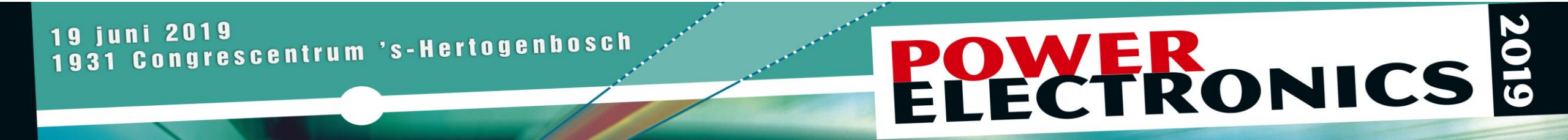
PCB technology for high currents up to 1000A

Phoenix Contact || Thijs van den Akker



PHOENIX CONTACT

- Founded in 1923, Essen Germany
- Headquarter in Blomberg Germany

- TO €2.38 billion (2018)
- 17,400 people in total

- Device Connectors
- Industrial Connectivity
- Industrial Electronics
- Industry Management & Automation

Group Center of Competence, Harrisburg/USA

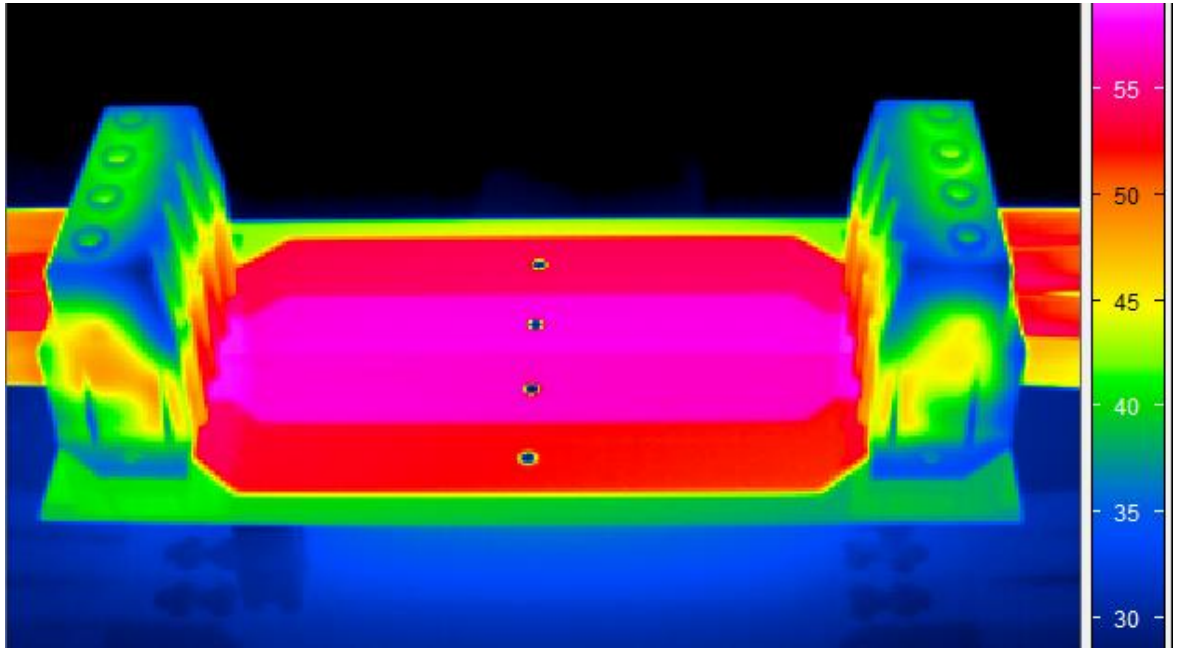
Innovation Center Electronics, Bad Pyrmont/Germany

Group Center of Competence, Nanjing/China

POWER ELECTRONICS 2019

Agenda

- **Why high currents over a PCB?**
- **PCB Technologies up to 1000A**
  - Two challenges
  - PCB technologies for high currents
- **Applications**
  - ‘Live application’ Frequency drive
  - E-mobility AC and DC charging
- **Products**
  - PCB terminals up to 232A



PCB technology for up to 1000A

Power electronics applications trends

50A?

<200A?

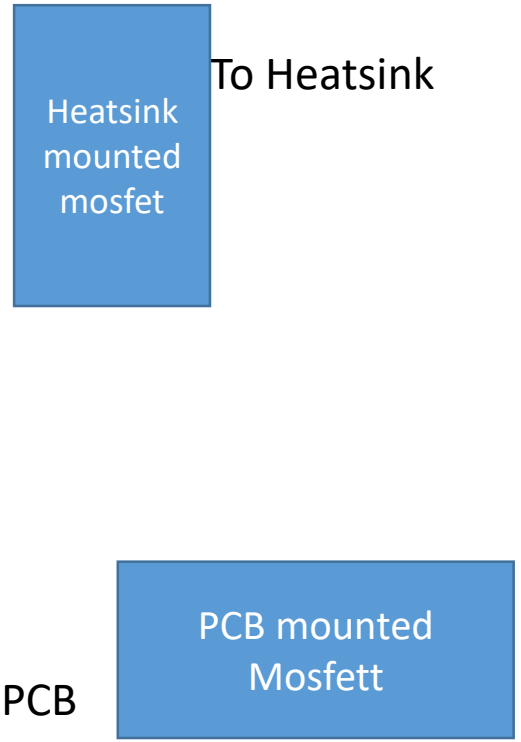
>500A?

PCB technology for up to 1000A

Select high power PCB technology

Two main PCB challenges:

- Carrying high currents
- Heat dissipation (traces + components)



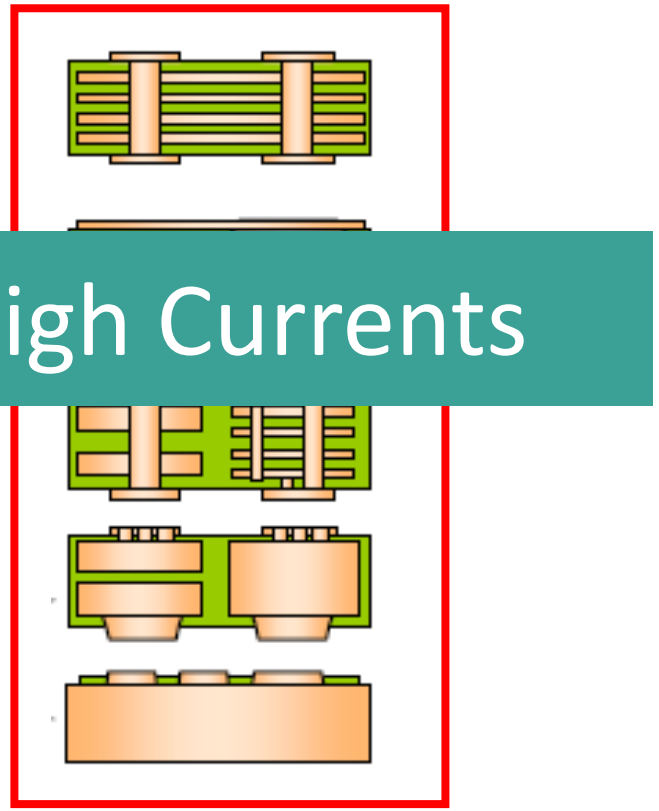
Heat dissipation Key questions:

- Where is the heat source located?
- Where does the heat has to go?
- How do we get it there?

