Session 4b
Leslie

Power Module Packaging & Integration

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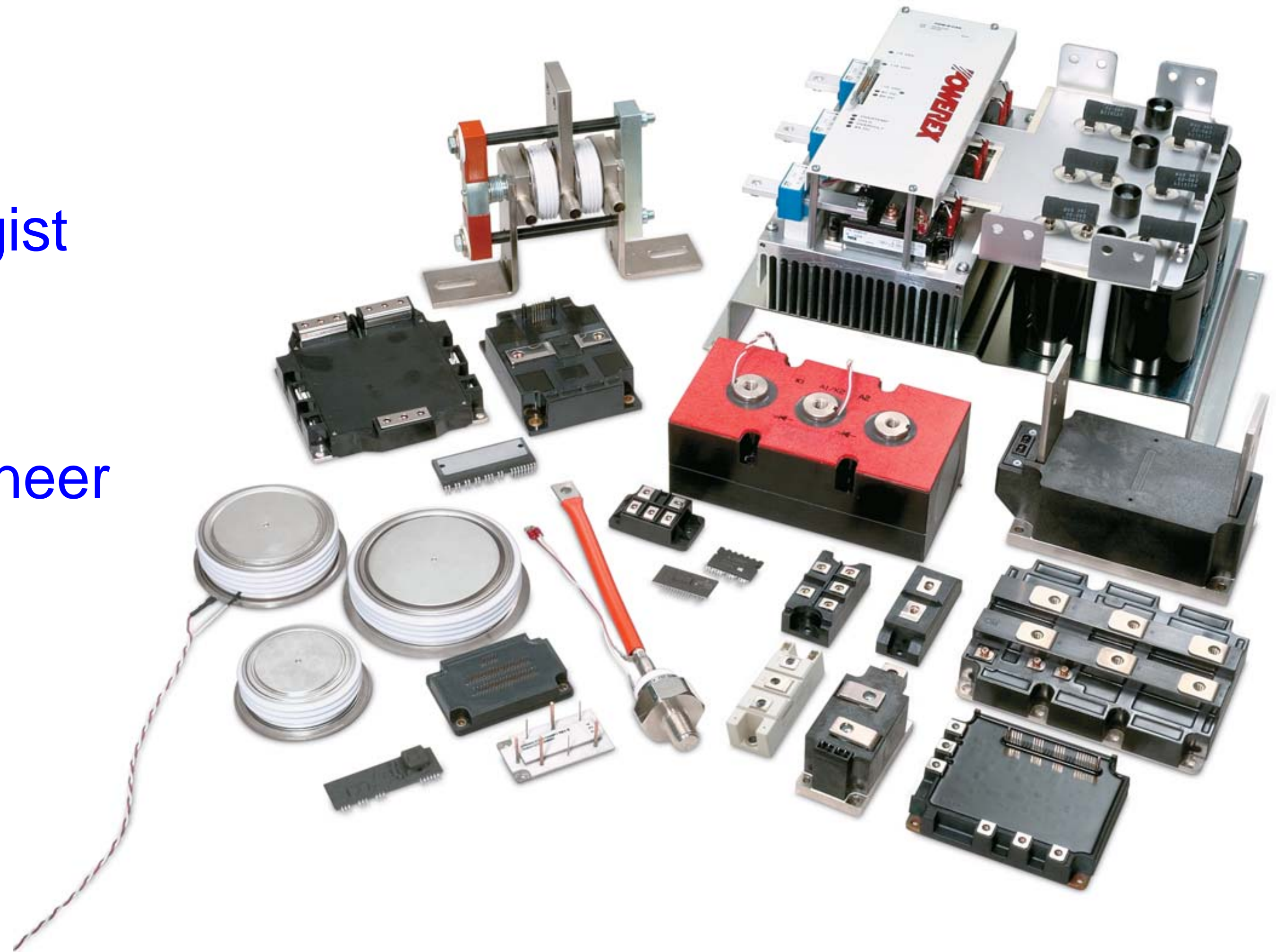
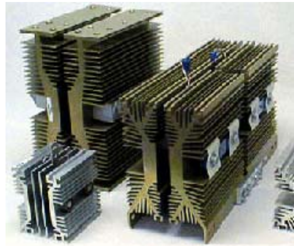


Power Semiconductor Module Integration - Outline

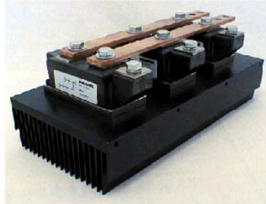
- Trends in IGBT Chip Technology
  - Size, Voltage, Power Losses & Frequency
  - Impact on Packaging
- Intelligent Power Modules
  - Integrating Gate Drive & Protection Features in the Module Package
- System in a Module
  - Further Integration of System Components within a Module Package
- High Voltage Power Modules
- Integrating Chip Cooling in the Module
- Integrated Power Sub-Systems

Power Semiconductor Device Evolution

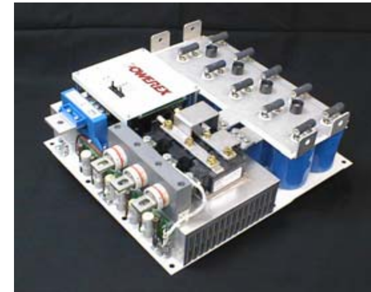
Discrete Assemblies



Module Assemblies



Complete Power System
Standard & Application Specific



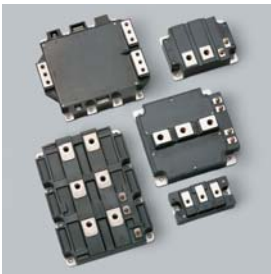
Powerex
Pow-R-Pak

Semikron
Skiip Pak

SCR / Diode / GTO Discretes

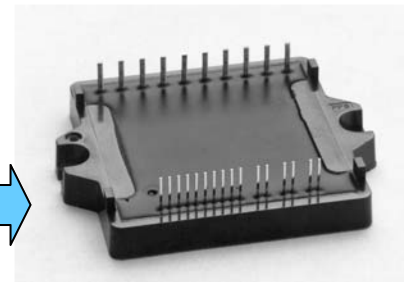
SCR / Diode Modules

BJT / MOSFET Discretes



Darlington Transistor / MOSFET / IGBT Modules

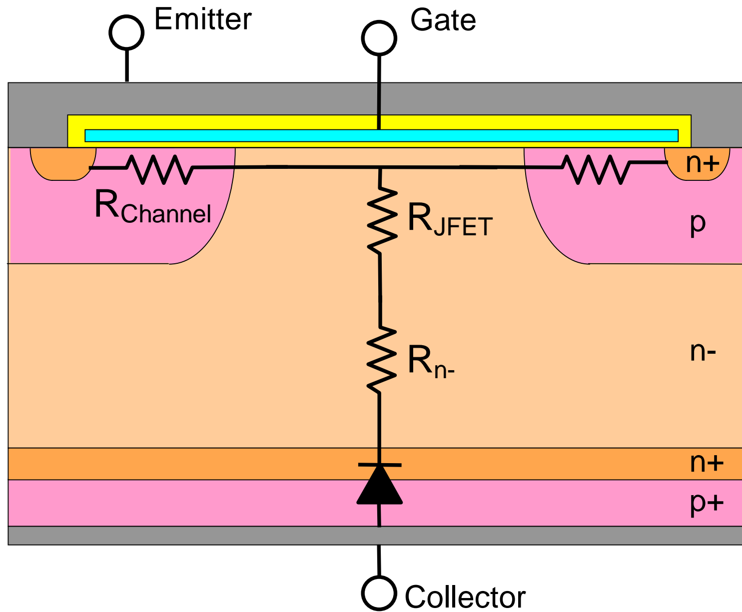
Intelligent IGBT Modules (IPM)



