

Electric Drive Cost Reduction by Design Simplification

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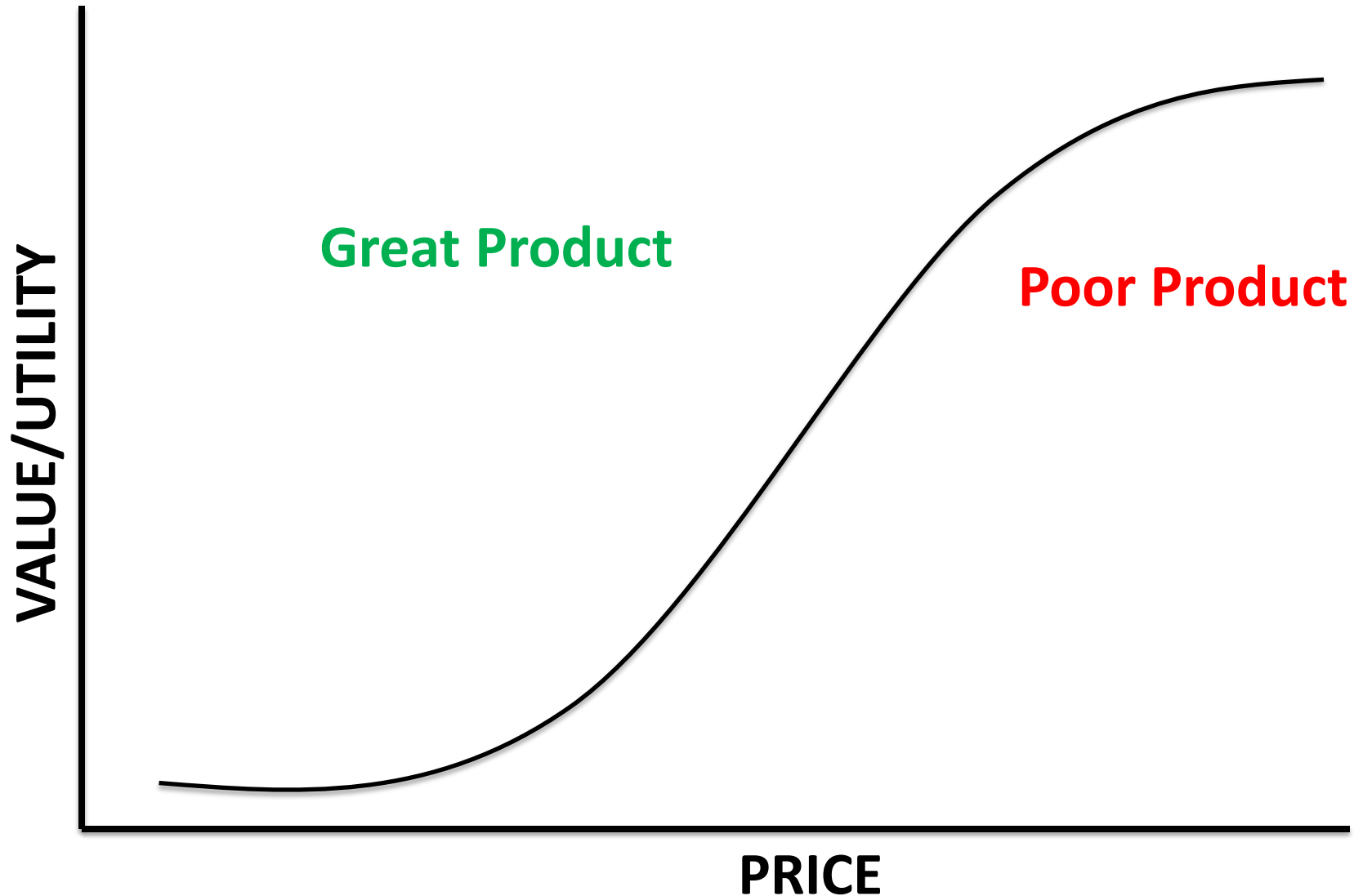
Hybrids and EV's in the 2012 Marketplace

- **Technical Feasibility Demonstrated**
- **Performance Competitive**
- **Customer Interest Growing**