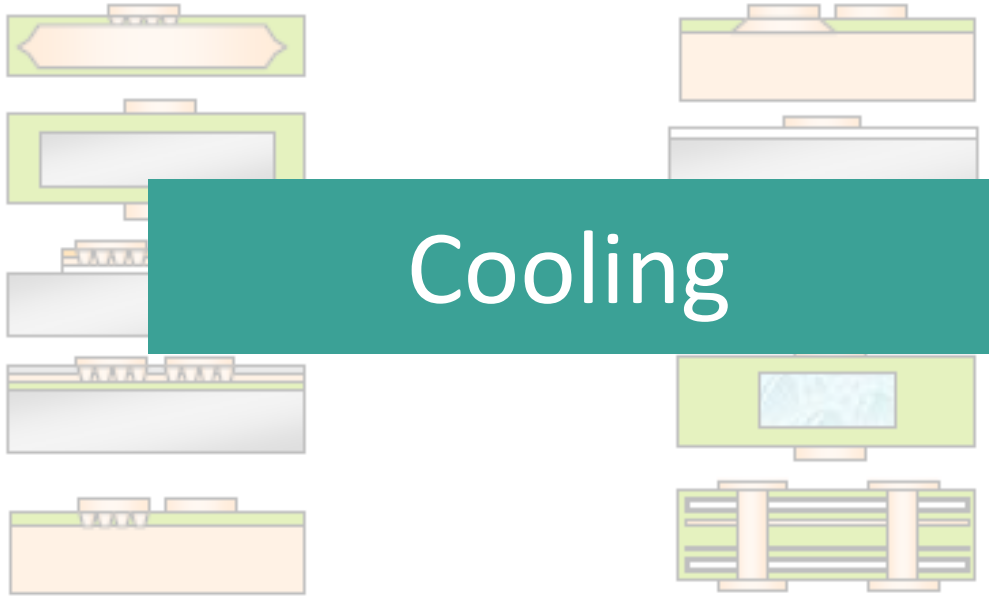
PCB technology for up to 1000A

Strategies to select high power PCB technology

Already a lot of PCB technologies out there:



High Currents



Cooling

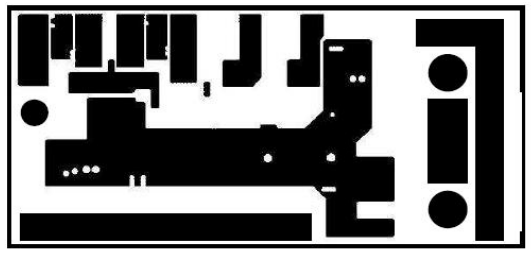
Source: Andus electronic

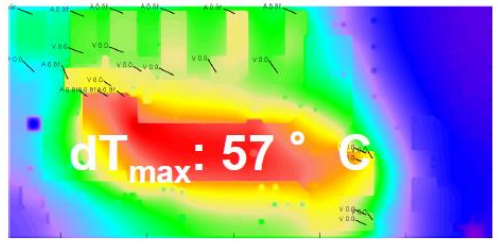
PCB technology for up to 1000A

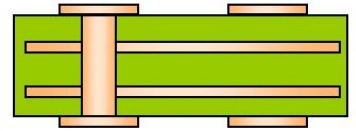
Strategies to select high power PCB technology

<u>Example: multilayer, 4 layers</u>

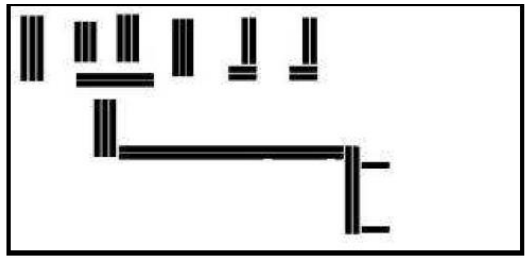
- Starting situation (inner layer):

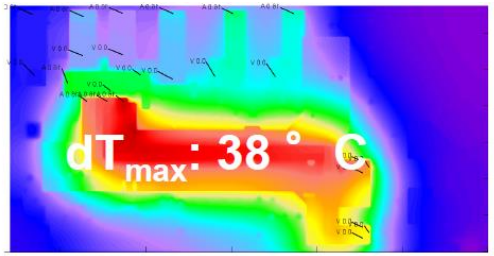


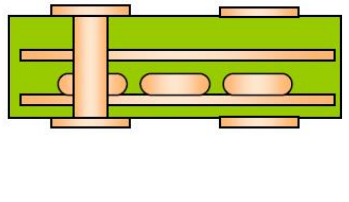




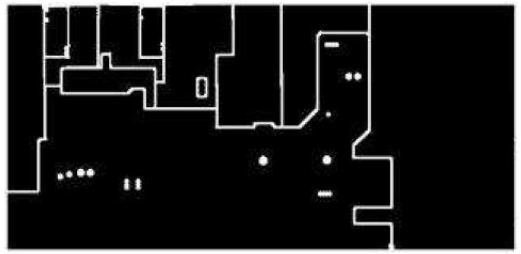
- Additional copper profiles welded to the inner layers:

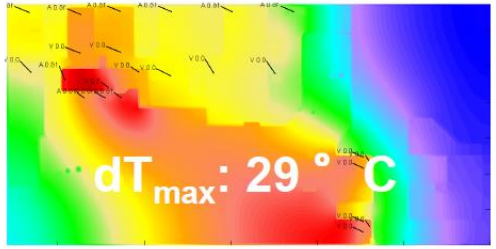


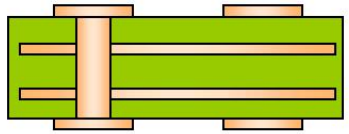




- Free alternative: optimization inner layer layout:







Source: Andus electronic

PCB technology for up to 1000A

Strategies to select high power PCB technology

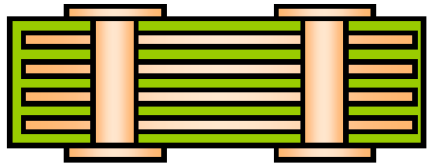
High Current <100A

High Current >100A – 1000A

Standard

Thick Copper PCB

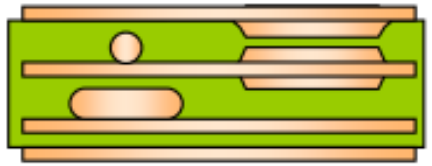
- Inner Layers up to 400 µm
- Outer Layers up to 210 µm
- Minimalize layer distance (100 µm)



Selective Heavy Copper

Iceberg technology

- Inner Layers up to 400 µm
- Outer Layers up to 400 µm



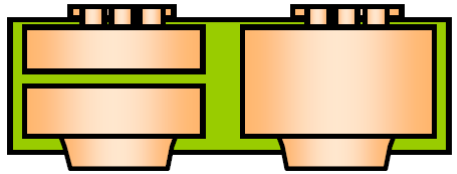
Wire-laid technology

(Häusermann: HSMTec)

