Power Electronic Module Packaging for Commercial, Construction and Agricultural Vehicle (CAV) Traction Drives

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Never stop thinking

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Introduction

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Two challenges - Smaller size and lower cost

Technical issue - How to manage temperature cost effectively

For power electronics:

- Reduce losses at source
- Packaging for high frequency switching
- Shrinking silicon size
- Alternative topologies
- Cooling system
- Module options

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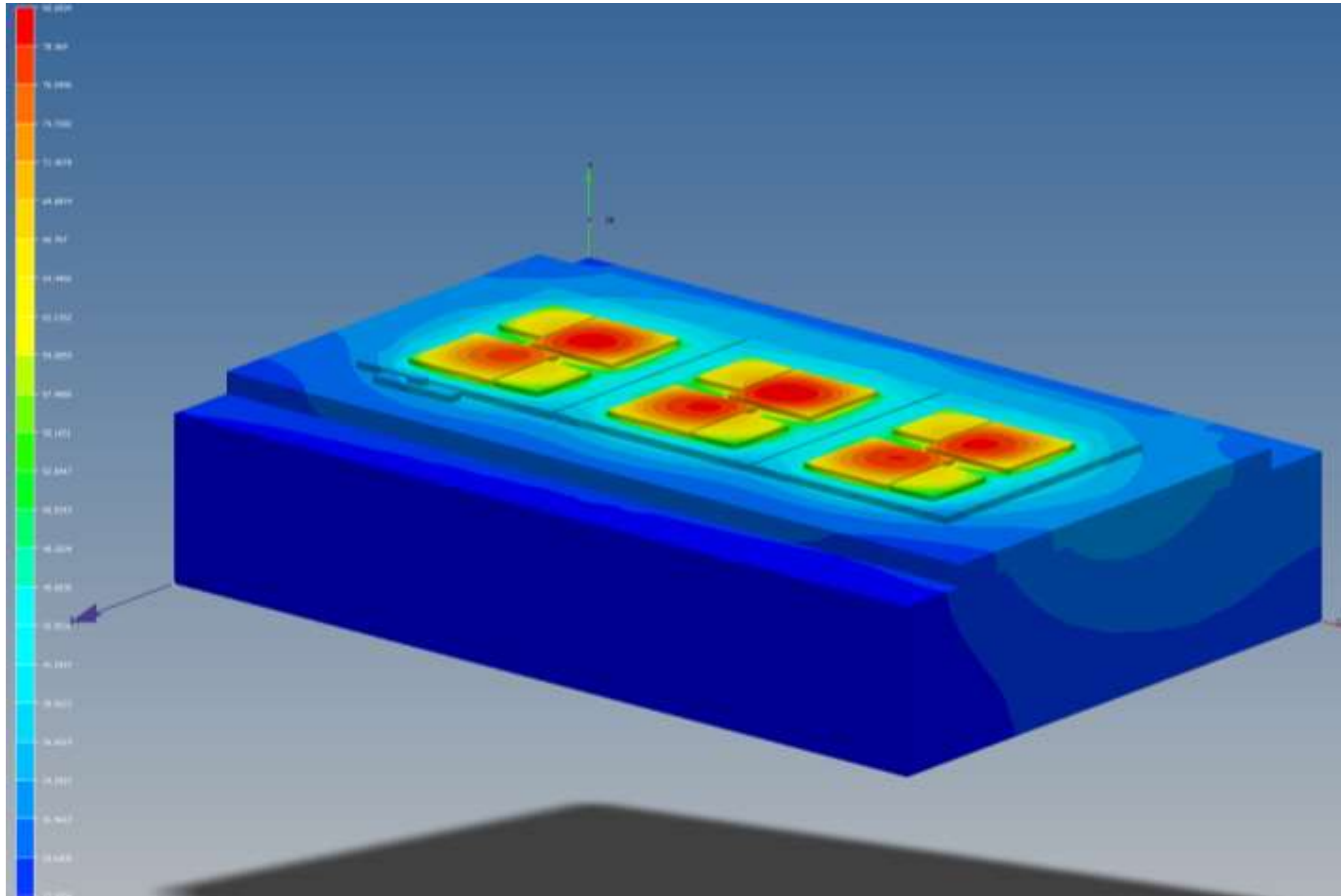
Power Losses.

Approximately 90% of the power loss is in power silicon



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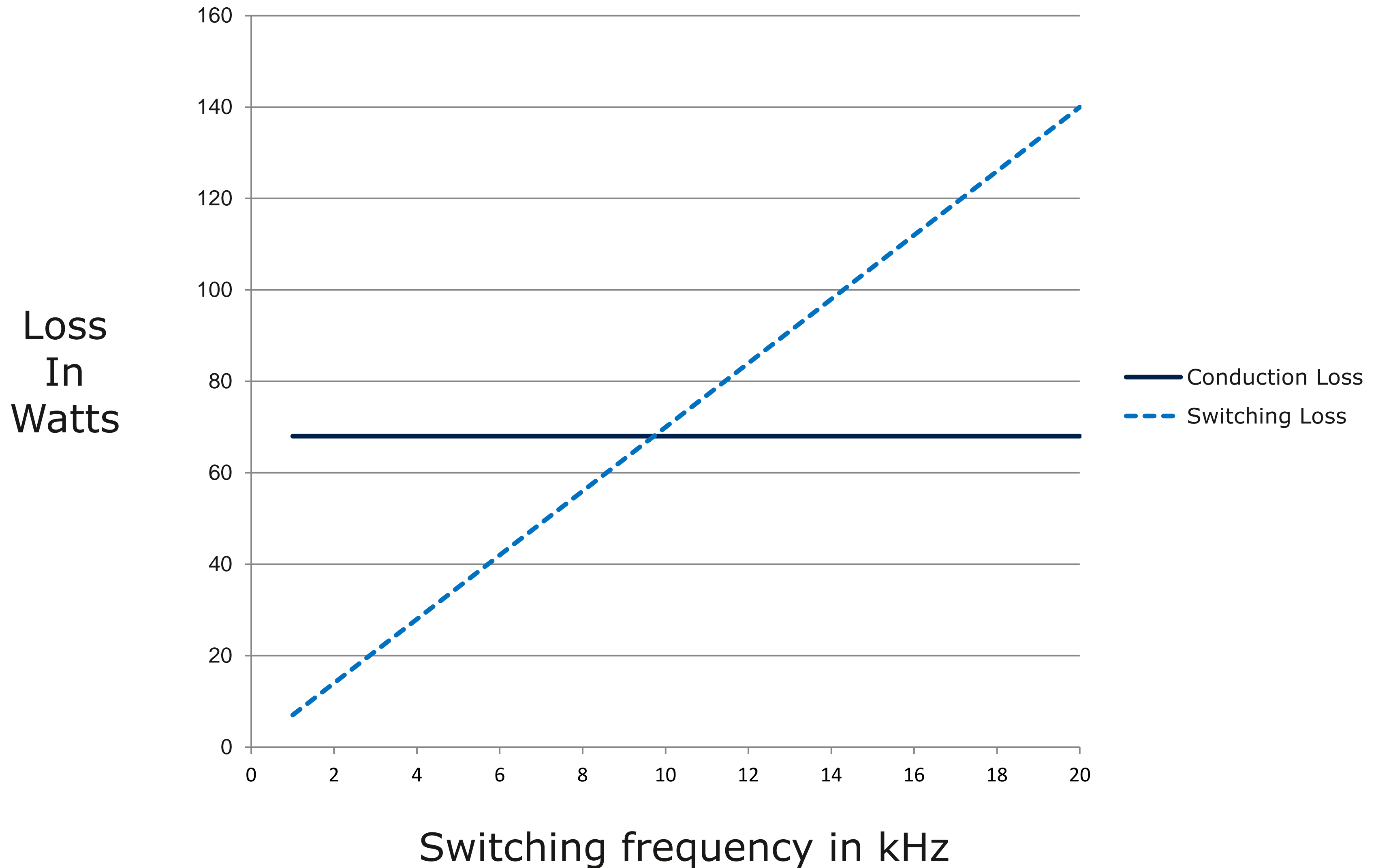
Static and dynamic losses