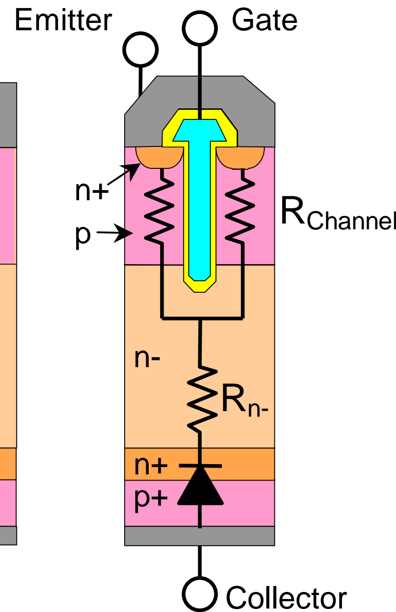
Application Specific IPM

Power Switch → **Electrical Isolation Integrated** → **Gate Drive & Protection Integrated** → **Low Power System in a Module** → **High Power System**

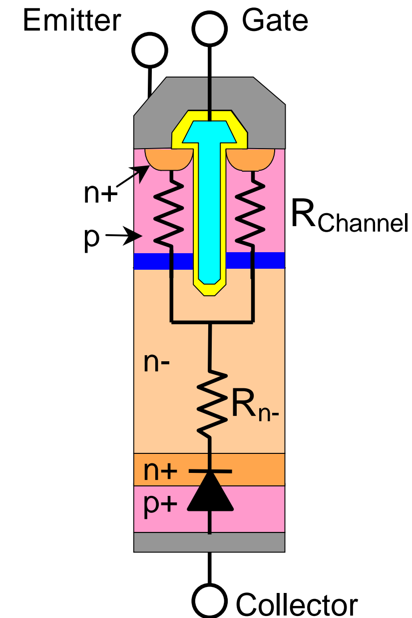
IGBT Chip Design Evolution



Horizontal Gate Channel



Vertical Gate (Trench) Design

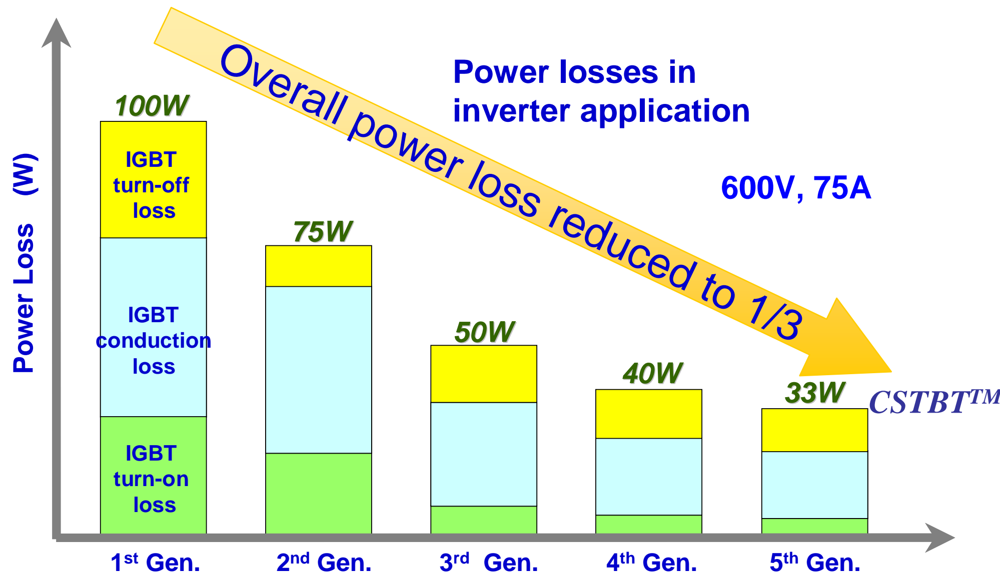


CSTBT Design

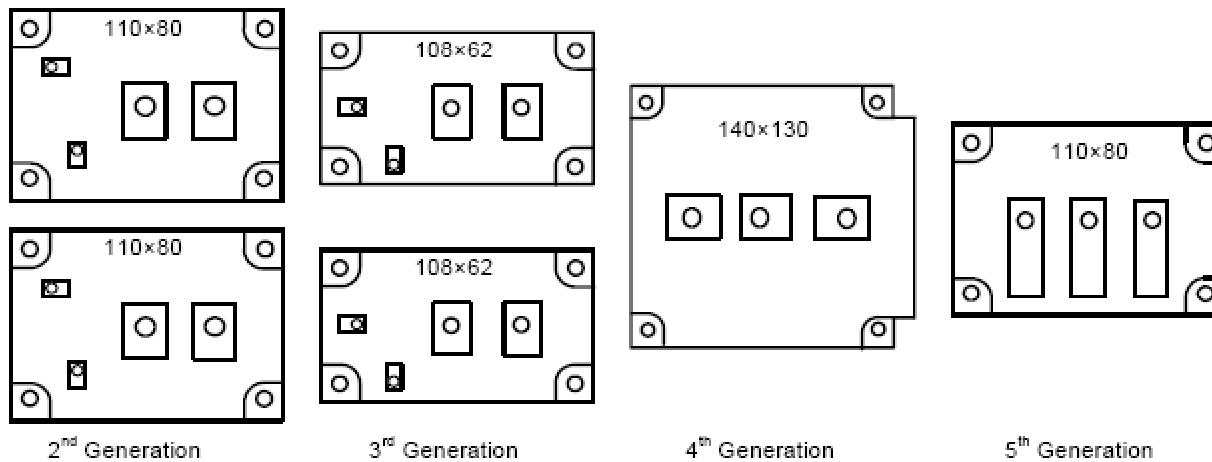
- Vertical channel requires less area compared to the horizontal channel of planar structure
- No R_{JFET} between adjacent cells

- **Greater cell density**
- **More uniform current flow through chip**
- **Robust Turn-Off Switching Capability**
- **Greater cell density**
- **Lower $V_{CE(SAT)}$**