High Power PCB's

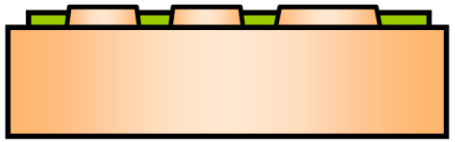
Inlay PCB

- 1-3mm thick copper inlay
- Filled microvias tab connection
- Inlay pads & external tabs



Inlay PCB

- X-cool SMT/IMS



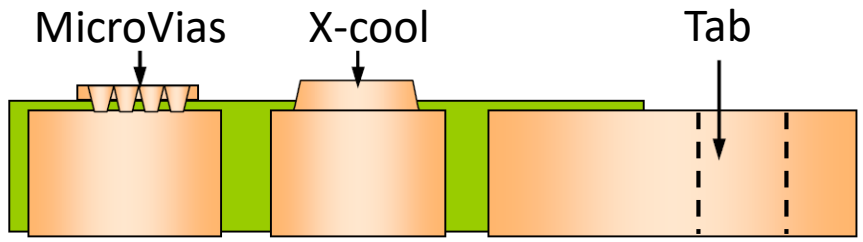
Source Pictures: Andus electronic

PCB technology for up to 1000A

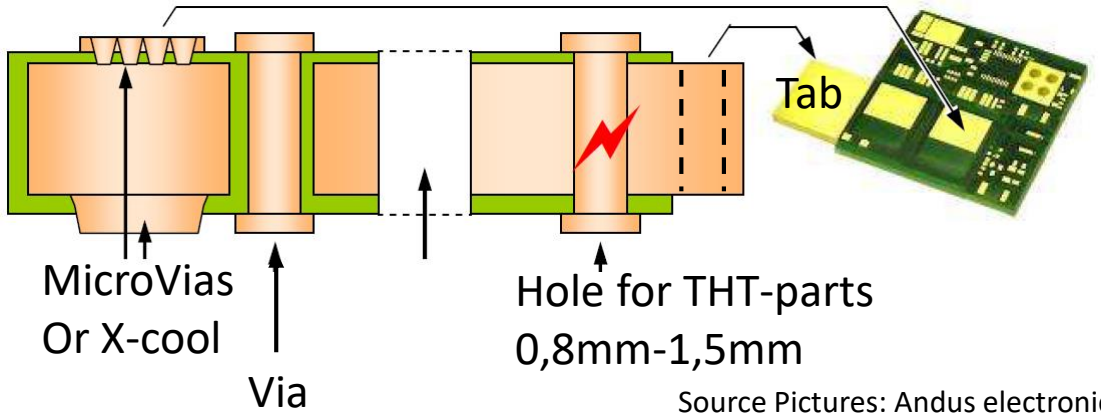
Strategies to select high power PCB technology

2 Inlay PCB variants

- 1 Inlay layer + 1 Outer layer



- 1 Inlay-layers + 2 Outer-layers
  - (Most common)



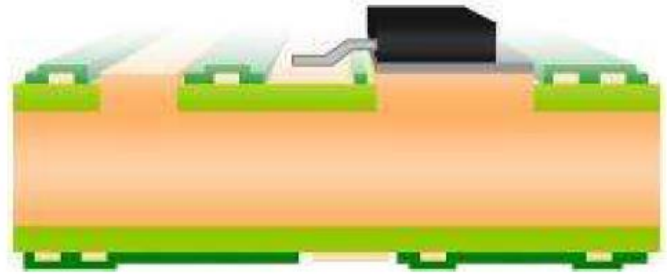
Source Pictures: Andus electronic

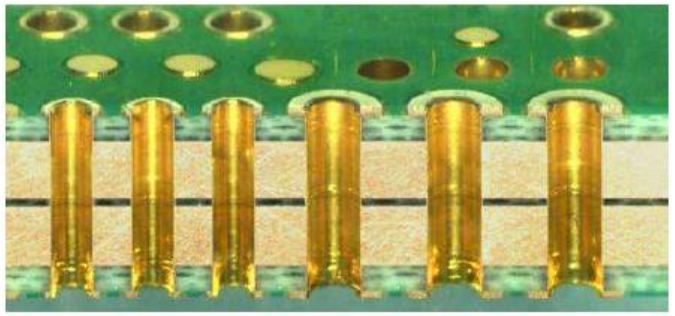
PCB technology for up to 1000A

Strategies to select high power PCB technology

Thick copper benefits against multilayer:

- High Currents & Good cooling for complete system
- Big cross-section at component (150A/15W per part)
- High reliability at connectivity (Soldering in stead of bolting)
- Use of standard SMD assembly (Preferable vapor phase)
- A lot of design freedom
- Saving of assembly effort, material and time





Source: Andus electronic

Example applications

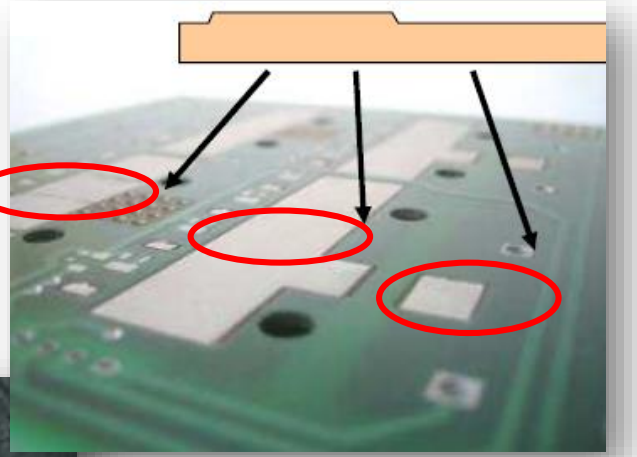
- (Solar/E-mobility) power converters
- Battery management Systems
- Motor drives
- Etc!

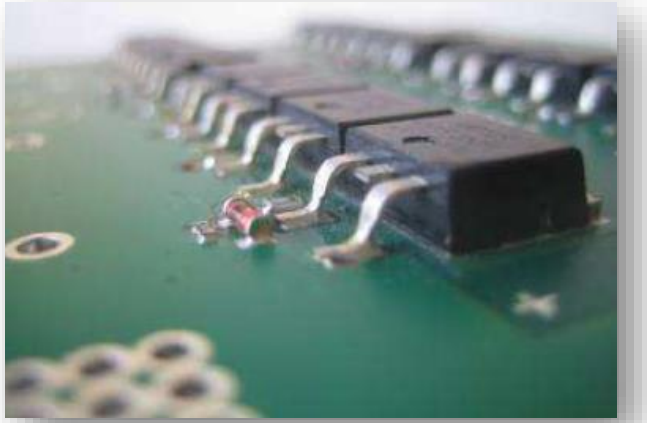
PCB technology for up to 1000A

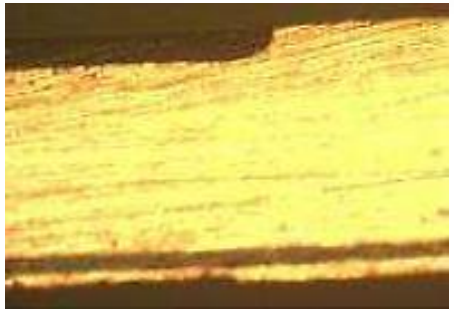
Strategies to select high power PCB technology