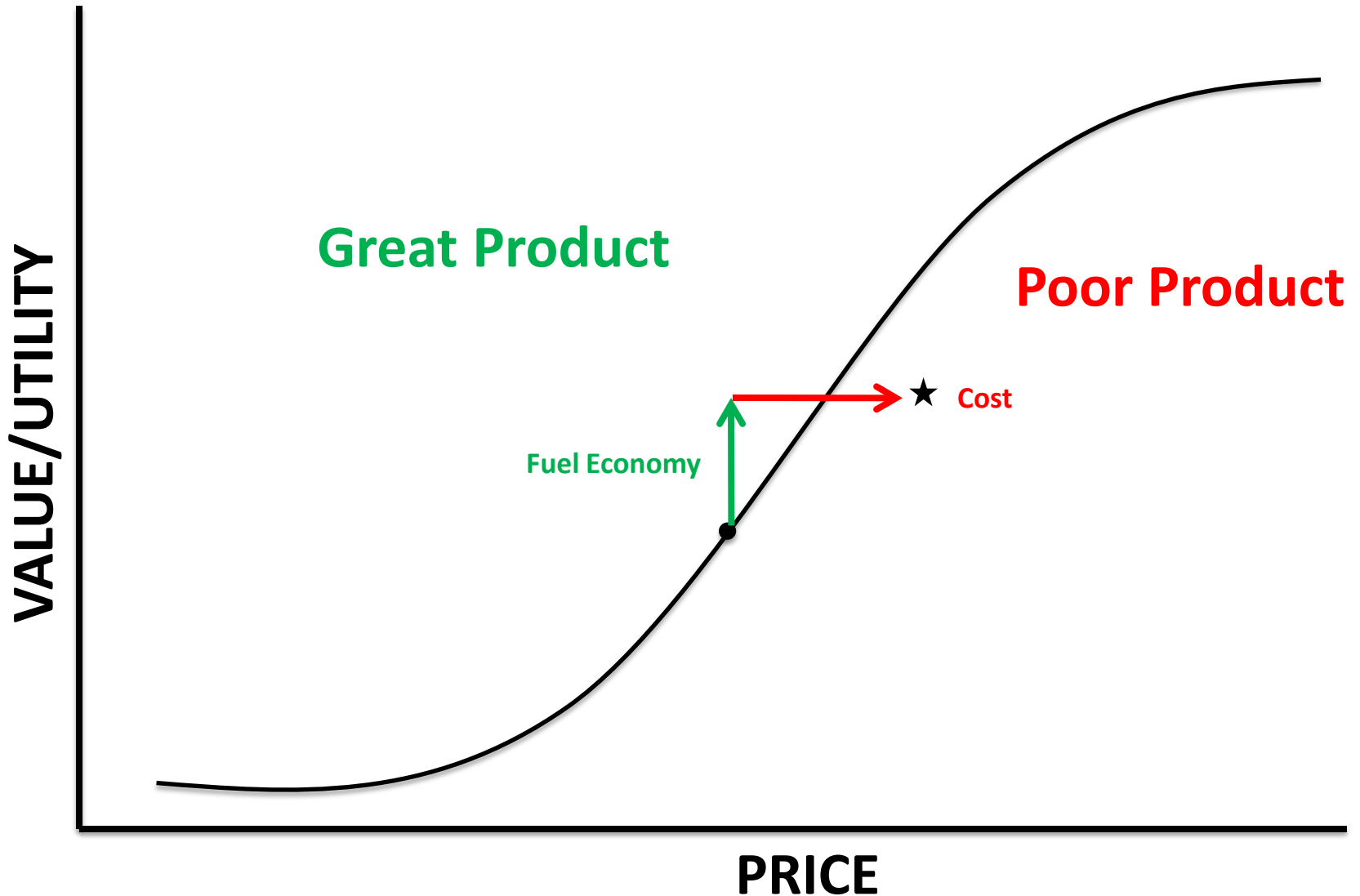
BUT

- **Market Take Rate Continues to be Hampered by Persistent High Costs**
- **Aggressive Cost Reduction at all Levels Essential for Commercial Viability and Mass Market Acceptance**