More Switching Power in a Smaller Package

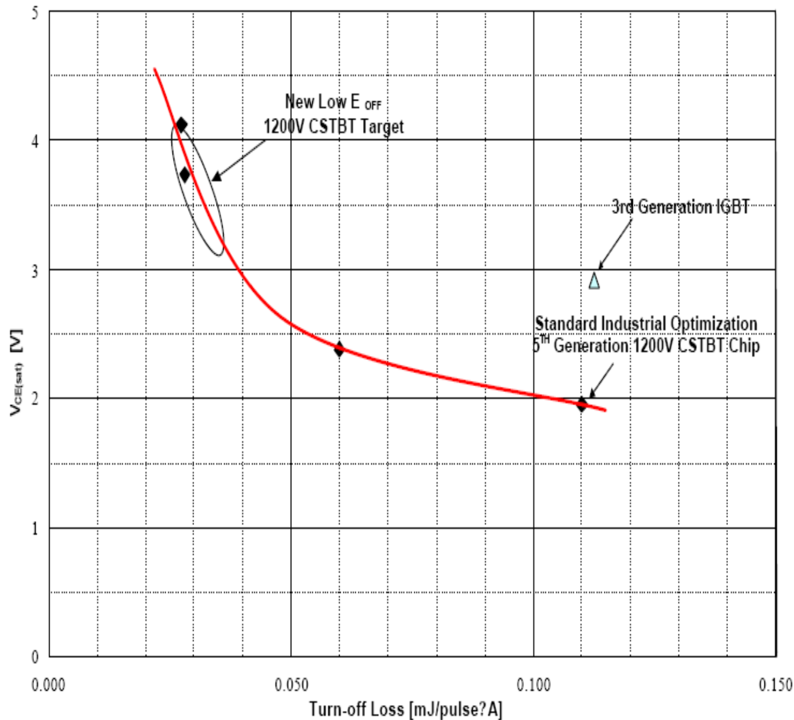


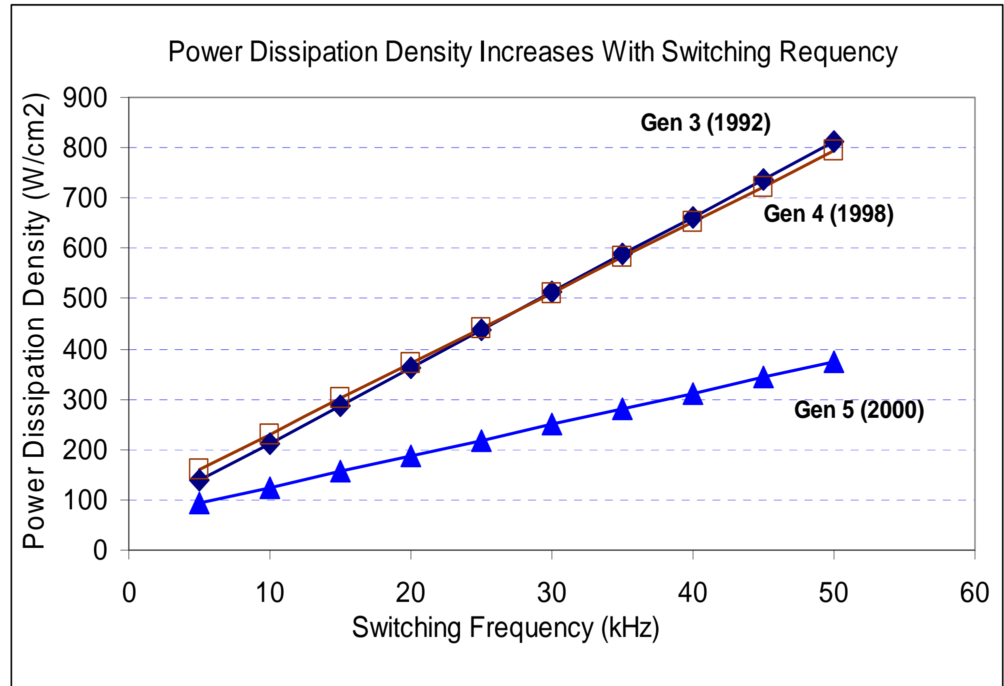
50 – 60% Reduction in Module Footprint Due to Decrease in IGBT Chip Losses Over Last 15 Years



1200V, 400A IGBT Module in Half H-Bridge Configuration

IGBT Switching Frequency Now Up to 50 kHz

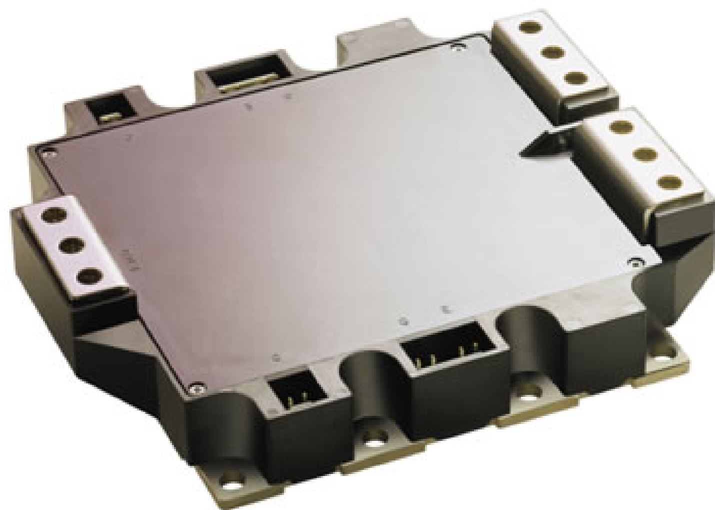




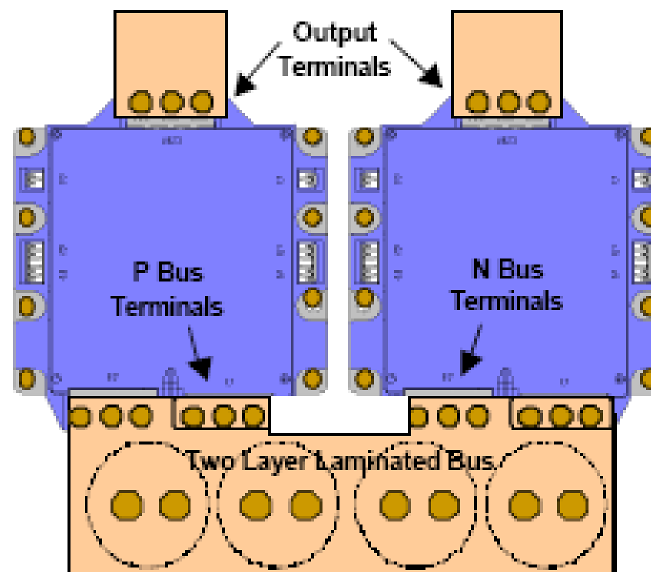
Conduction vs Switching Loss Trade-Off

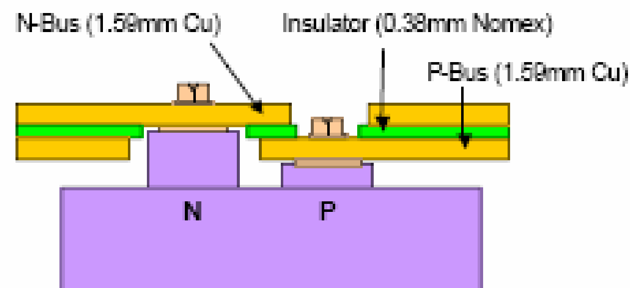
Vcc = 600V, Ic = 100A, 50% Duty Cycle -- Calculated

Module Design Reduces System Inductance & Complexity



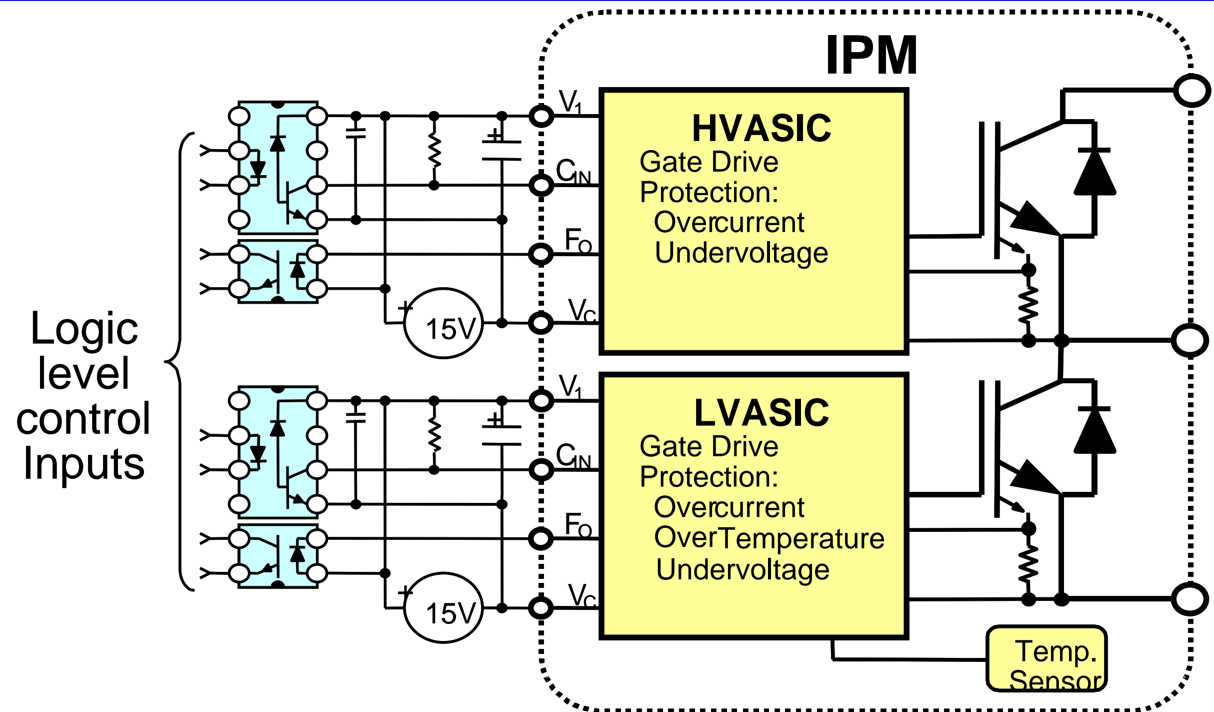
1200V, 900A Mega Power Dual IGBT Module with Internal Laminated Bus