Power PCB Example #1

- 1 Inlay + 2 Outer layers







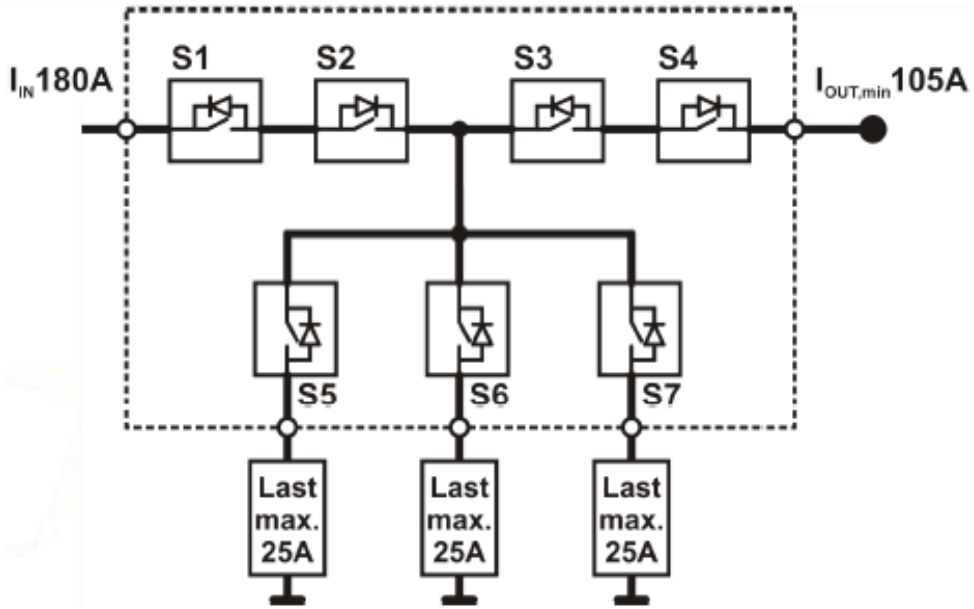
Source Pictures: Andus electronic

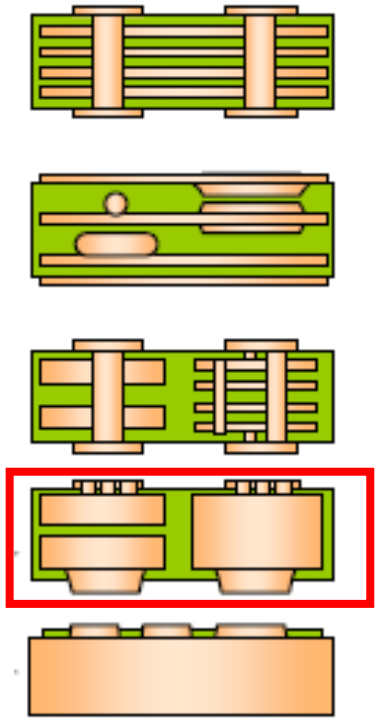
PCB technology for up to 1000A

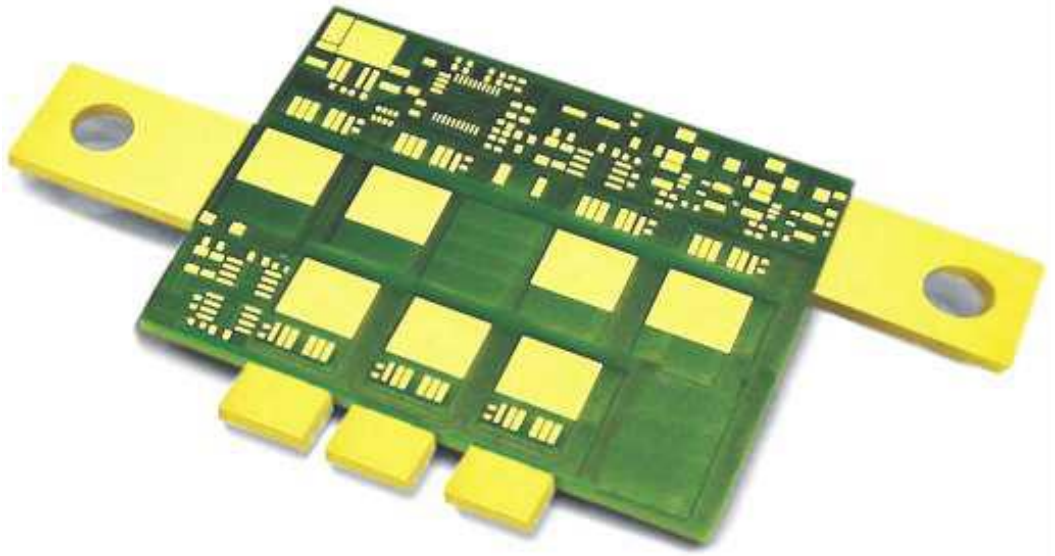
Strategies to select high power PCB technology

Power PCB Example #2

- 2 mm inner layer







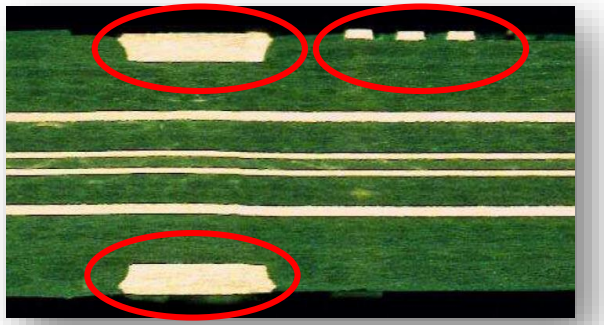
Source: Andus electronic

PCB technology for up to 1000A

Strategies to select high power PCB technology

How to combine Power and Control electronics?