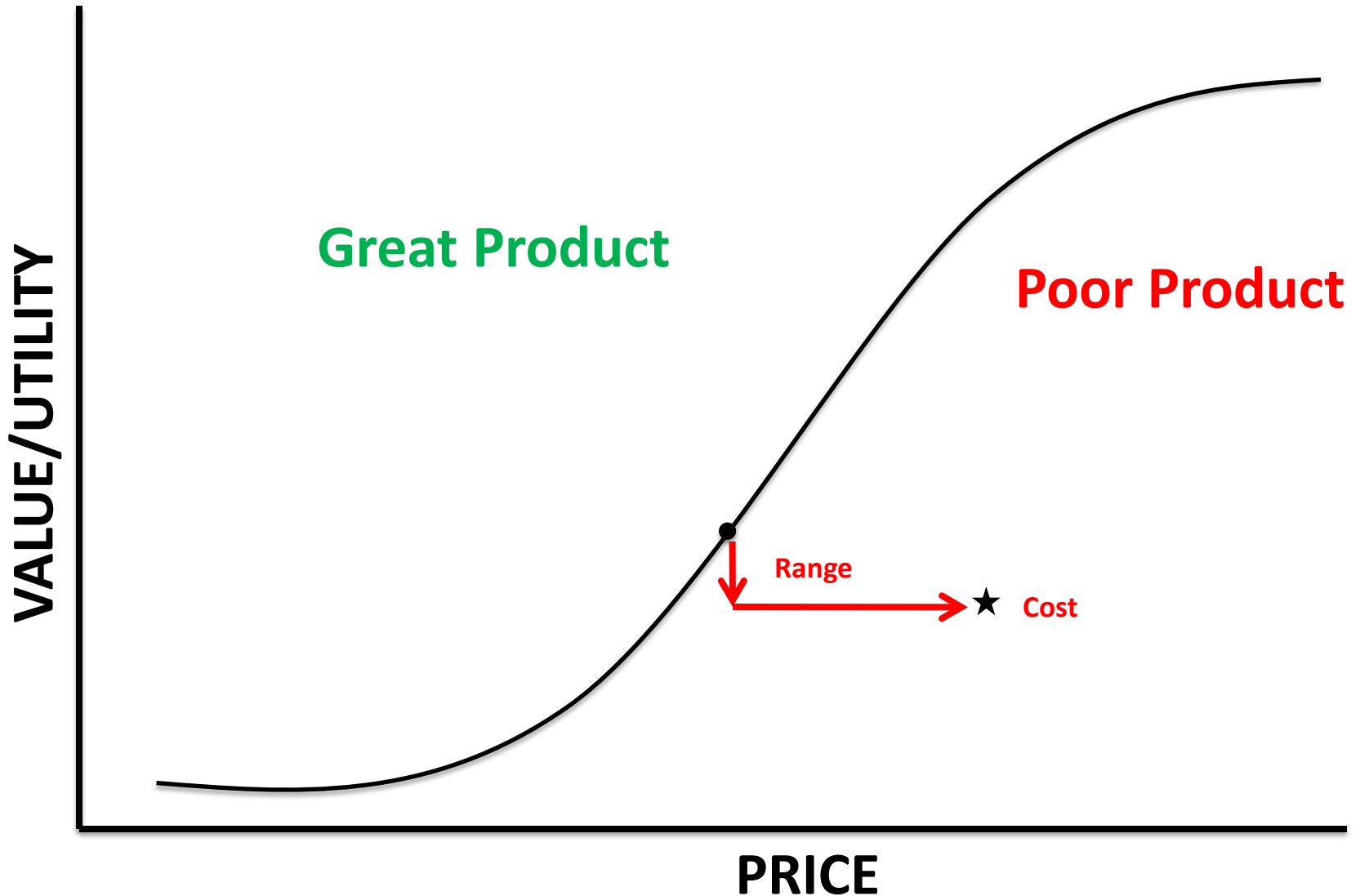
Customer Value Proposition



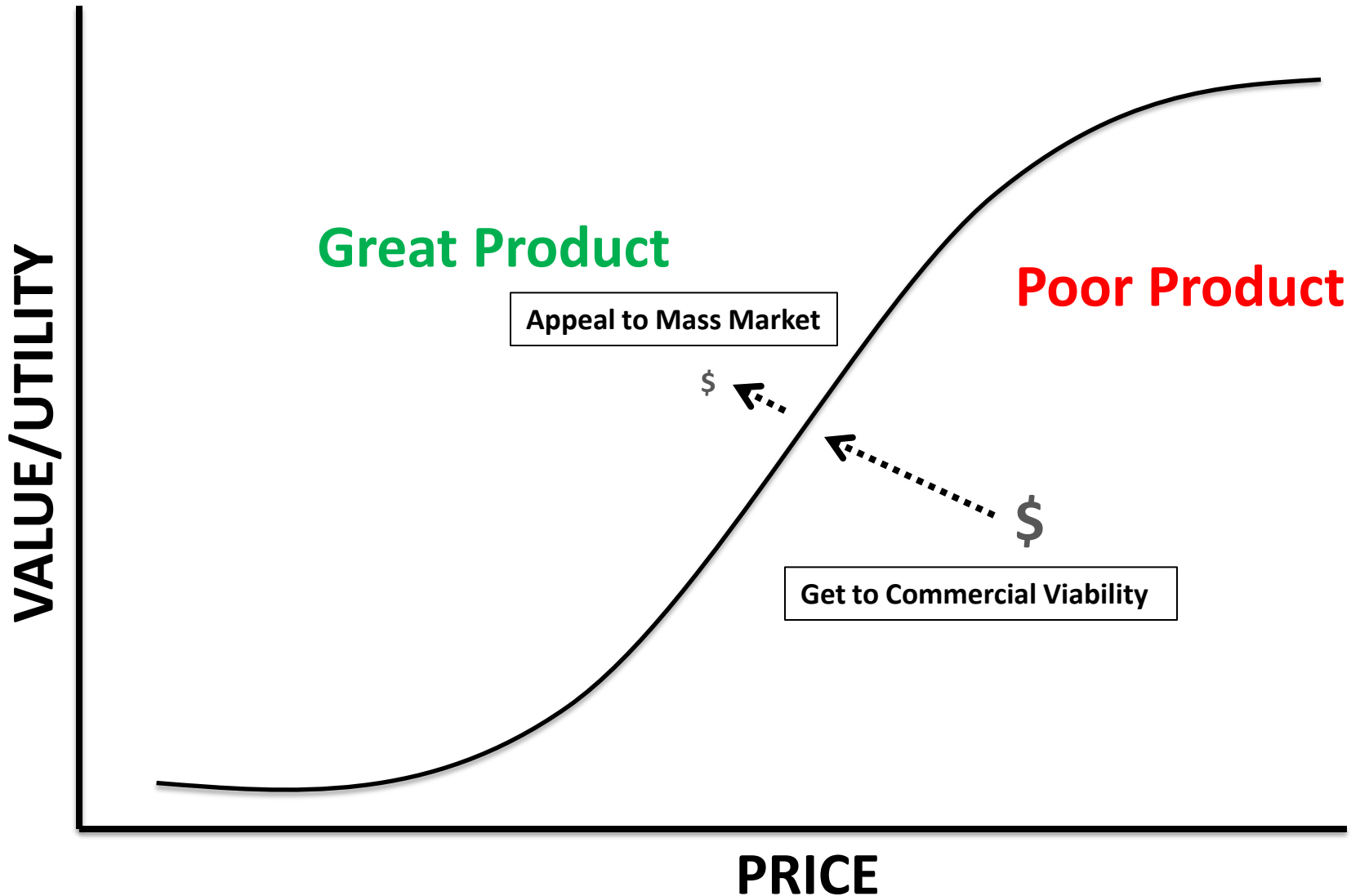
Hybrid Value Proposition



Electric Vehicle Value Proposition



Hybrid and EV Cost Challenge



High Cost of Electric Drive Systems

- **Electric Drive Systems are Typically Considered Mature Today**
 - Inverter
 - Electric Motor
 - Reduction Gear
- **Mature in Size and Mass**
- **Mature in Performance**
- **But not Yet Mature in Cost**