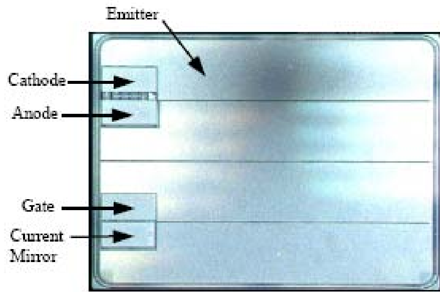
Integrated “Intelligent” Power Module = IGBT + Smarts

- Gate drive, temperature sensing & protection elements are integrated in the power switch package
- Protection for:
  - **Overtemperature**
  - **Overcurrent & short circuit**
  - **Low/high gate supply voltage**
  - **Fault signal feedback**
- Improves switch performance since protection functions are integrated in package

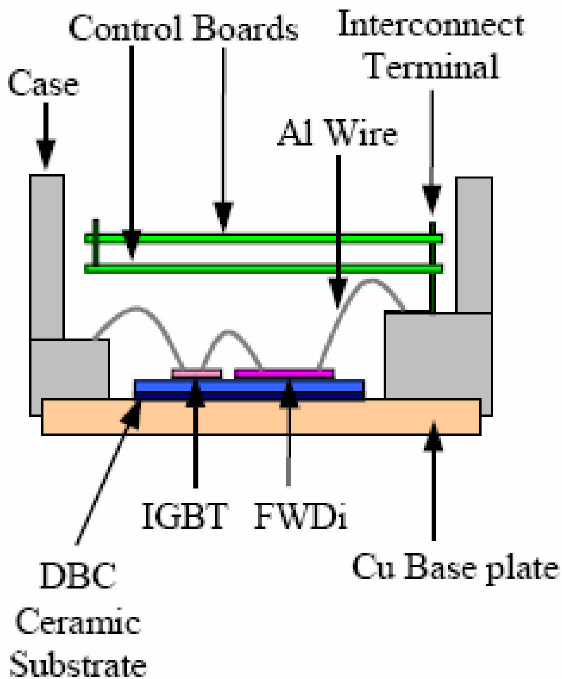


Intelligent Power Modules

IGBT Module Integration – Sensing & Protection

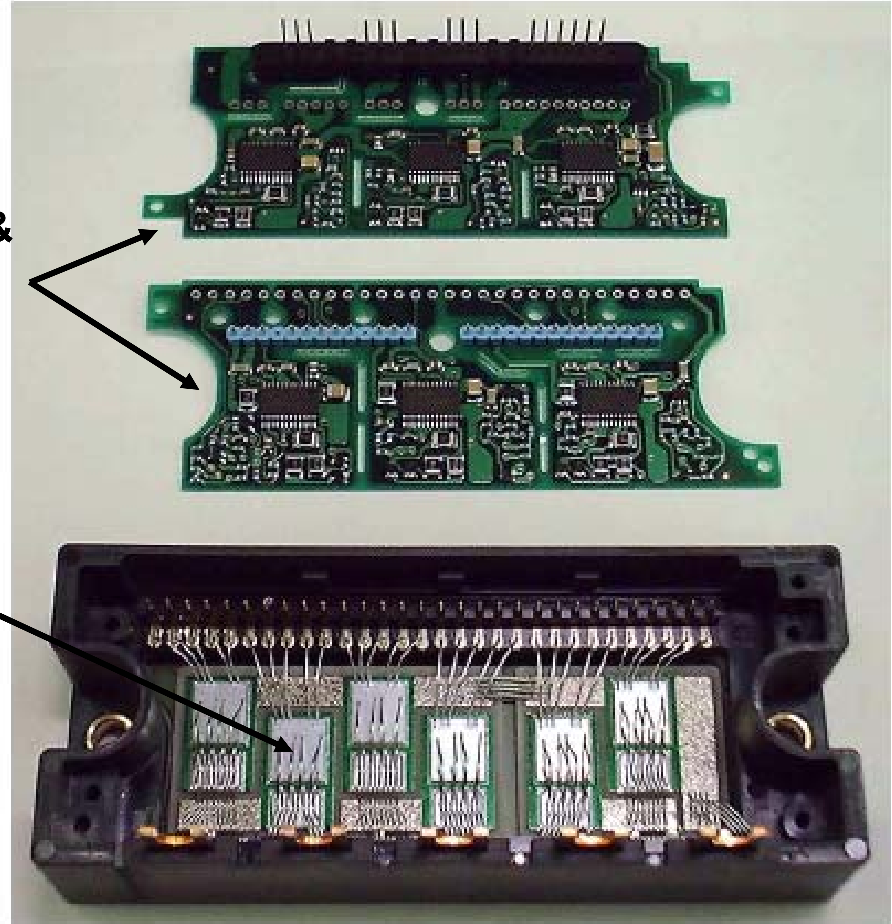


On chip current & temperature sensing



Gate drive & protection circuitry

Power switches



Fault Types & Intelligent Power Module Countermeasures

- Chip Overtemperature
  - Gate Drive Turns IGBT Off – Fault Signal Sent to Controller
- Over Current/Short Circuit
  - Short Circuit & RBSOA (Switching Protection)
  - Gate Drive Turns IGBT Off – Fault Signal Sent to Controller
- Gate Drive Supply Under Voltage
  - Gate Drive Turns IGBT Off – Fault Signal Sent to Controller