- Thick and Thin copper combined
  - Possible, think of alternatives*



Source: Andus electronic

- Add-on PCB
  - Separately; better solderable

*take thick copper in consideration

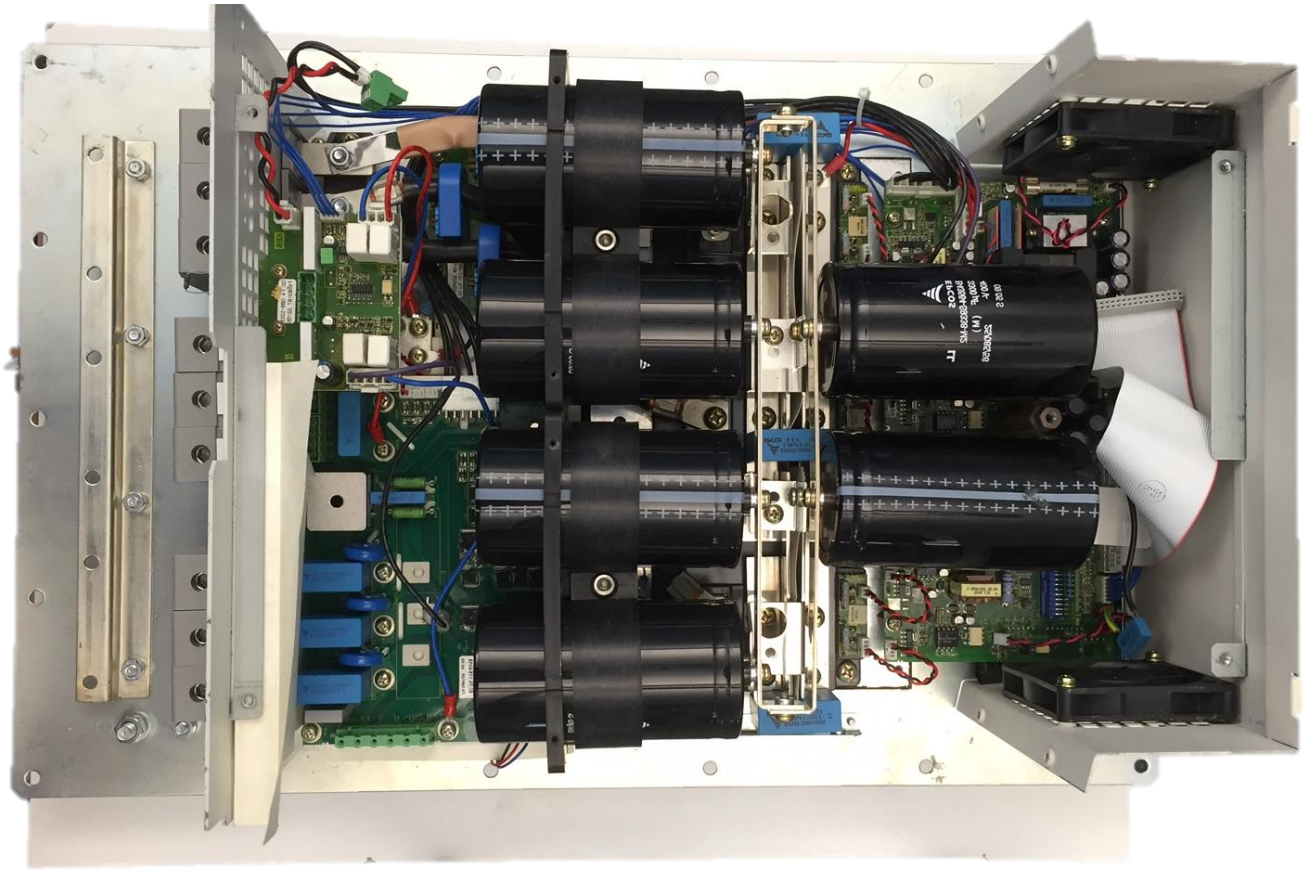
PCB technology for up to 1000A

Practical ‘live’ example: Frequency drive

<u>Old style</u> device build-up

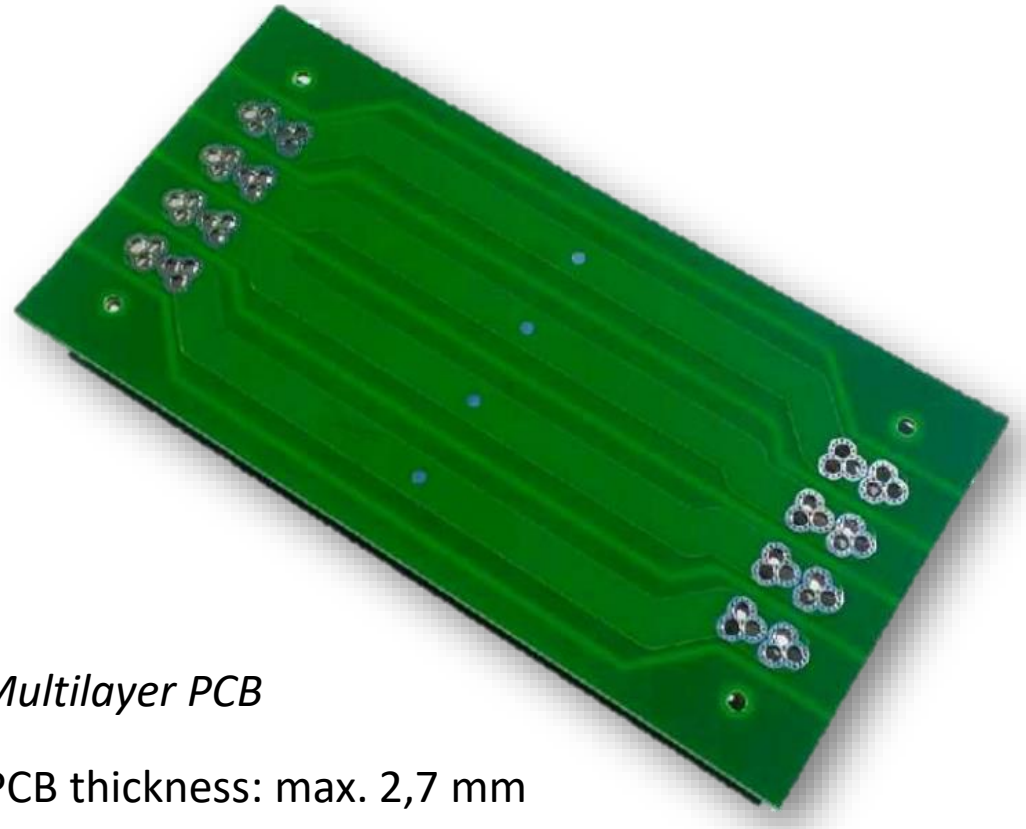
- Lot of (mechanical) materials
- Big assembly effort,
- Time consuming

Can we design this more efficient?



PCB technology for up to 1000A

Practical ‘live’ example: Frequency drive



Multilayer PCB

PCB thickness: max. 2,7 mm

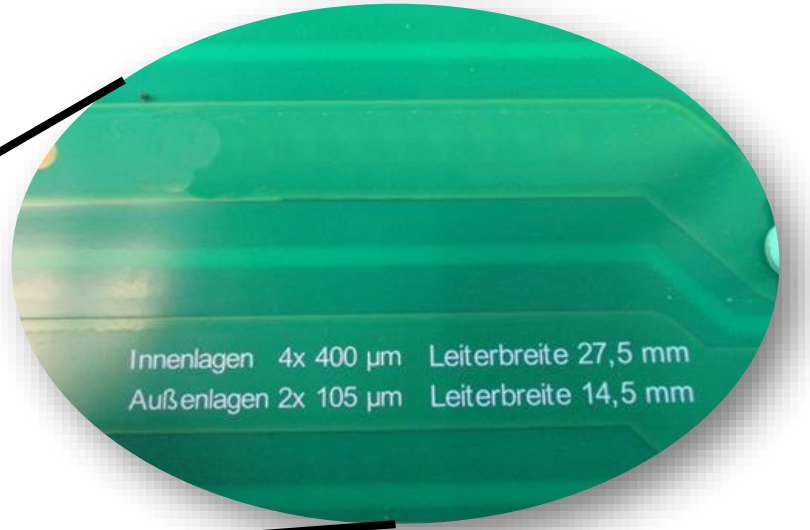
+

MKDSP 95

PCB technology for up to 1000A

Practical ‘live’ example: Frequency drive

PCB Layout for 232 A permanent (example PCB)			
	Number of layers	**Layer thickness**	**Track Width**
Outer layer	2x	105 µm	14,5 mm
Inner Layer	4x	400 µm	27,5mm