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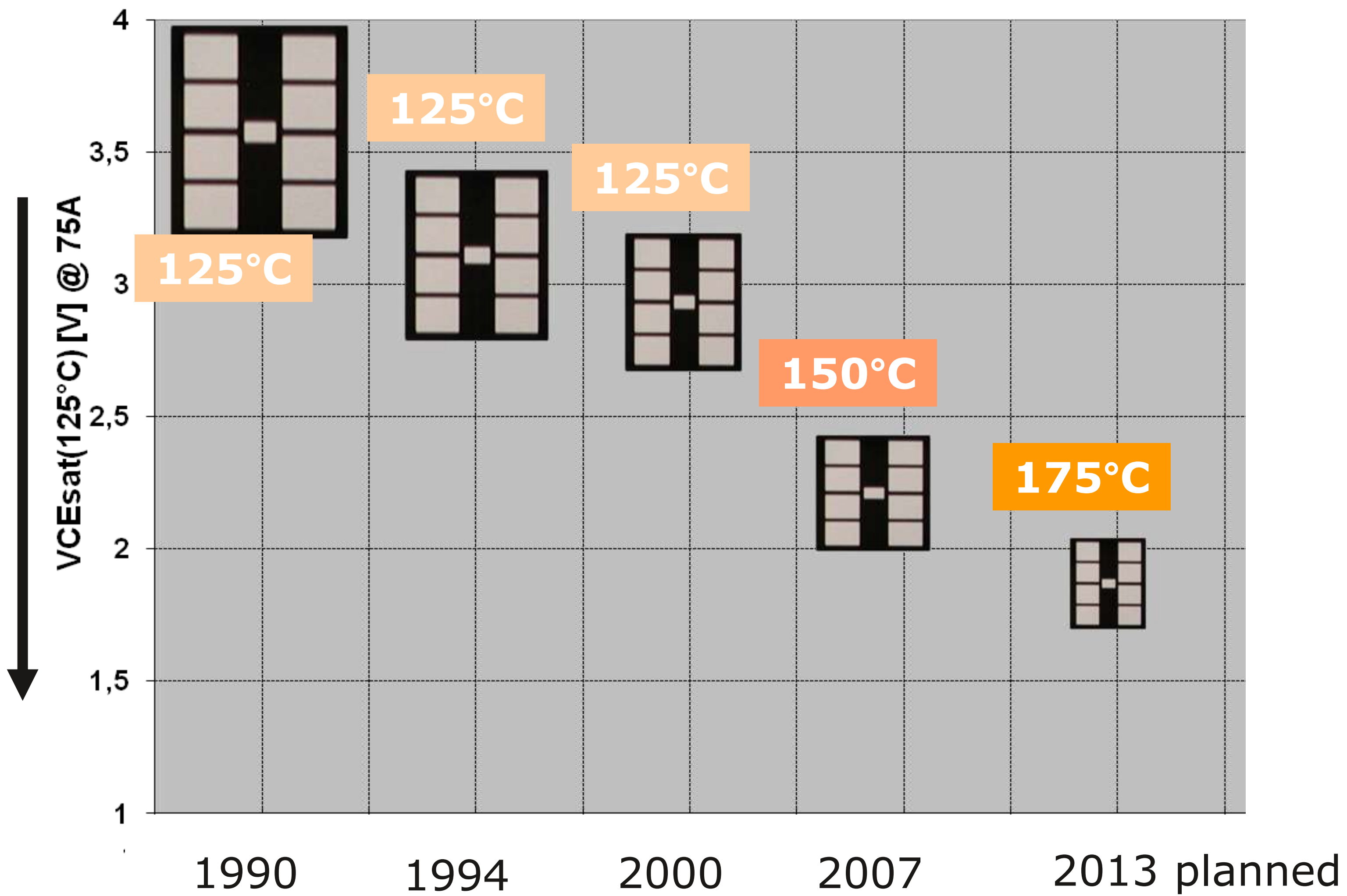
Improvements in Vcesat levels for reduced conduction losses

It is getting more difficult to get significant gains in Vce sat voltage.



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Opportunities for reduction in switching losses

- Optimize silicon for application
- Use of SiC
- Improved module packaging
- Negative effects of high frequency switching

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Different loss distribution for different silicon types

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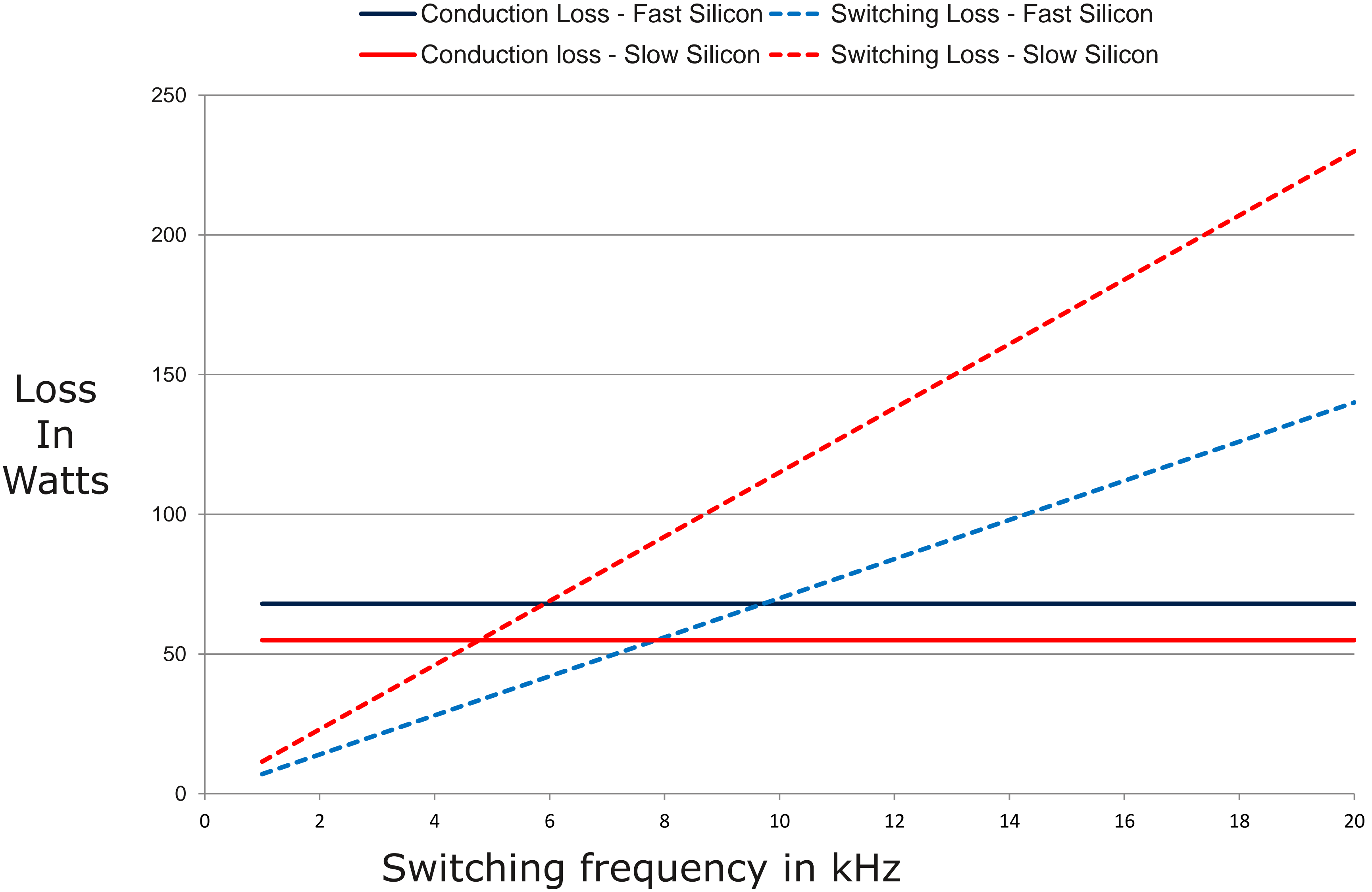

