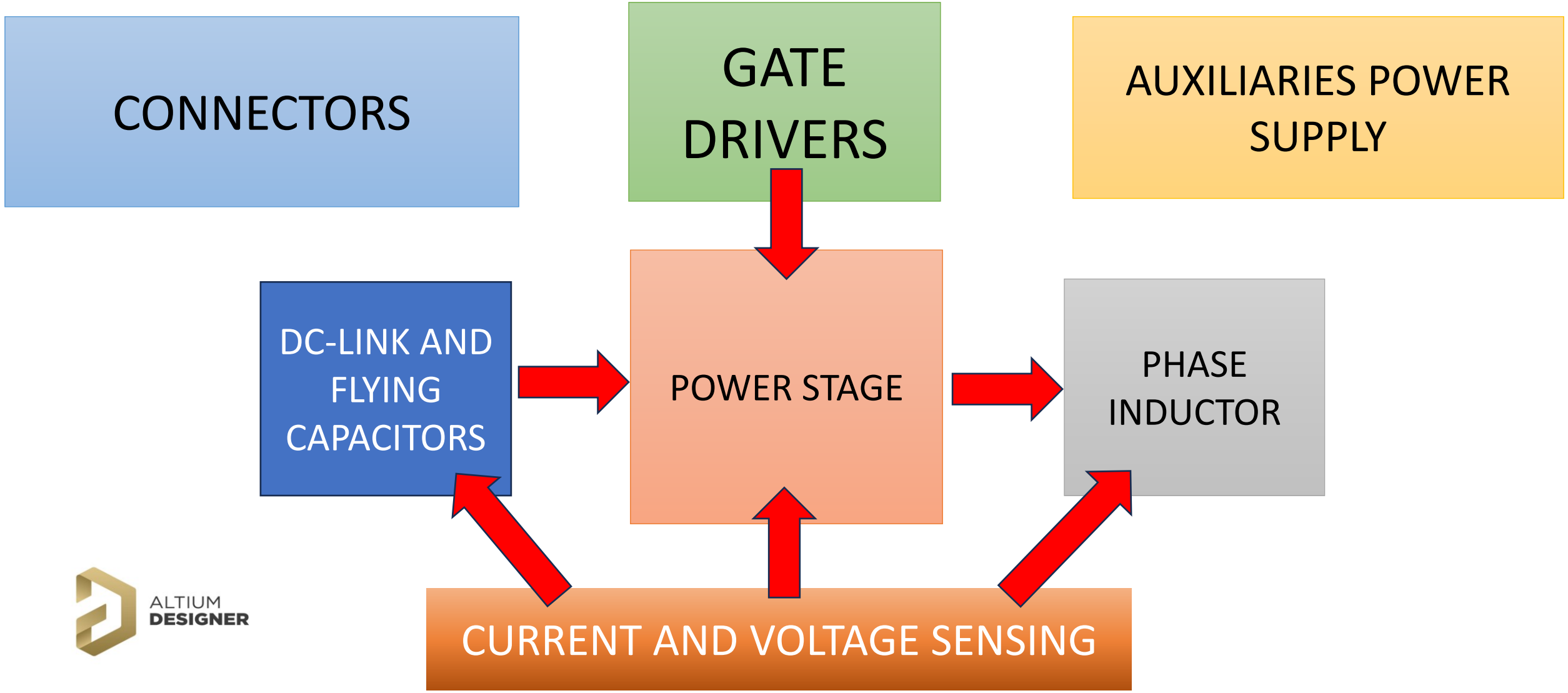


- 90% of requested output voltage
- 5% of ripple
- 2.68 µF of capacitance

ZOOM



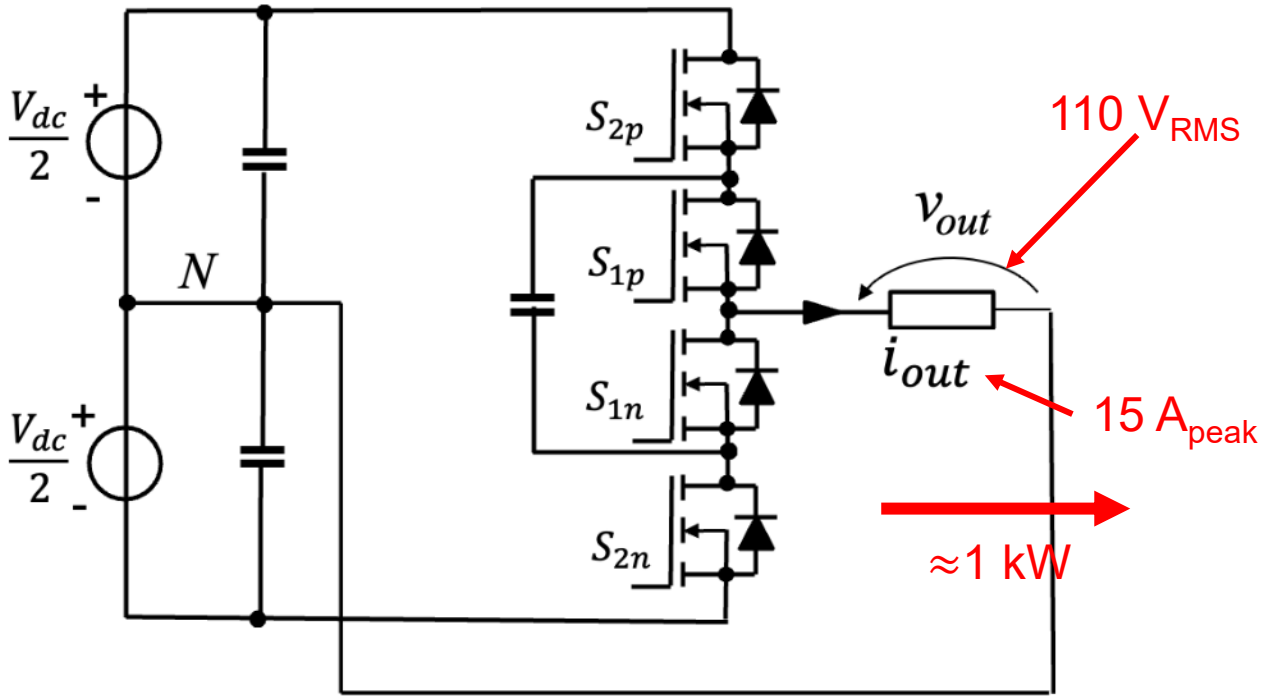
Components and Schematics



ALTIUM DESIGNER

Conclusions

Inverter main characteristics



Future plans

- PCB and prototype of inverter
- Testing

Personal Contributions

- Multilevel converters state of art study
- Design with simulation runs of the inverter
- Sizing of the inverter components
- Drawing of schematics

Thank you!