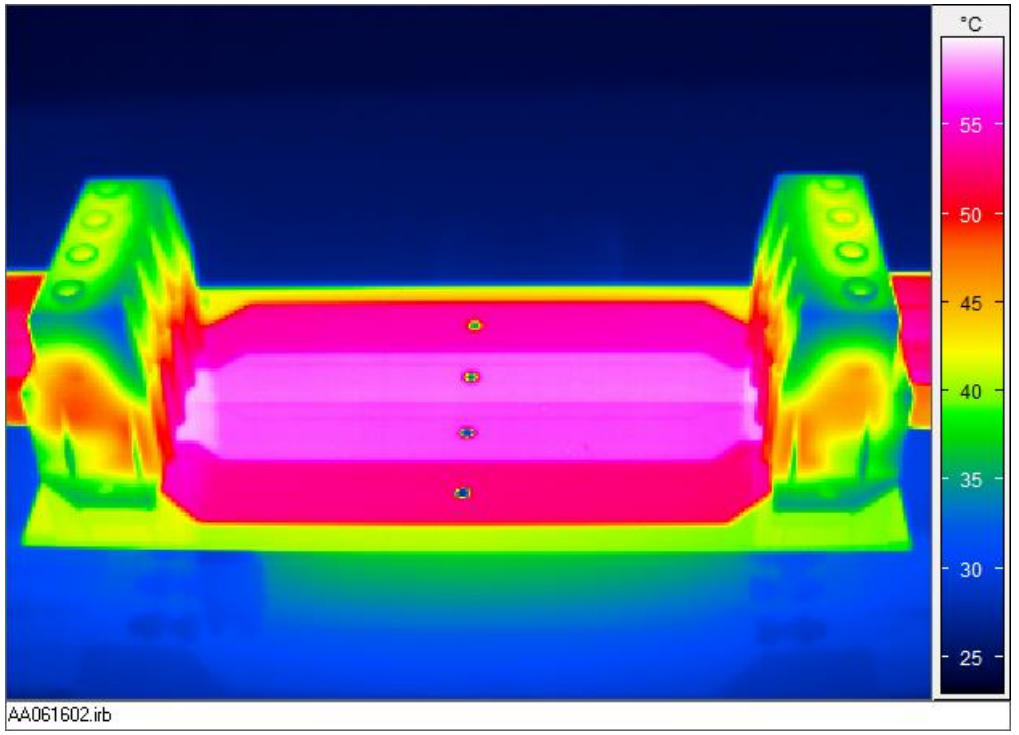
PCB technology for up to 1000A

Practical ‘live’ example: Frequency drive

- Results with permanent test current **232 A**

Temperature rise			
Test Current	***150 A***	***180 A***	***232A****
dT_{max} [K]	*18 K*	*24 K*	*38 K*

- Most applications don´t require 232A permanently
- Big conductor size for devices is often requested
- Maximum conductor size for the MKDSP 95 is 95 mm² (with ferrule!)

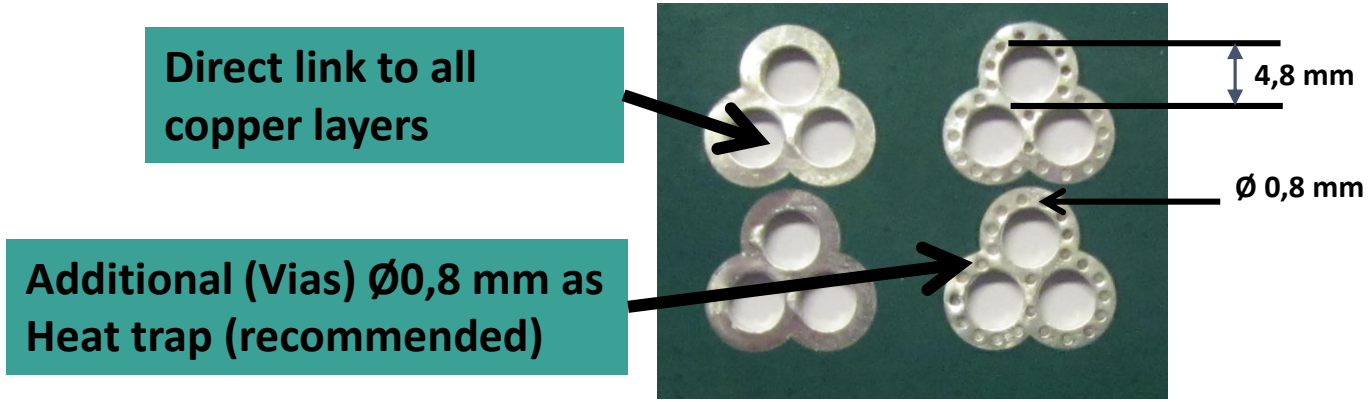


**The measured temperature of the PCB is 60°C, the ambient Temperature was 22°C. This results a temperature rise of 38 K.*