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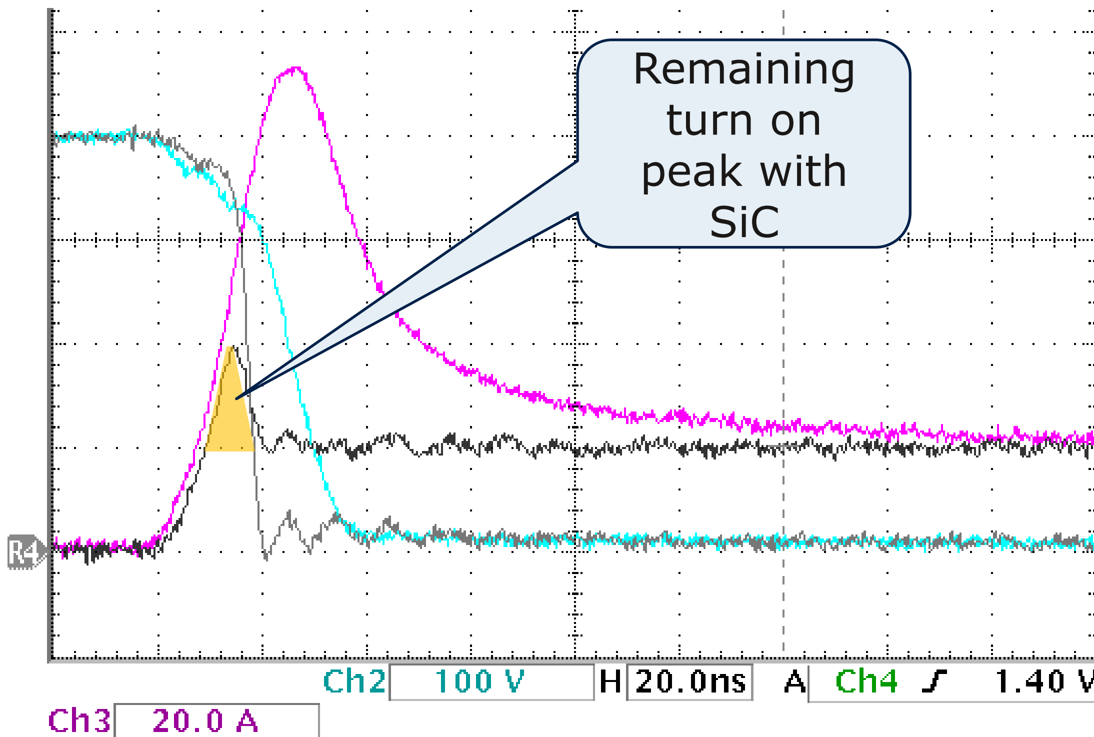
600V Si-IGBT Inductive Switching: Turn-On @ T_J = 175 °C



Losses at 20A 400V

Fast Silicon Diode

E_{onIGBT} 450 µJ

$E_{offDiode}$ 75 µJ

SiC Diode

E_{onIGBT} 125 µJ

$E_{offDiode}$ 5µJ

The reduction in turn on reverse recovery current not only reduces switching losses but can reduce turn on EMI.

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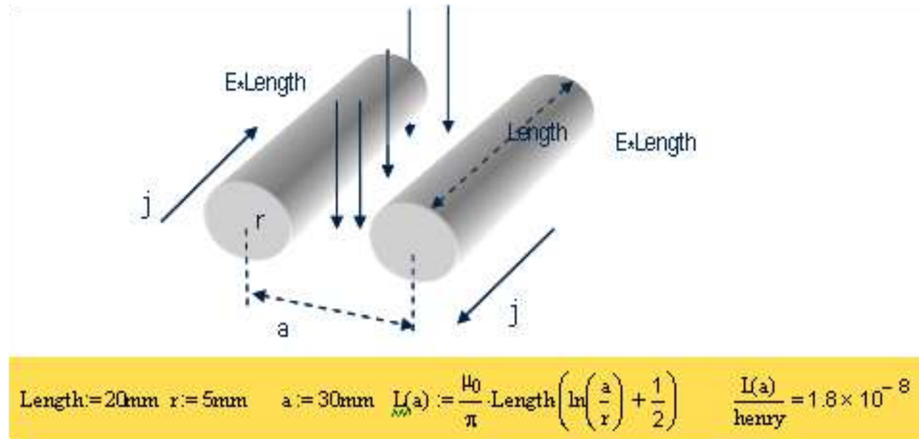
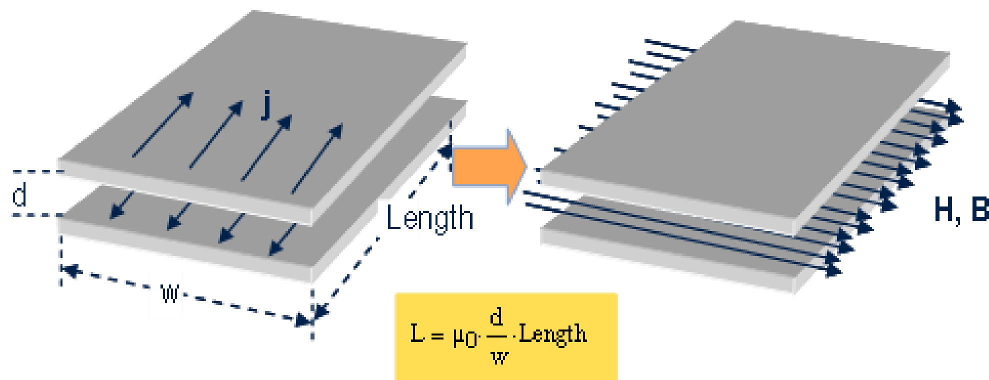
Inductance Plates vs. parallel wires

Inductance does not mix well with high di/dt levels in silicon.

How to reduce system inductance?