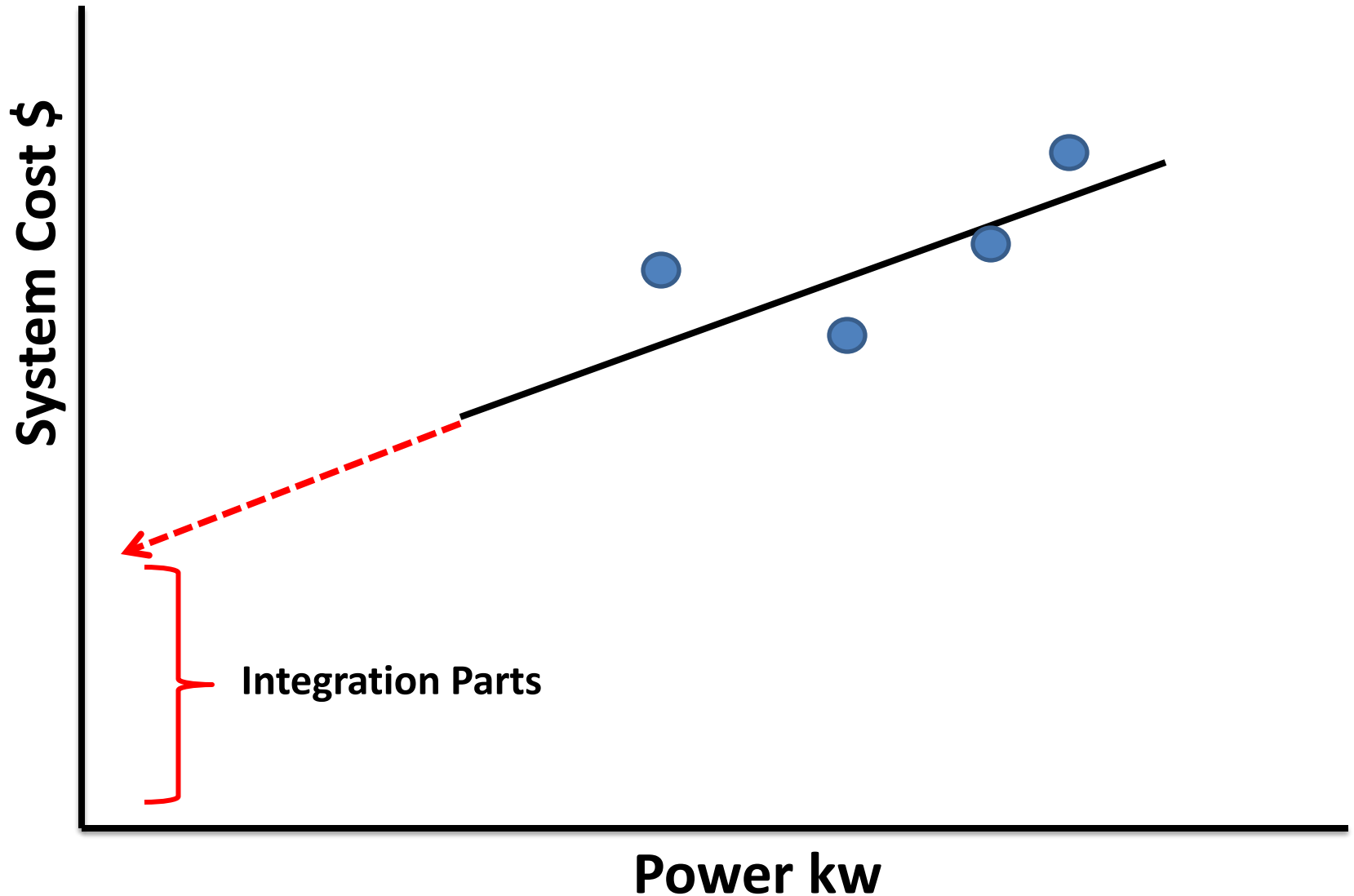
1995 EV1 Inverter



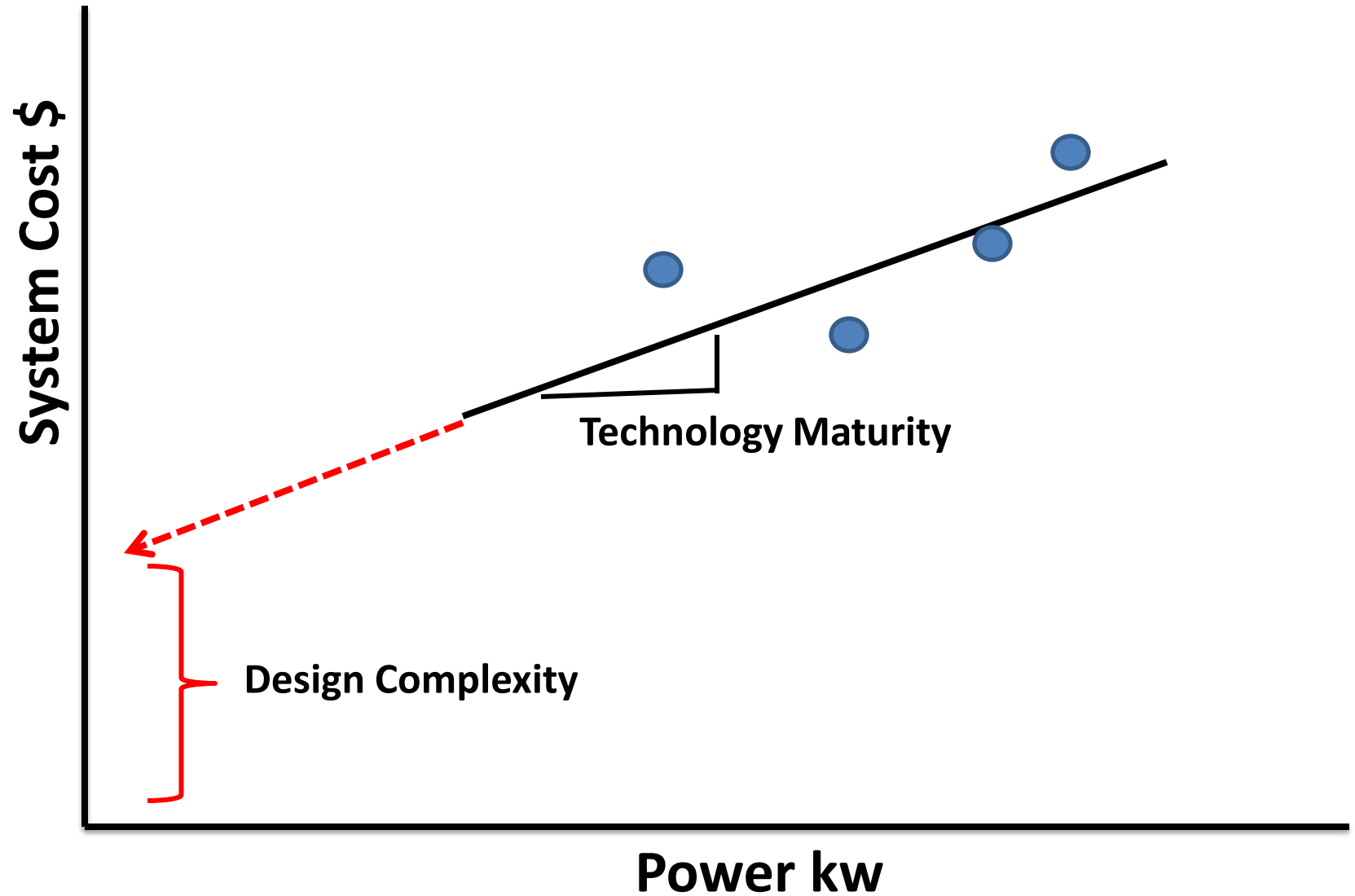
2012 Magna E Car Inverter



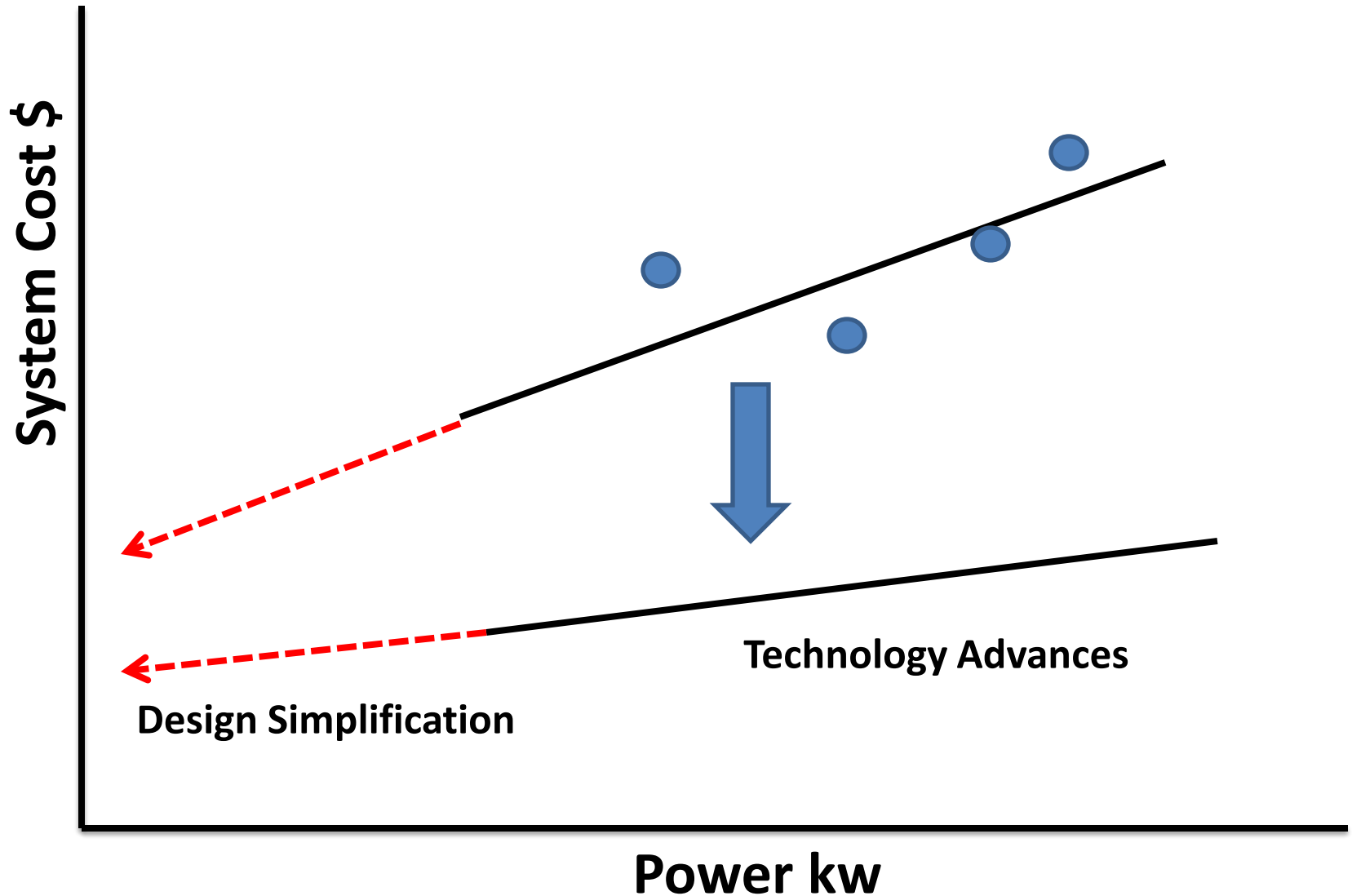
Cost of Integration Parts



Cost Drivers



Cost Reduction Requires Technology & Design

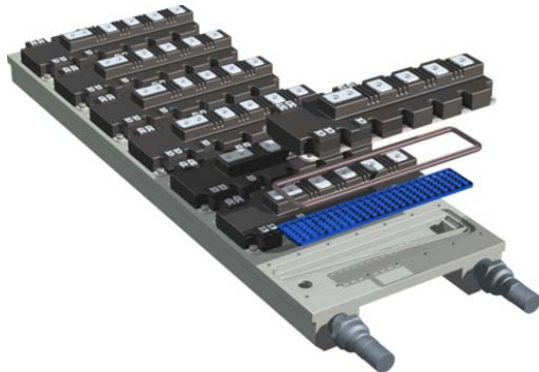