Complete Power System Integration in a Module

Conventional IPM

Current Sensor

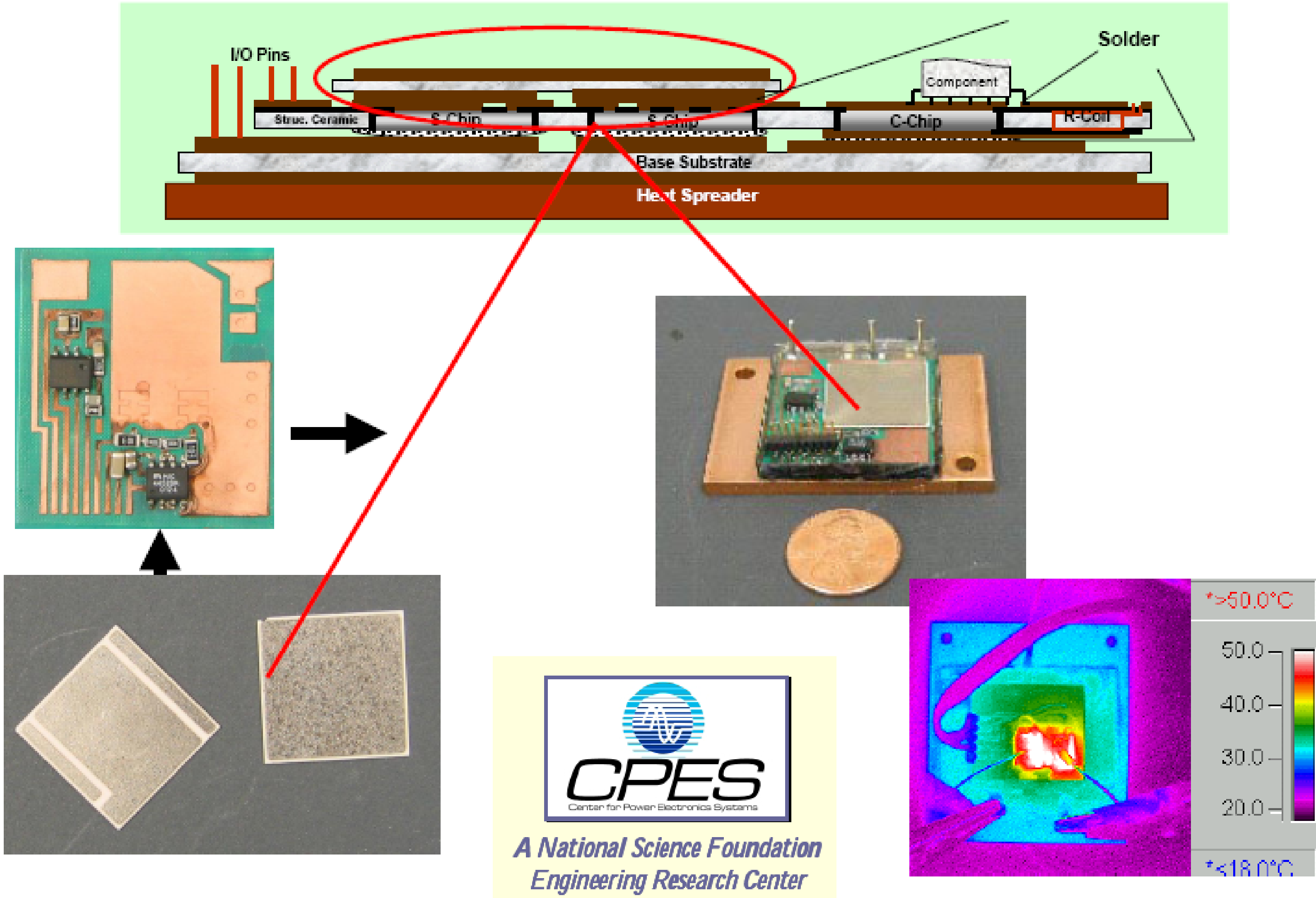
Rectifier

Optocouplers

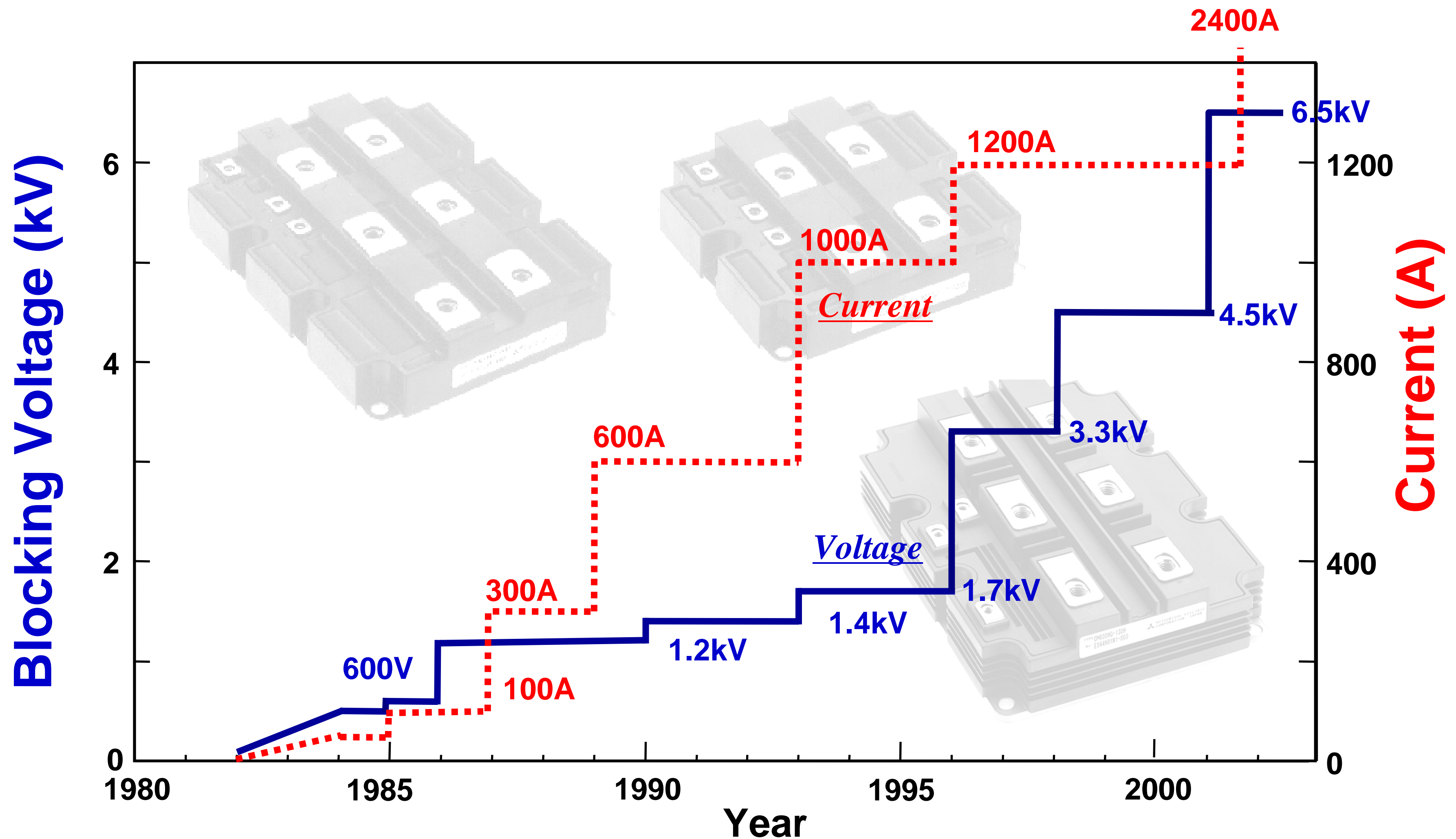
Small 3-Phase Motor Drive System Integrated in an ASIPM Module

600V, 50A & 1200V, 25A

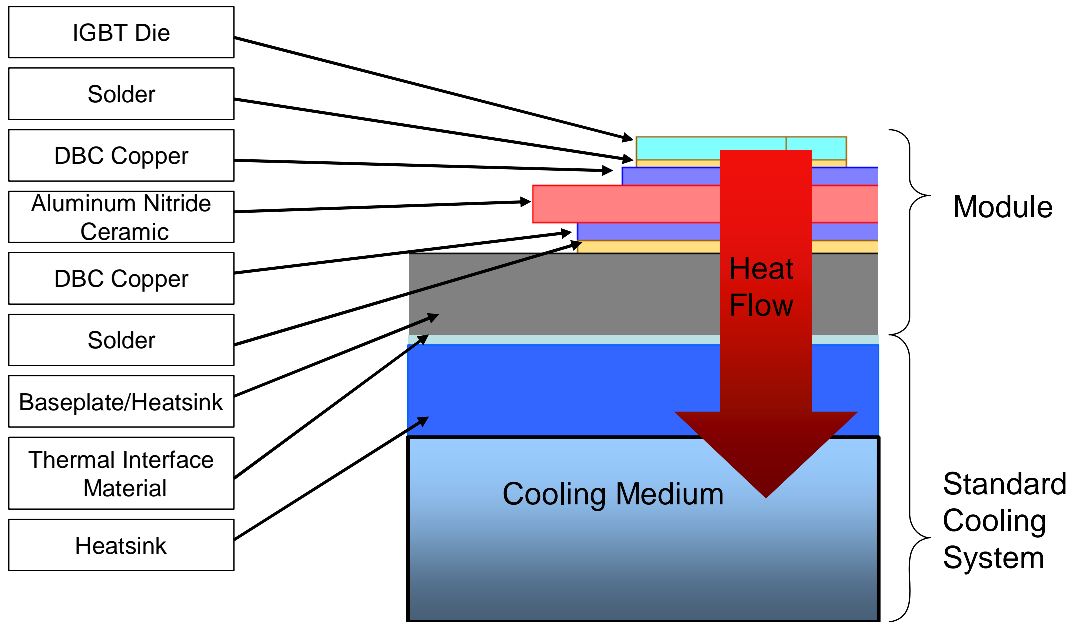
Integration of Passives in Power Semiconductor Modules