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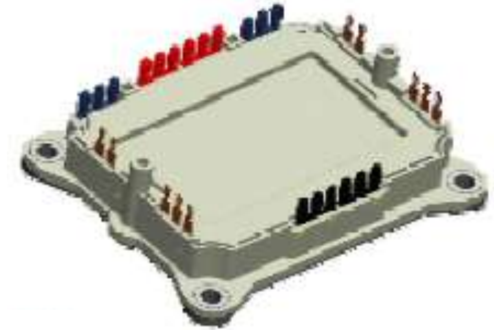
Strip line design module inductance reduction



Prototype module

Current density

Reduction of inductance by 75% is possible

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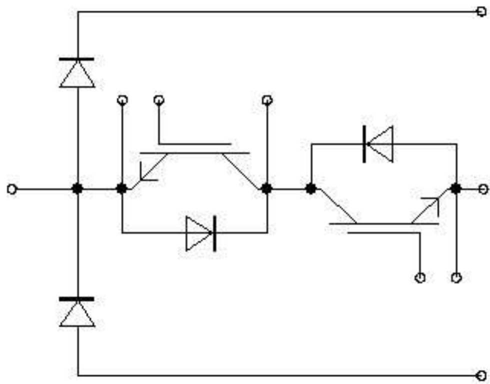
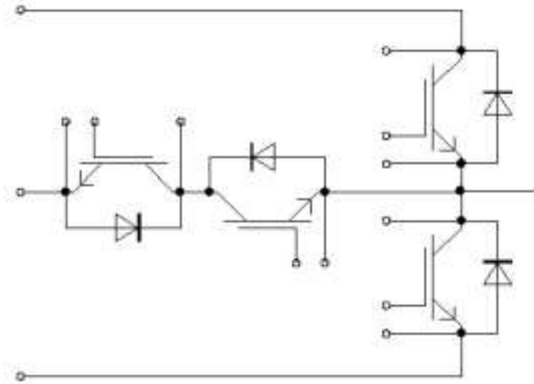
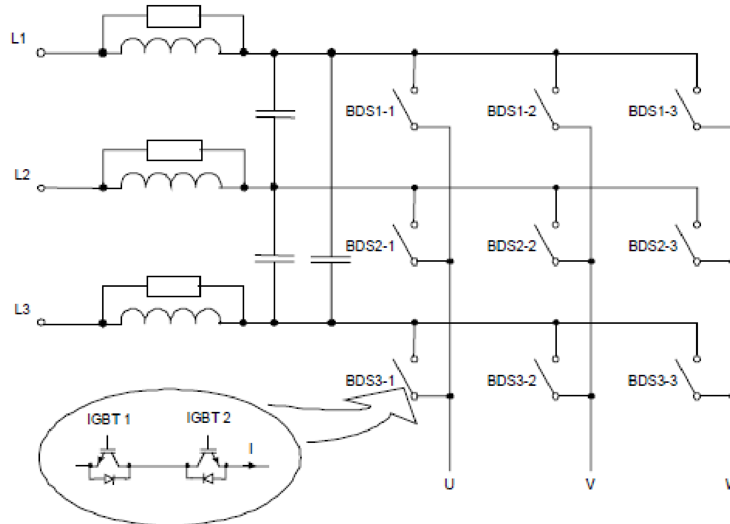
Alternate topologies. Three level NPC2 or Matrix

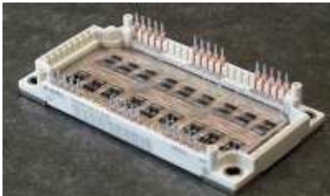
Active rectifier

Output phase









Matrix topology for AC to AC conversion.

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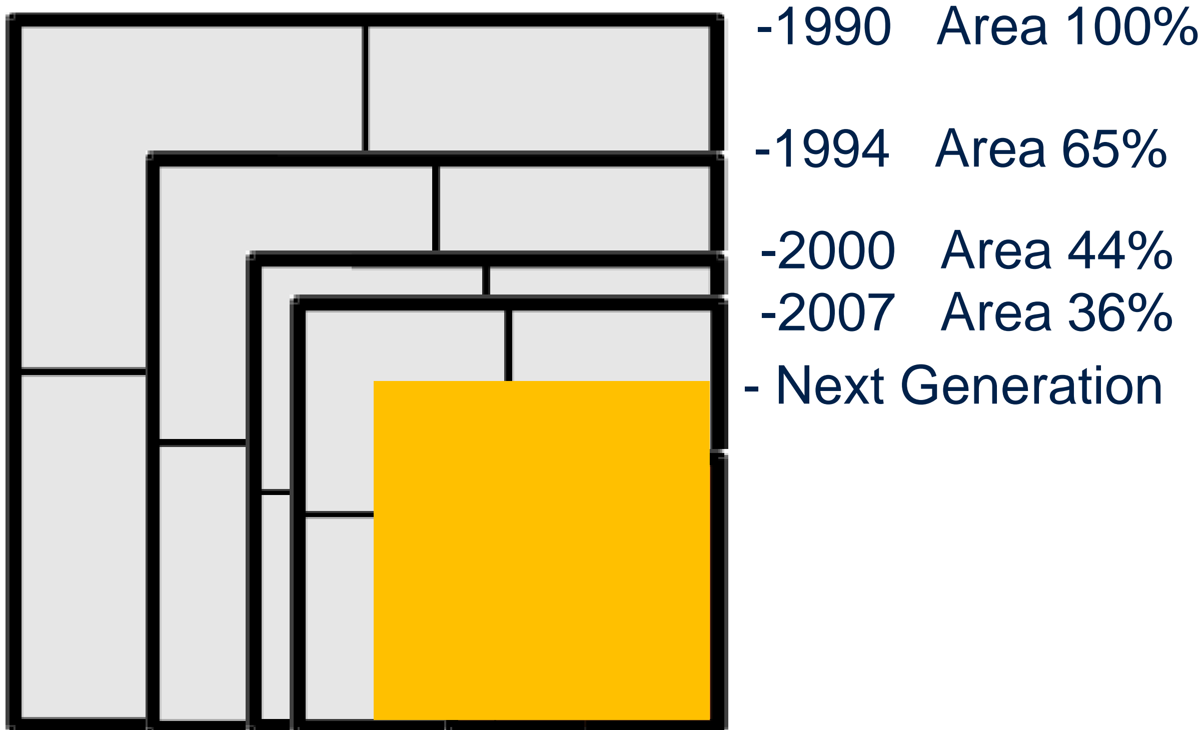
Why the drive to make chips smaller

Smaller chips and larger wafers = reduced cost + increased power density.



Consequences?

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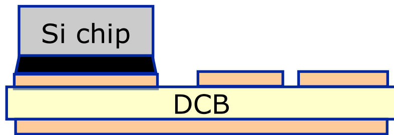
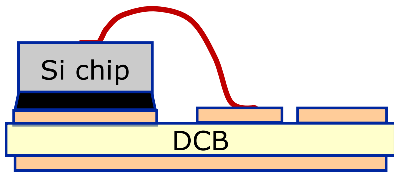
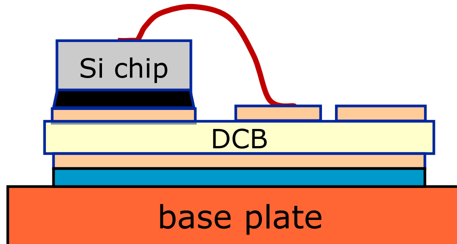
New technology for high temperature packaging

	Standard Technology	New Technology
Chip to substrate	Soft soldering with SnAg paste	Diffusion soldering
Chip top side	Al wedge bonding	Cu wedge bonding
Substrate to baseplate	Soft soldering with SnAg pre form	High reliability system soldering