Inverter Simplification/Integration Advances

After Two Decades of IGBT Silicon DIE Size Reduction and Space Efficiency Improvements of 75% and Junction Temperatures up to 150C

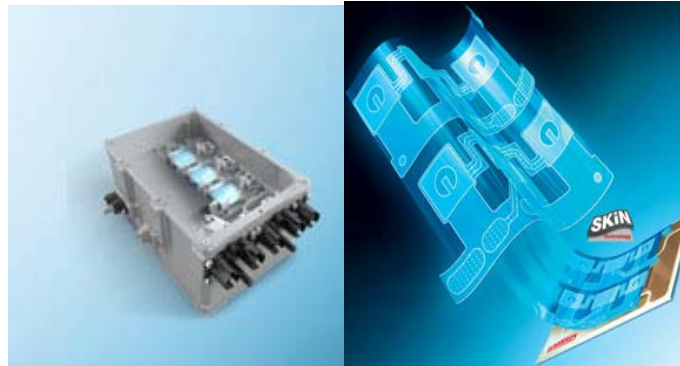
Innovation Has Now Reached the Module Level

Danfoss



Direct Path Cooling

Semikron



Wire Bond Free High Power Density Interconnect

Infineon

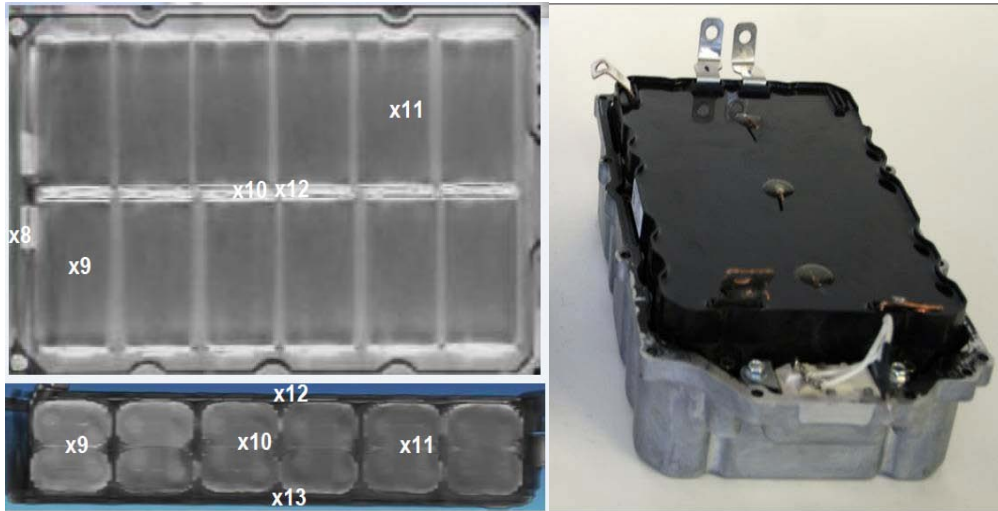


Integrated Current Sensors /Drivers

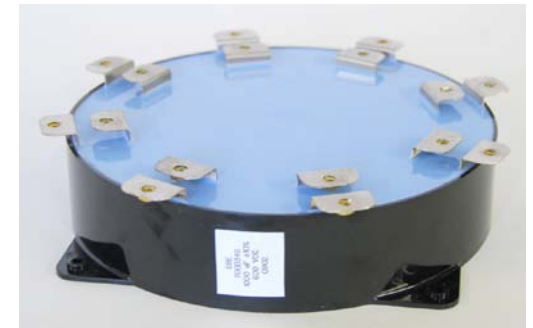
To Get Further Down the Cost Curve, More Design Simplification and Reduction of Integration Parts is Needed