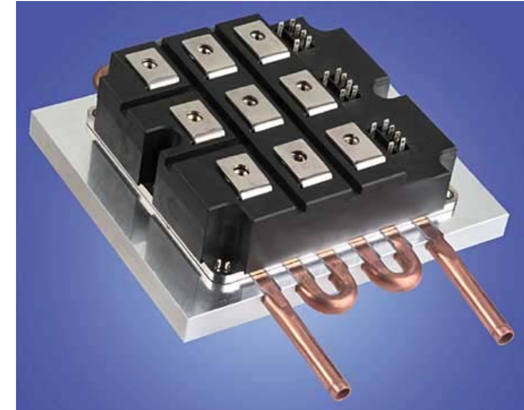


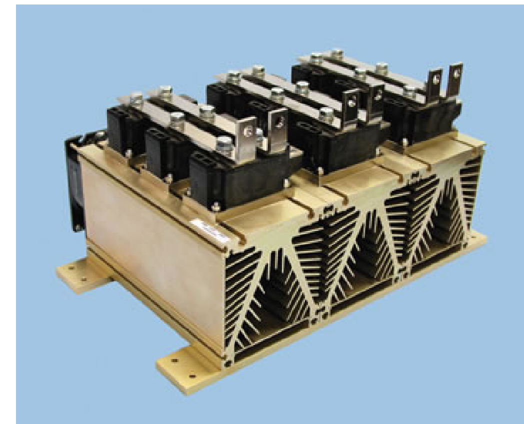
HV-IGBT Voltage Ratings Now Up to 6.5kV



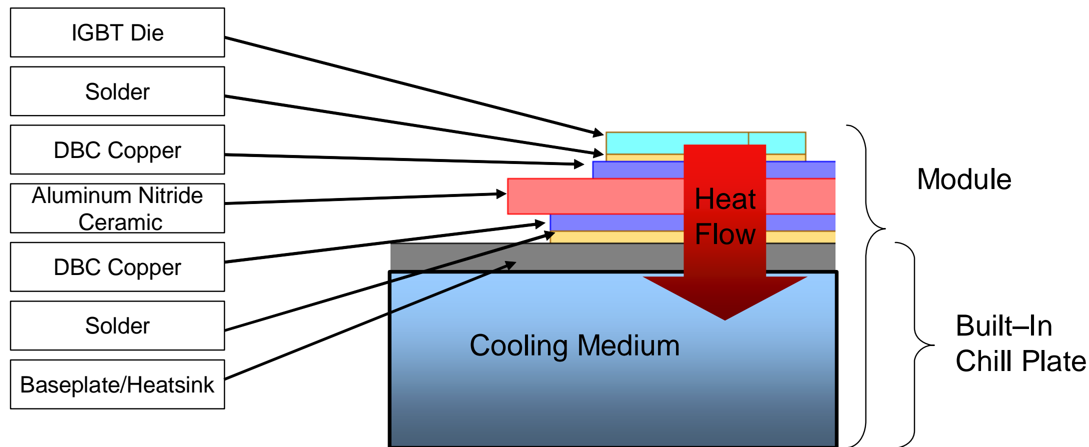
Standard Power Module Cooling



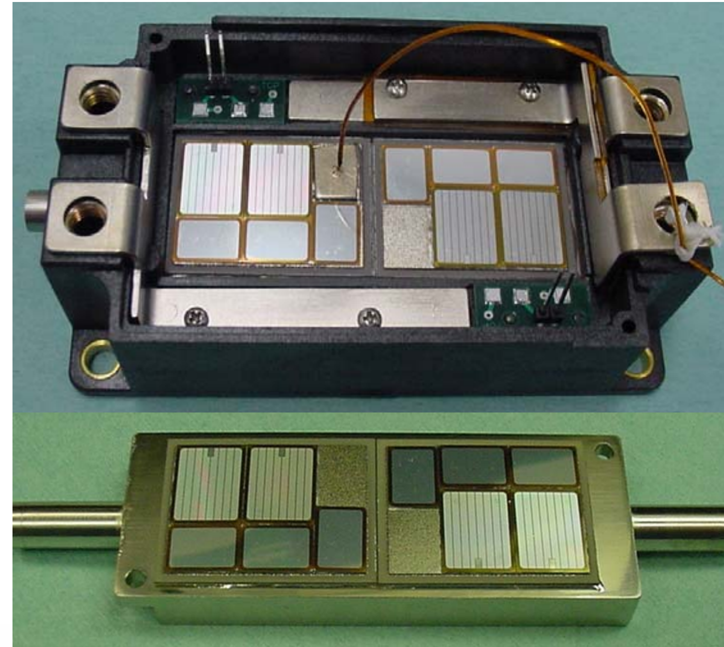


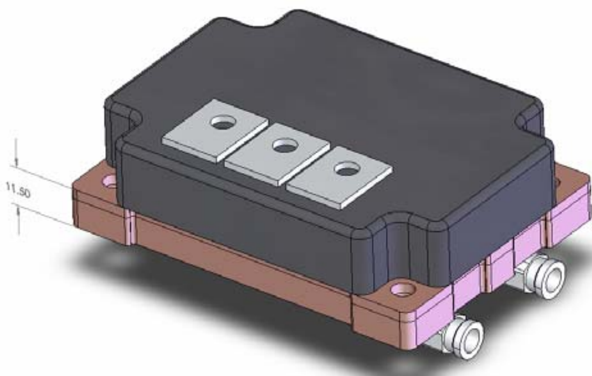


Modules with Built-In Heatsink – Reduced Heat Flow Path

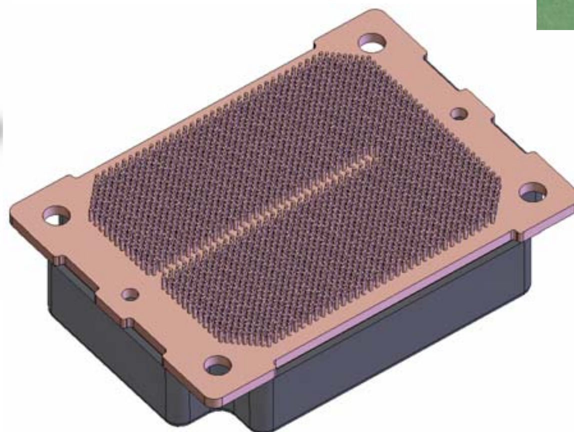


Normal Flow Microchannel Cold Plate

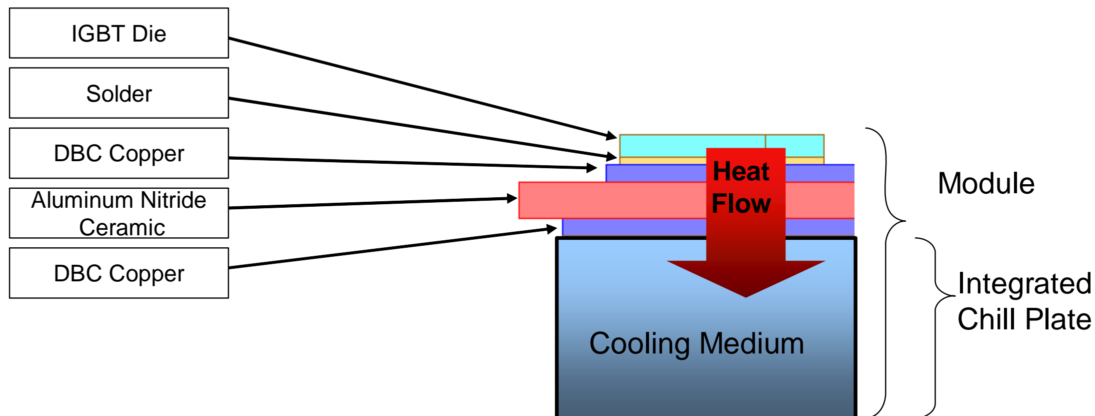