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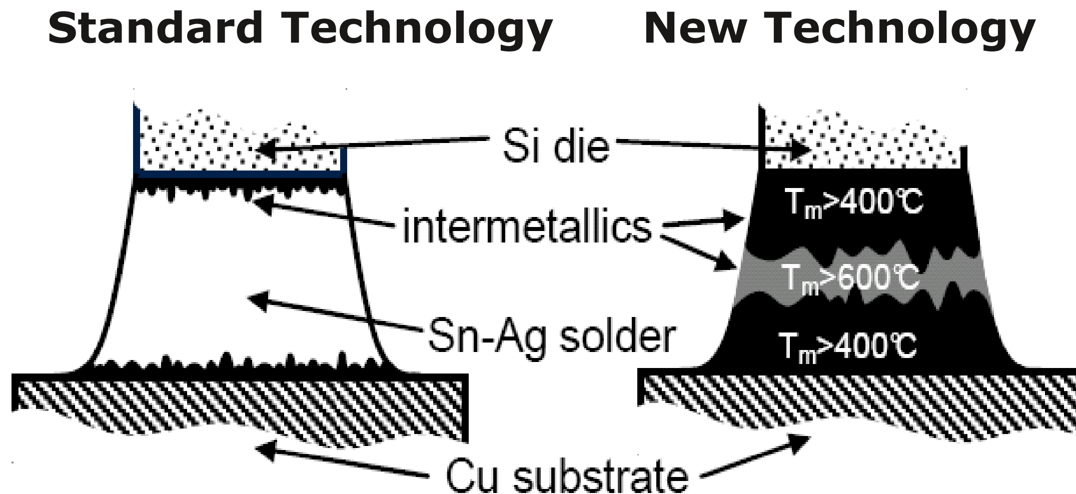
Diffusion soldering

- Very thin, Sn based solder
- T_{melt} > 400°C
- Comparable to discrete component assembly
- Fast process, highly integrated, high volume compatible

Standard Technology **New Technology**



Schematic comparison of a standard solder joint (left) and a diffusion soldered joint (right).

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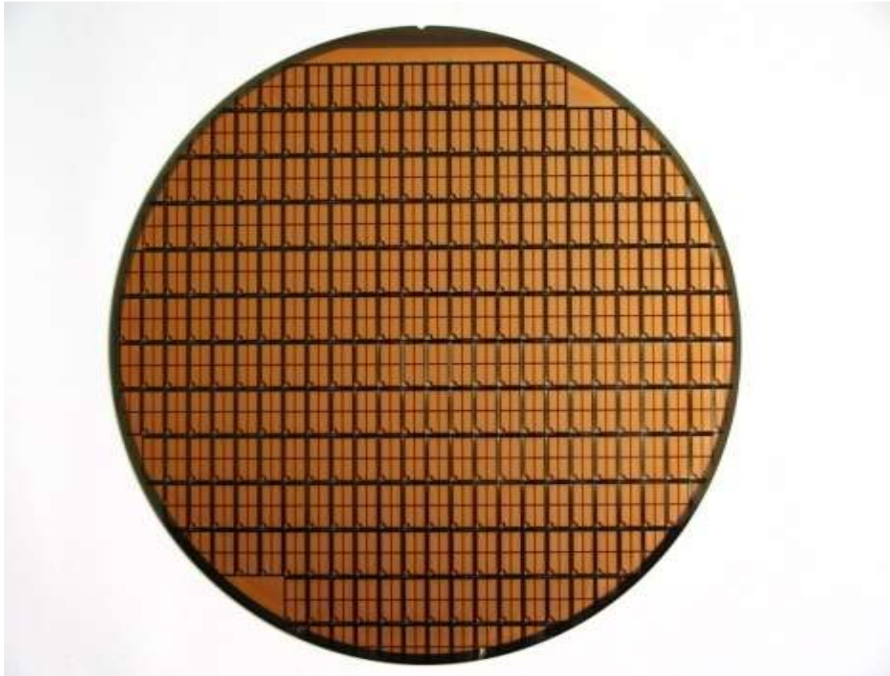
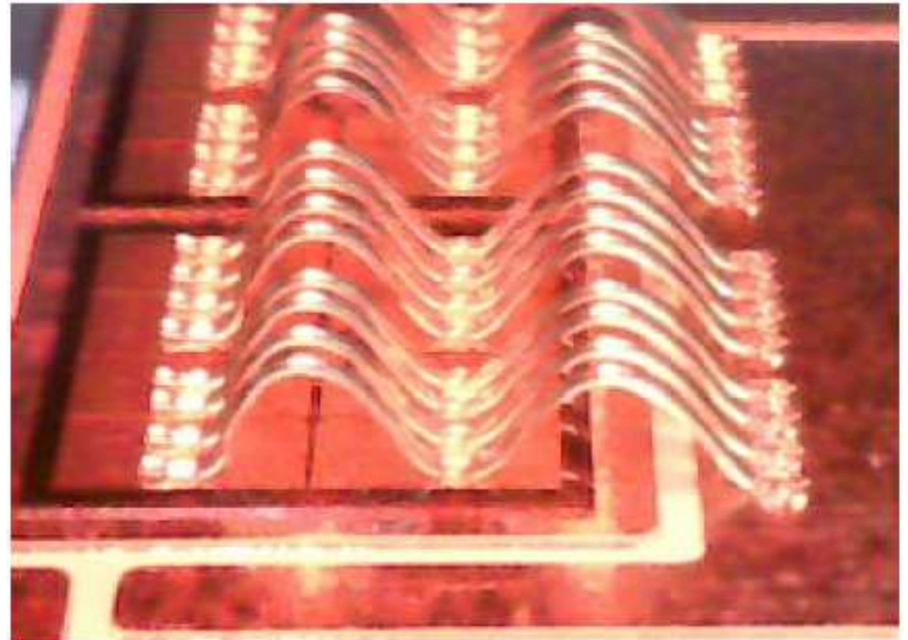
The future of bond wiring – Copper

Top side metallization of chips allows for copper bonding





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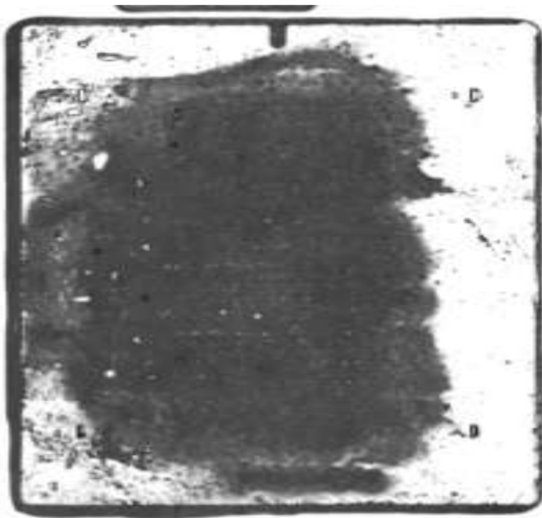
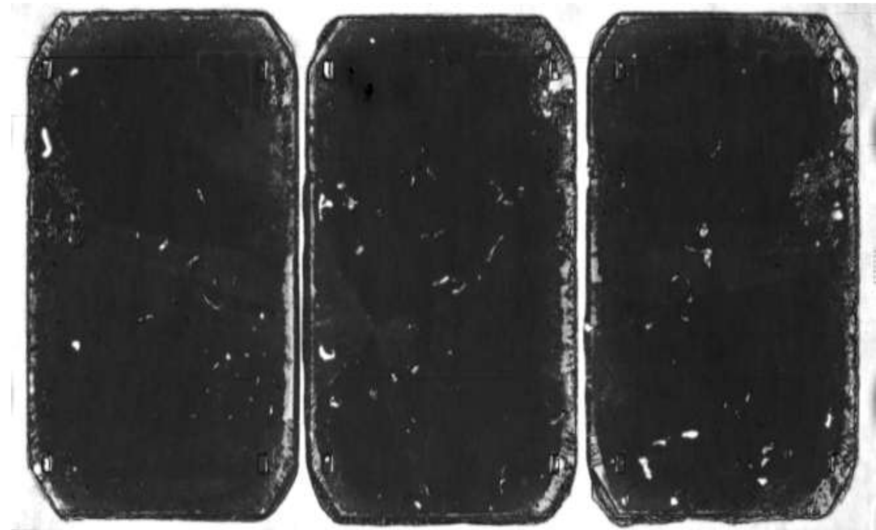
High reliability system soldering