SBE Technology Integrates DC BUS Capacitors

Many Individual Components



SBE Power Ring Capacitor

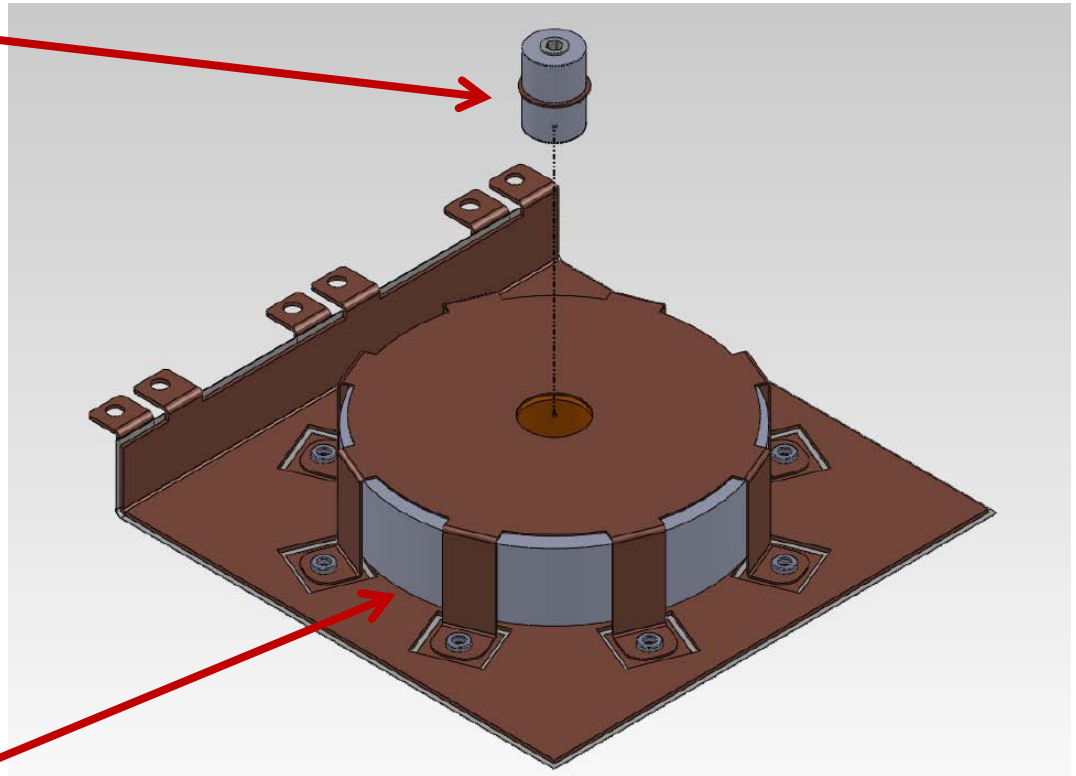


Leading Edge Performance
1,000 μ F, 600 Volt
125 micro-Ohms at 20 kHz
5 nH
105 C

Enabling Further Inverter Simplification ,Integration & Cost Reduction

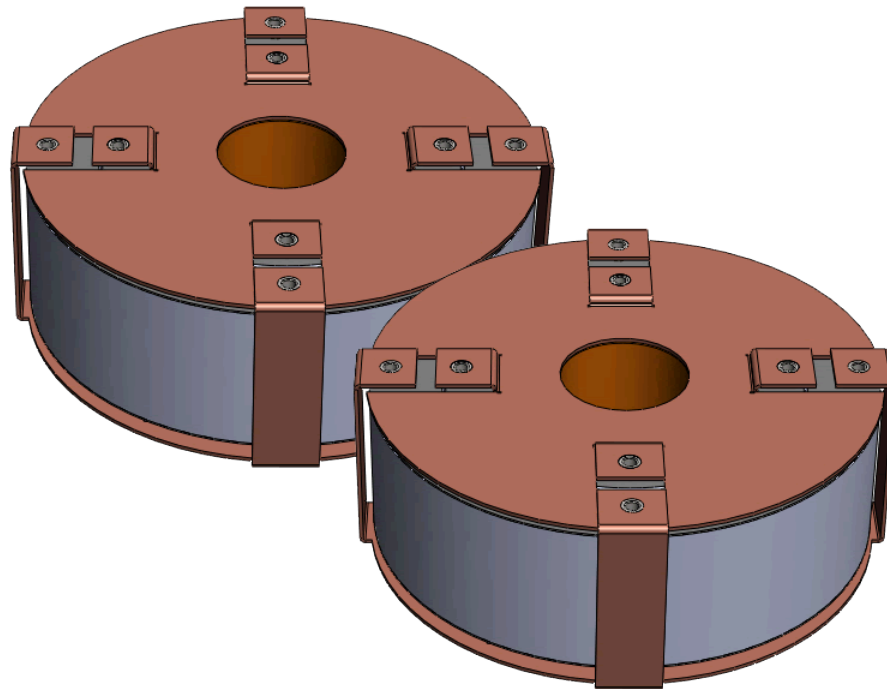
Even More Integration Possible

Integrated EMI High
Frequency Filter “Cartridge”
Saves Space and Reduces
Assembly Time