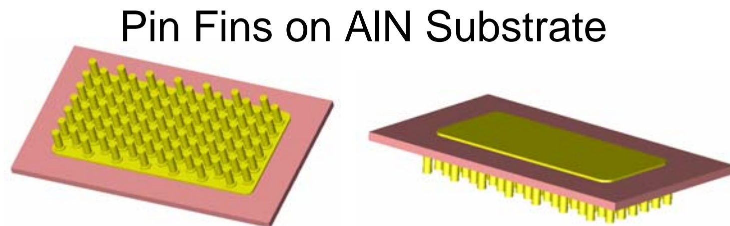
"Pin Fin" Baseplate

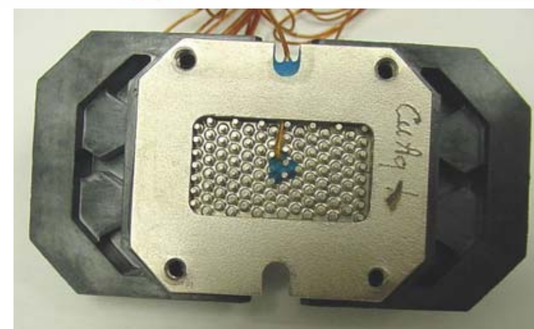


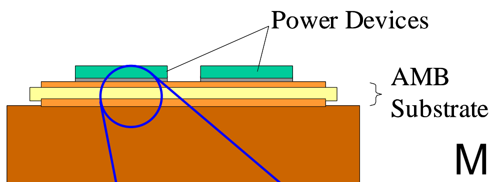
Modules with Integrated Heatsink – Reduced Heat Flow Path



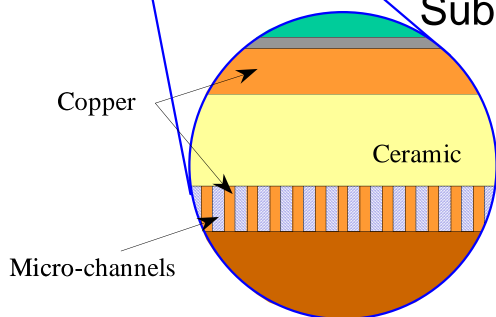
Pin Fins on AlN Substrate



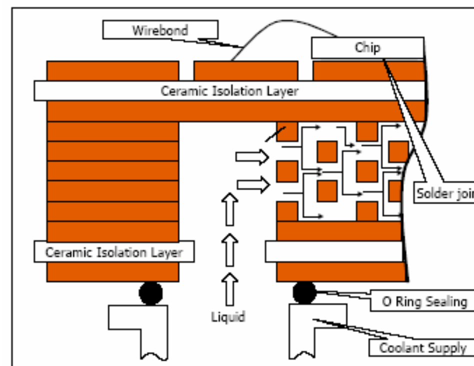


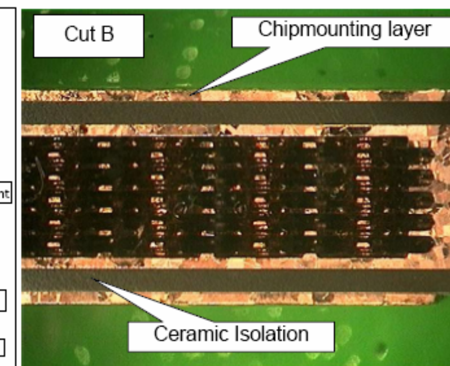


Microchannels Machined in AlN Substrate (GECRD)

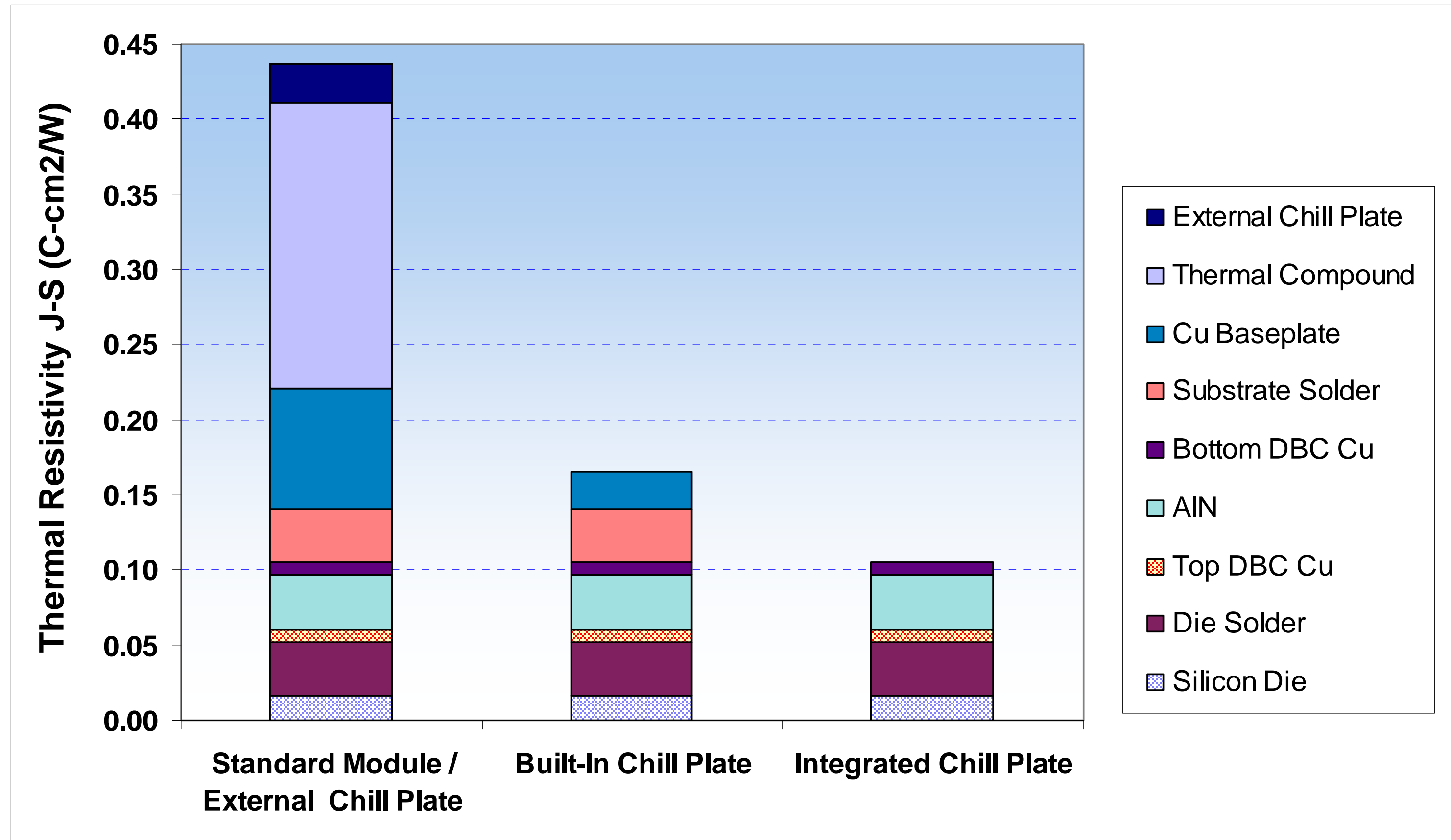


AlN/Cu Substrate Micro Channel Cooler (Curamik)