- Base plate modules have thermal advantages for thermal management in vehicle drives
- Improvements in soldering process and alloys



Existing solder after 400 TST



Improved solder after 2000 TST

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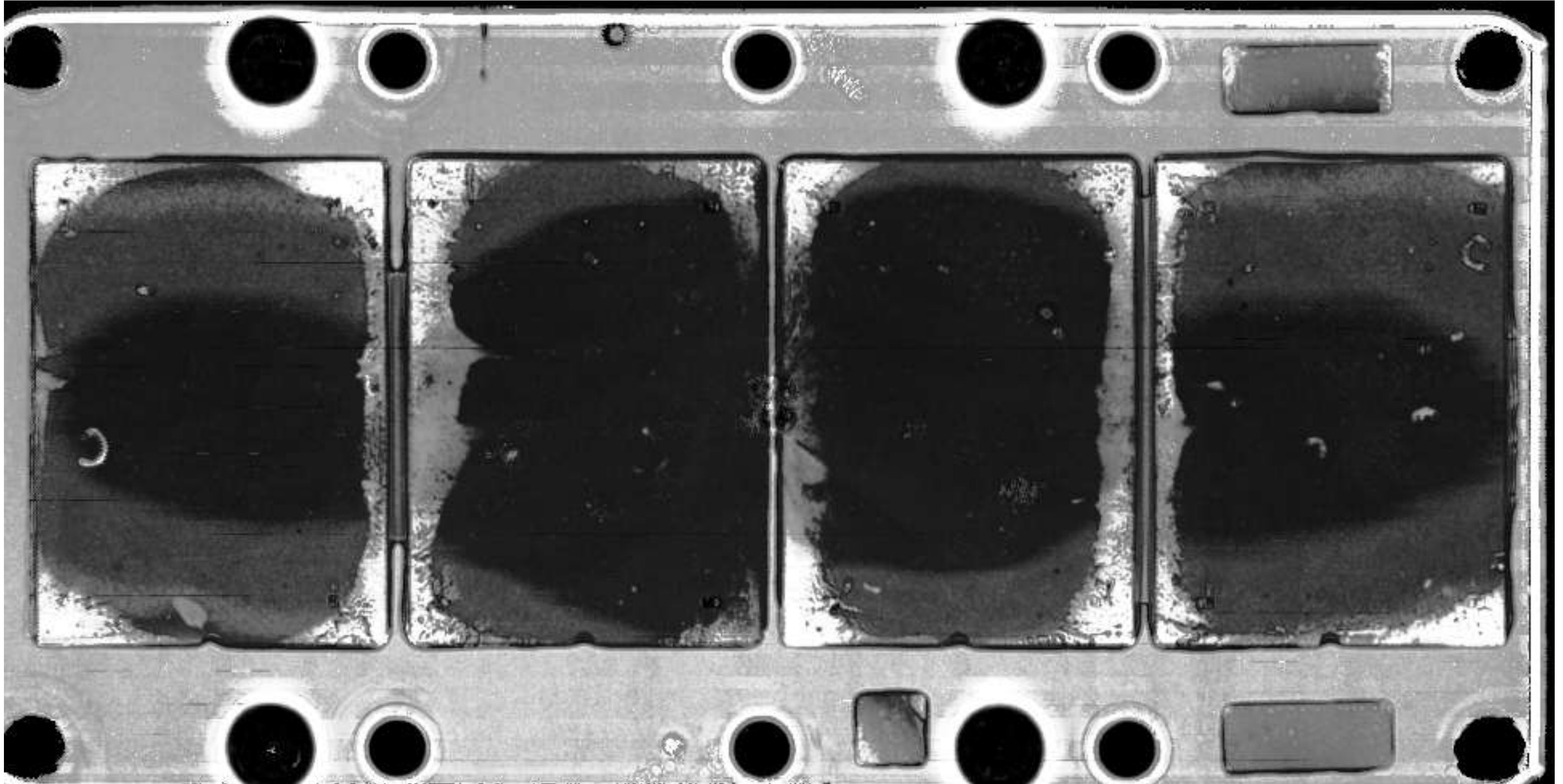
Delamination image of solder layer



DCB to baseplate solder layer at end of design life thermal cycles

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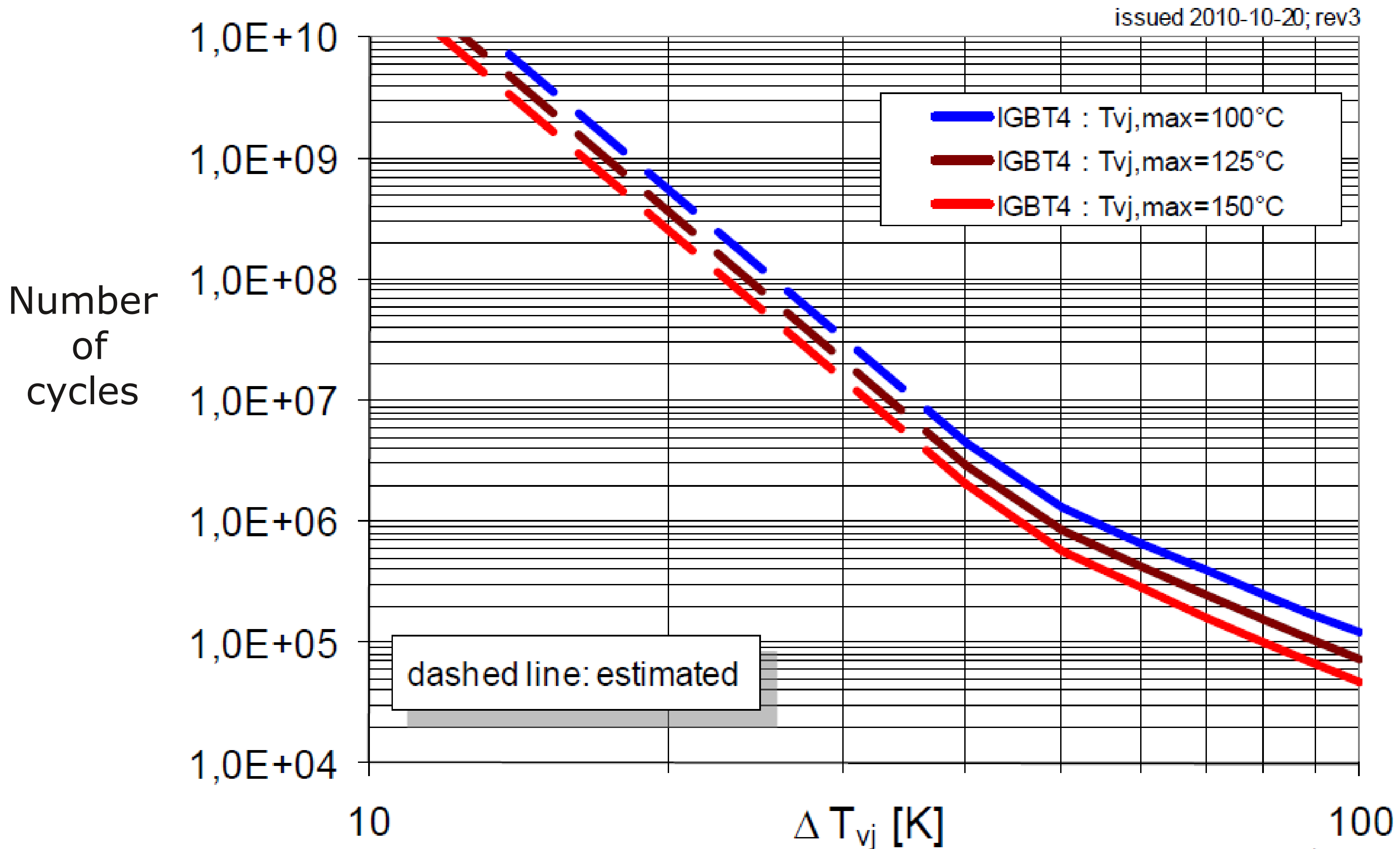
Power cycling life data curves

How are these generated and what are their limitations?