PCB technology for up to 1000A

Practical ‘live’ example: Frequency drive

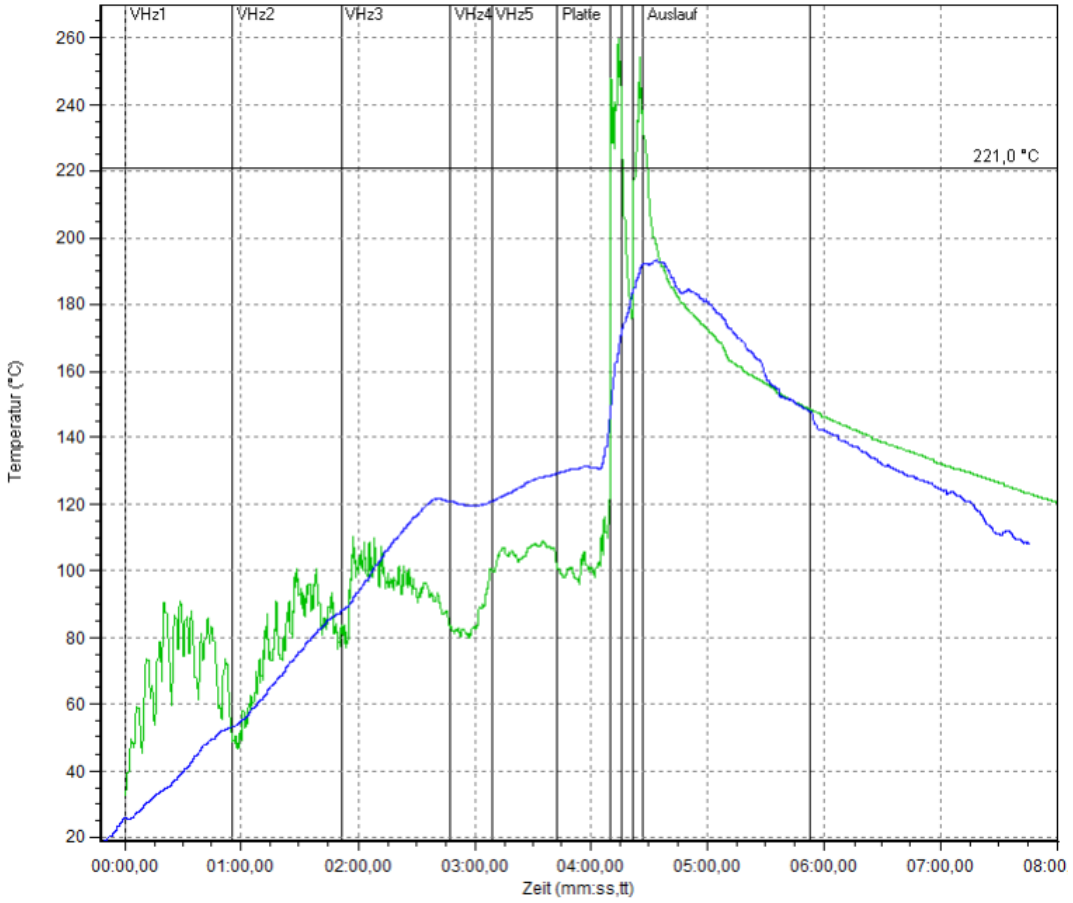
- Soldering pads surround pins 360 deg. (in contrast to square press in pins)
- Vias (drilled holes) are recommended due to a better thermal behaviour,
- Note: They reduce cooling down of the component / the soldering pins.



Note: The PCB layout has to be defined in dependence to the application.

PCB technology for up to 1000A

Practical ‘live’ example: Frequency drive



Real example for a soldering process with Ersa Powerflow

PCB top side Temp.: ———

Wave Temp. : ———

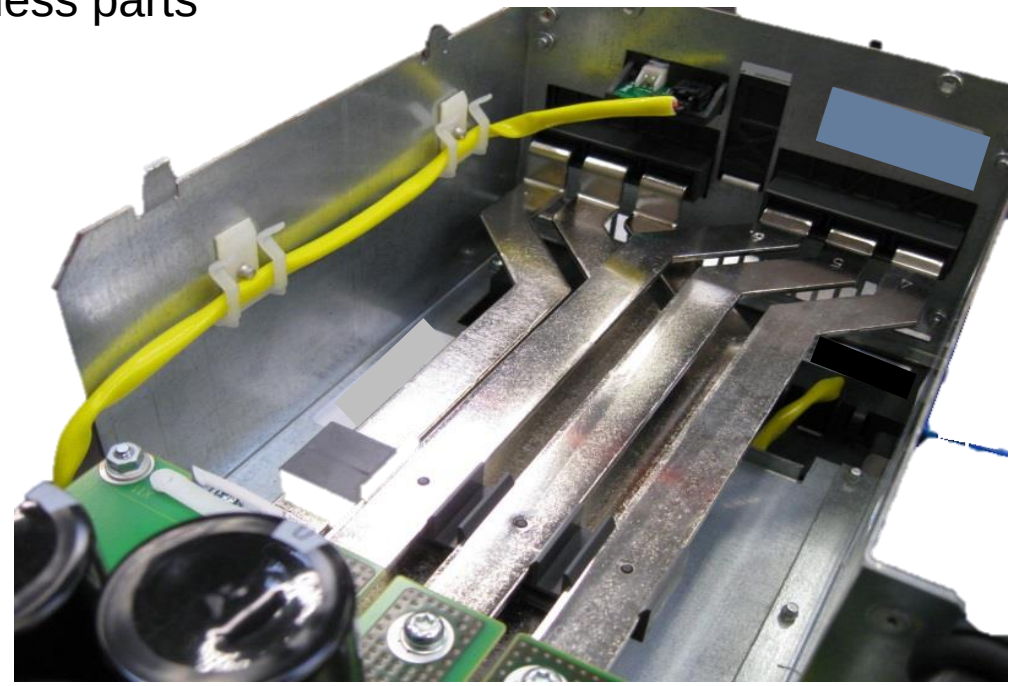
Note: The diagram is only an example, it works also with shorter preheating.

PCB technology for up to 1000A

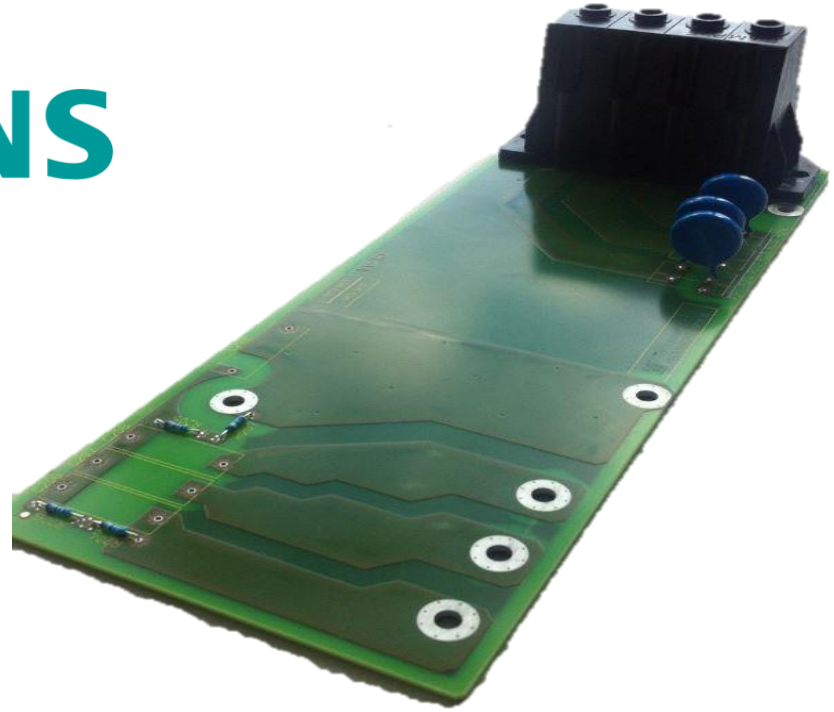
Practical ‘live’ example: Frequency drive

- ☑ Alternative for copper bars
- ☑ 35% cost reduction possible
- ☑ 80% less parts