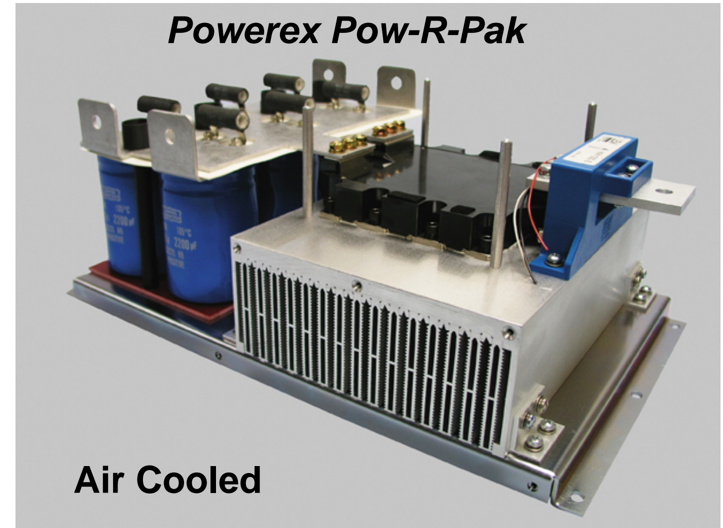
Thermal Resistivity Comparison of Paths to Cooling Medium



Assembly Subsystems – Beyond Systems in a Module

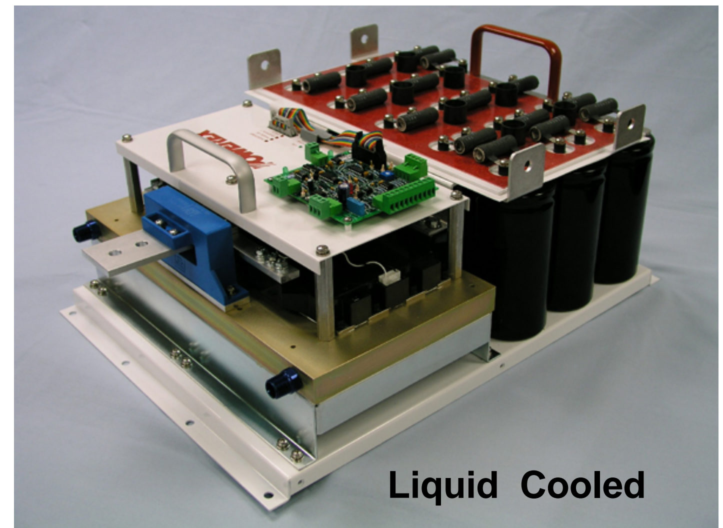
- Power switches
- Energy storage devices
- Current sensing
- Gate drives
- Protection
- Cooling

Powerex Pow-R-Pak



Air Cooled

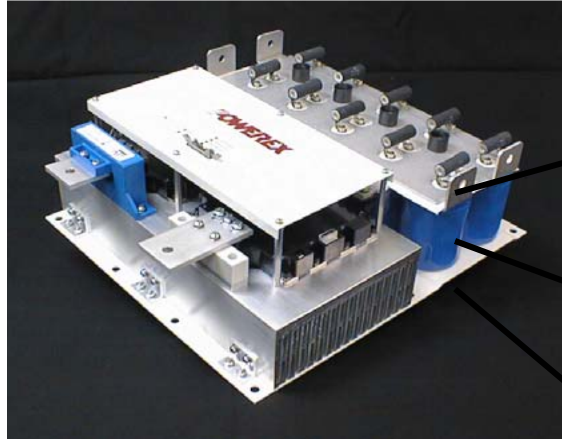
Semikron Skiip Pack



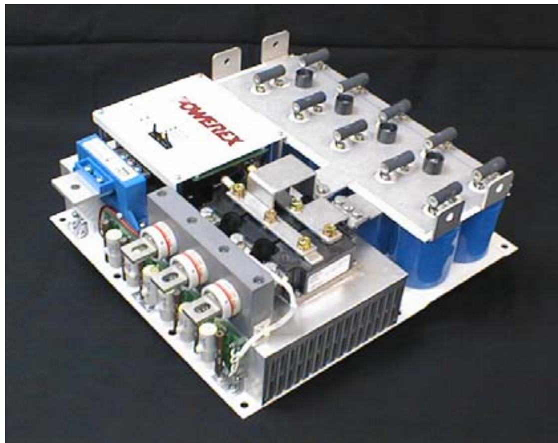
Liquid Cooled

System Integration

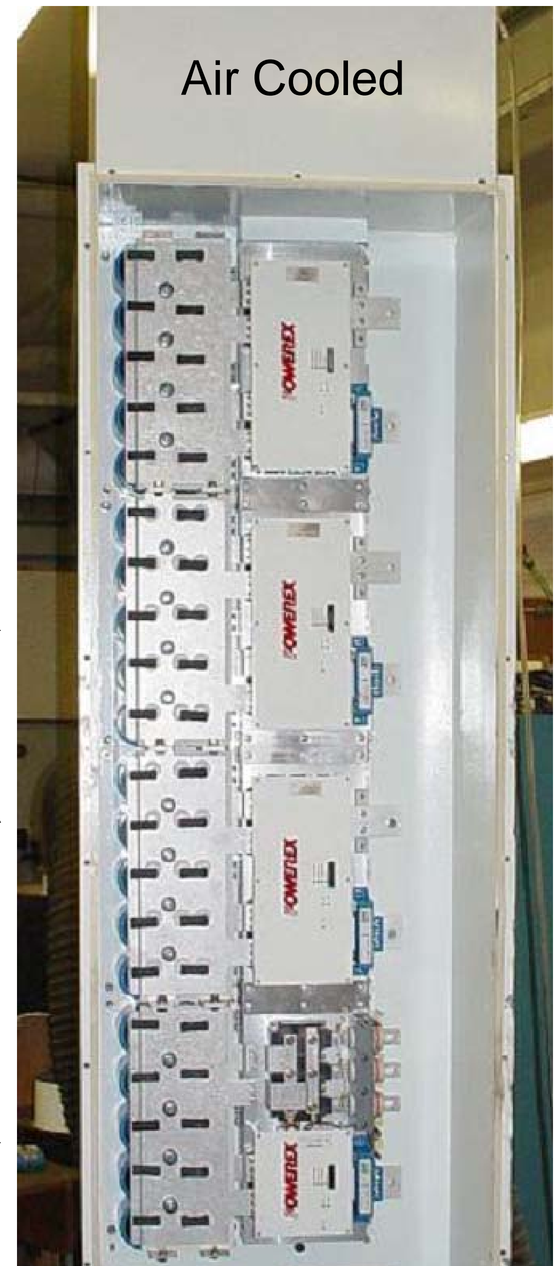
Motor Leg Inverter



Converter & Brake Chopper



Air Cooled



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