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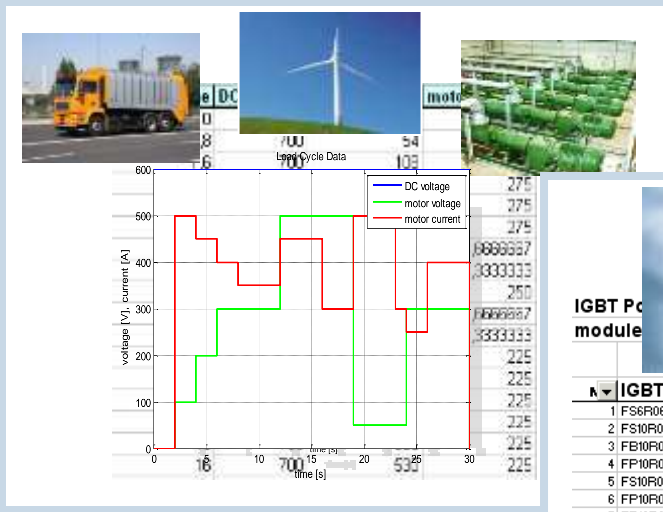
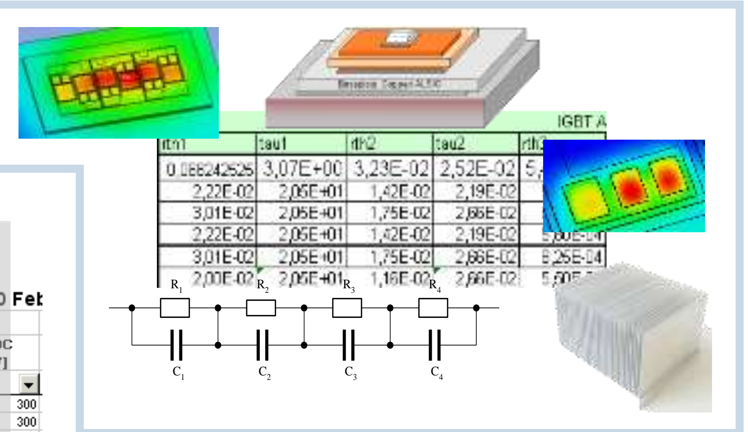
From mission profile to design life

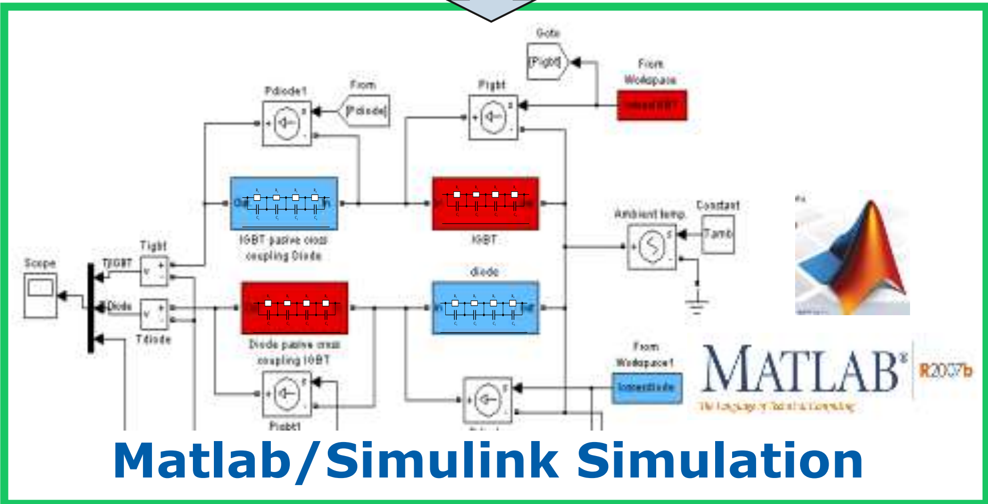


Module Electrical model

Thermal model: module + cooling system



Mission profile



Matlab/Simulink Simulation

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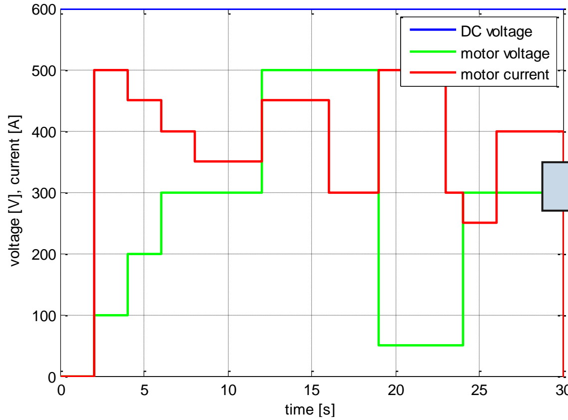
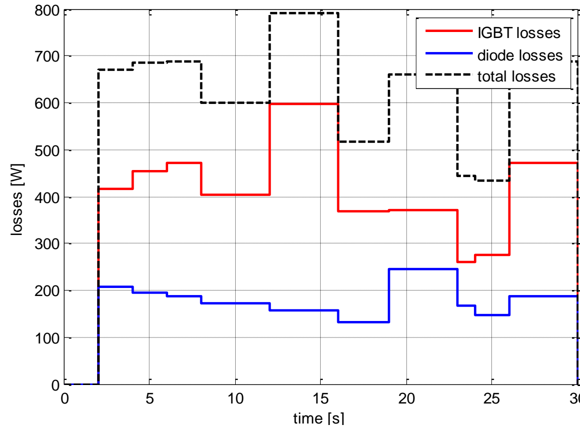
From mission profile to design life