SIEMENS



Previous design



Actual design with **MKDSP 95**

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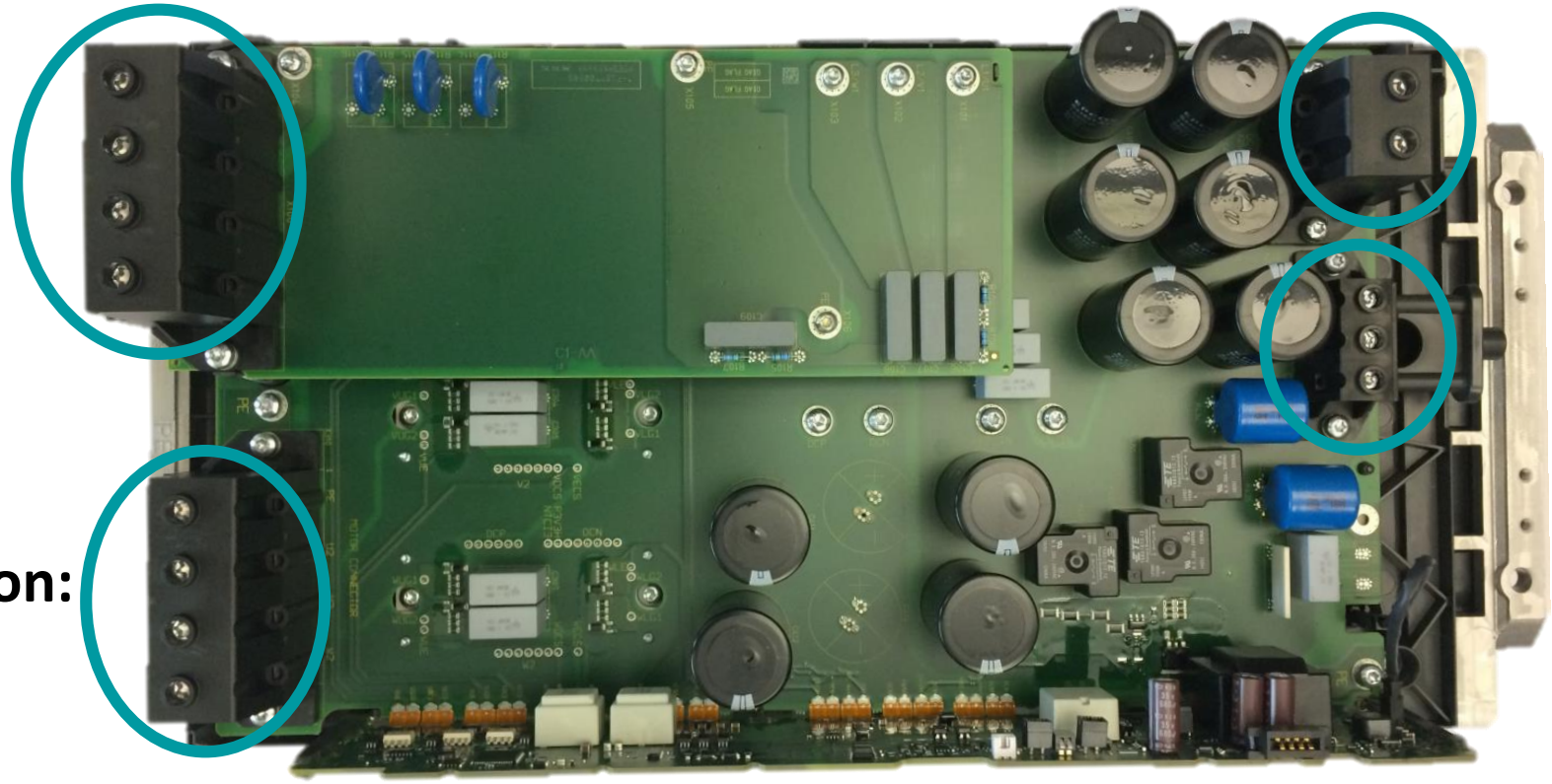
PCB technology for up to 1000A

Practical ‘live’ example: Frequency drive

Line:
MKDSP95 / 4-20



DC Bus:
MKDSP 95 / 2 - 20

Braking Resistor:
MKDSP 25 / 3 - 15

Motor Connection:
MKDSP95 / 4-20

SIEMENS **Type: PM 240 – 2 „FSE“**

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PCB technology for up to 1000A

PCB terminals up to 232A

- Classic‘ wave solderable PCB terminals up to 232A
- 232 A through the PCB → For sure no Problem!

MKDS 5N

- 41 A
- 1000 V (IEC)
- 4 mm²

MKDSP 10

- 76 A
- 1000 V (IEC)
- 16 mm²

MKDSP 25

- 125 A
- 1000 V (IEC)
- 35 mm²

MKDSP 50

- 150 A
- 1000 V (IEC)
- 50 mm²

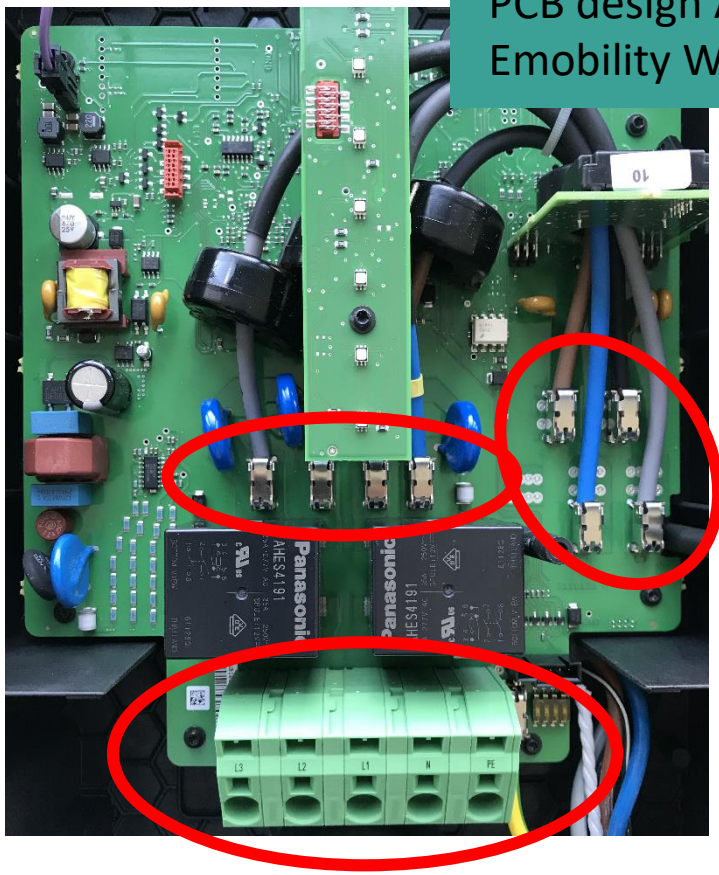
MKDSP 95

- 232 A
- 1000 V (IEC)
- 95 mm²

PCB technology for up to 1000A

Practical ‘live’ example: E-mobility AC/DC charging

PCB design AC
Emobility Wall charger



22kW /32A / 400VAC

High Power Charger
liquid cooled upto 500kW

Questions?

1. **General on connection technology/ shown applications :**
   Please see us and the applications at our tabletop (#26)
2. **Support for specific challenge:**
   Feel free to contact me to connect your with one of our partners
3. **Deeper knowledge about this topic**
   Feel free to contact me for a advanced web/seminar on this topics