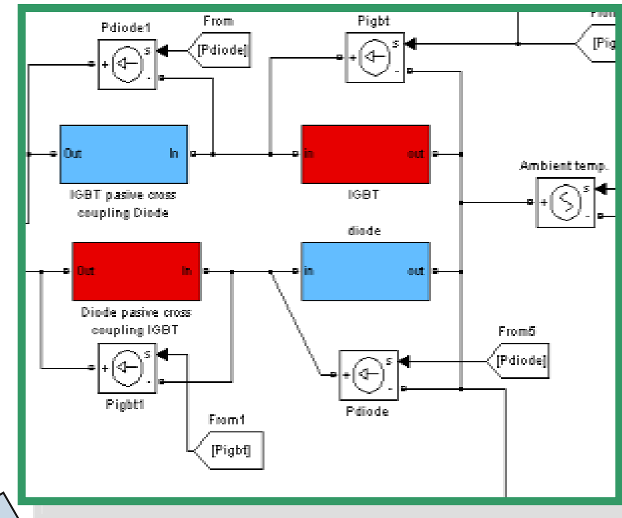
Mission profile

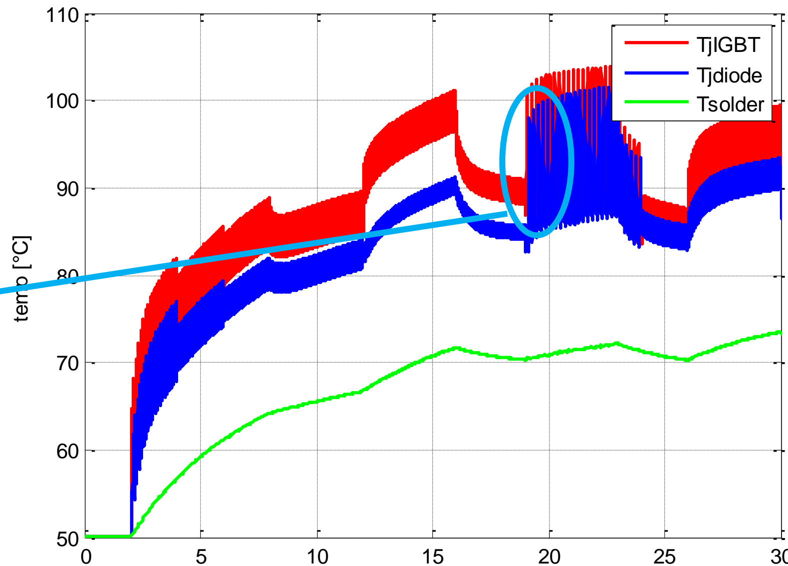


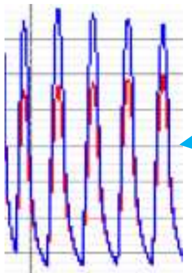
Losses



Simulation







Temperatures in detail

IGBT, Diode and Solder layer temperature profile

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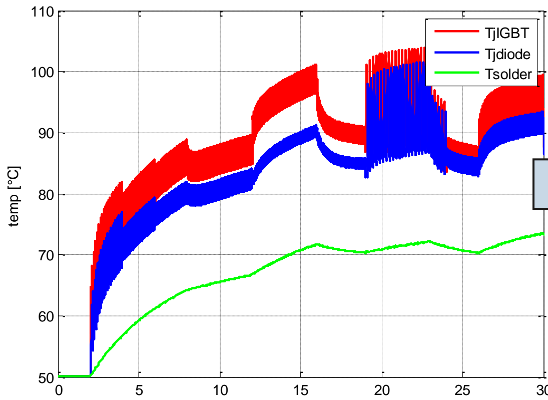
From mission profile to design life



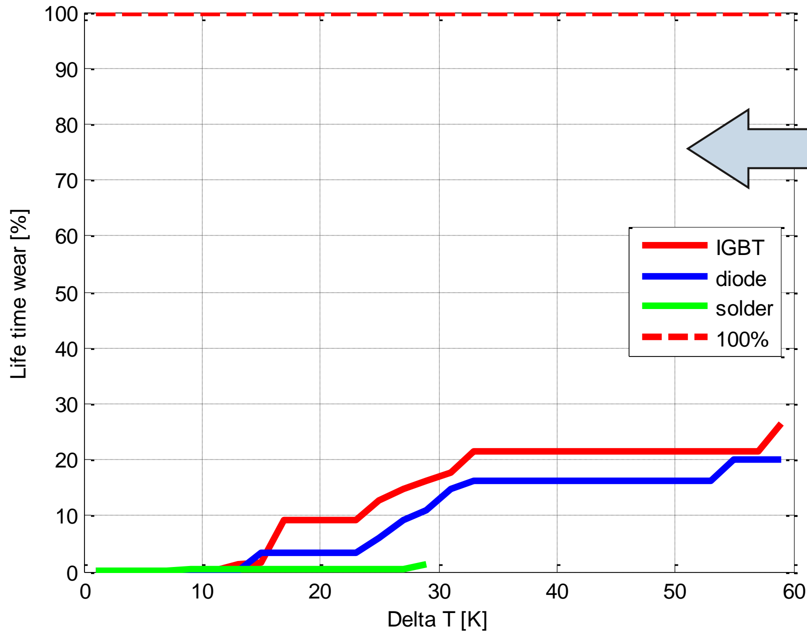
Rainflow

IGBT

Diode

Solder

Design life wear in %



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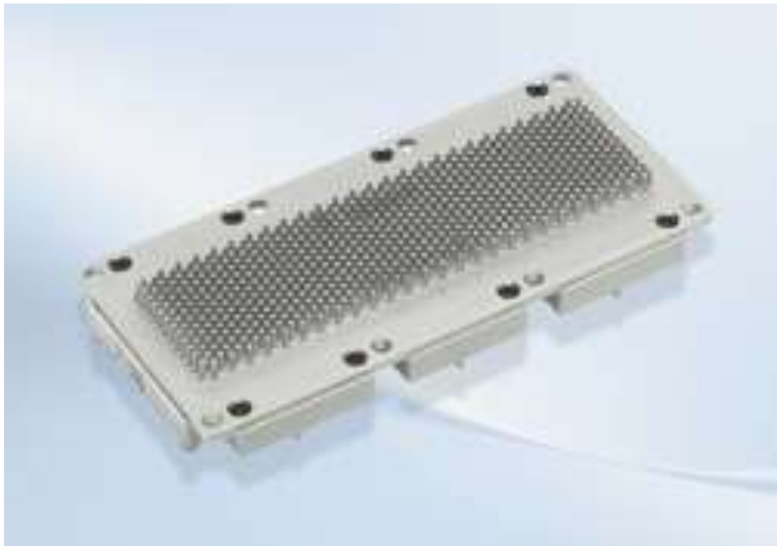
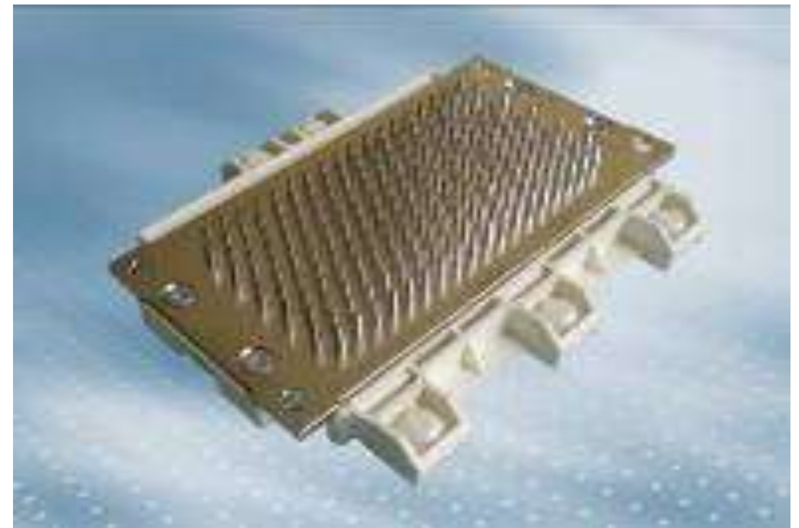
Pin-fin modules for improved cooling

Copper or AlSiC pin fin construction?





HybridPack 1 and 2 modules with direct pin-fin cooled base plate

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Module Selection some options

Non standard products

Design a custom package with optimized pin out, silicon and topology

High volume - Long time to market

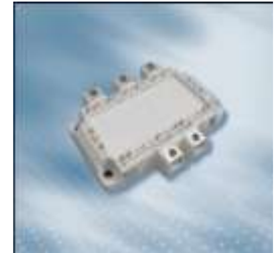
Use an existing package and pin out; but, use specific silicon or topology

Medium volume - Short time to market

Standard products

- AQS 1002 qualified
- 200A – 800A parts available.
- 650V and 1200V.

- Module series qualified for CAV applications - high vibration and temperature cycling capability
- 100A – 1400A parts available
- 650V, 1200V and 1700V



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