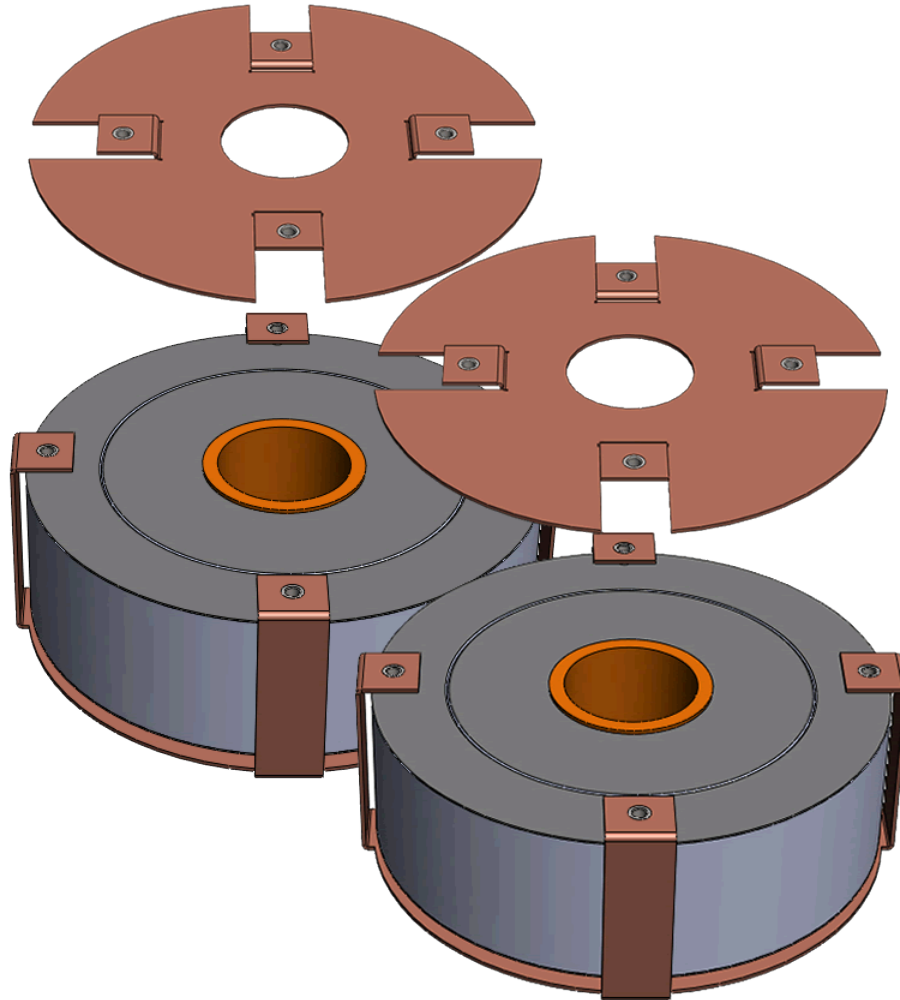


Direct Connection to
Laminated Bus Bar
Eliminates a
Terminal Plate

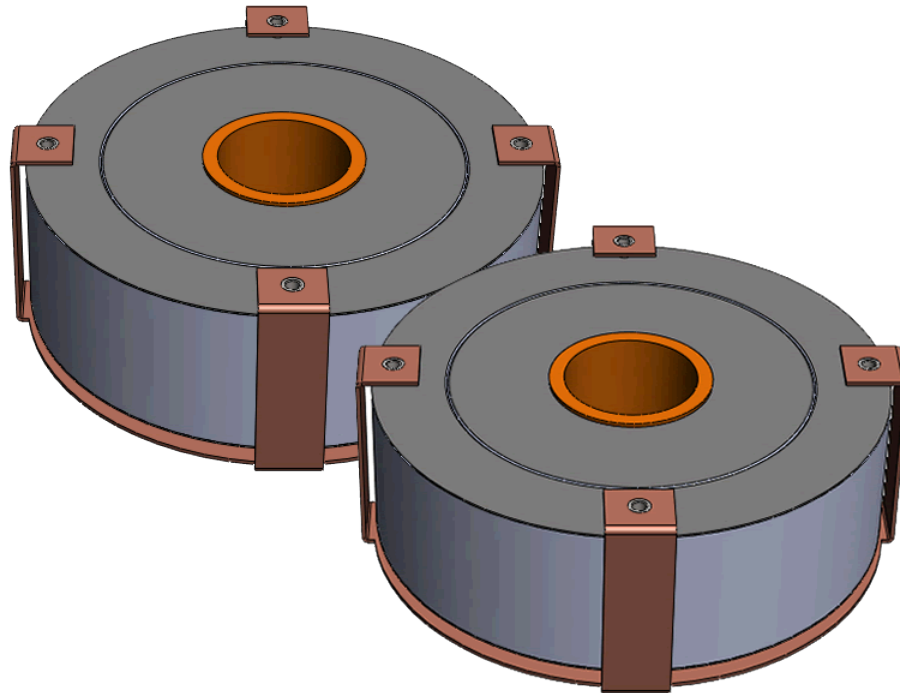
Next Level of Integration Facilitated by SBE



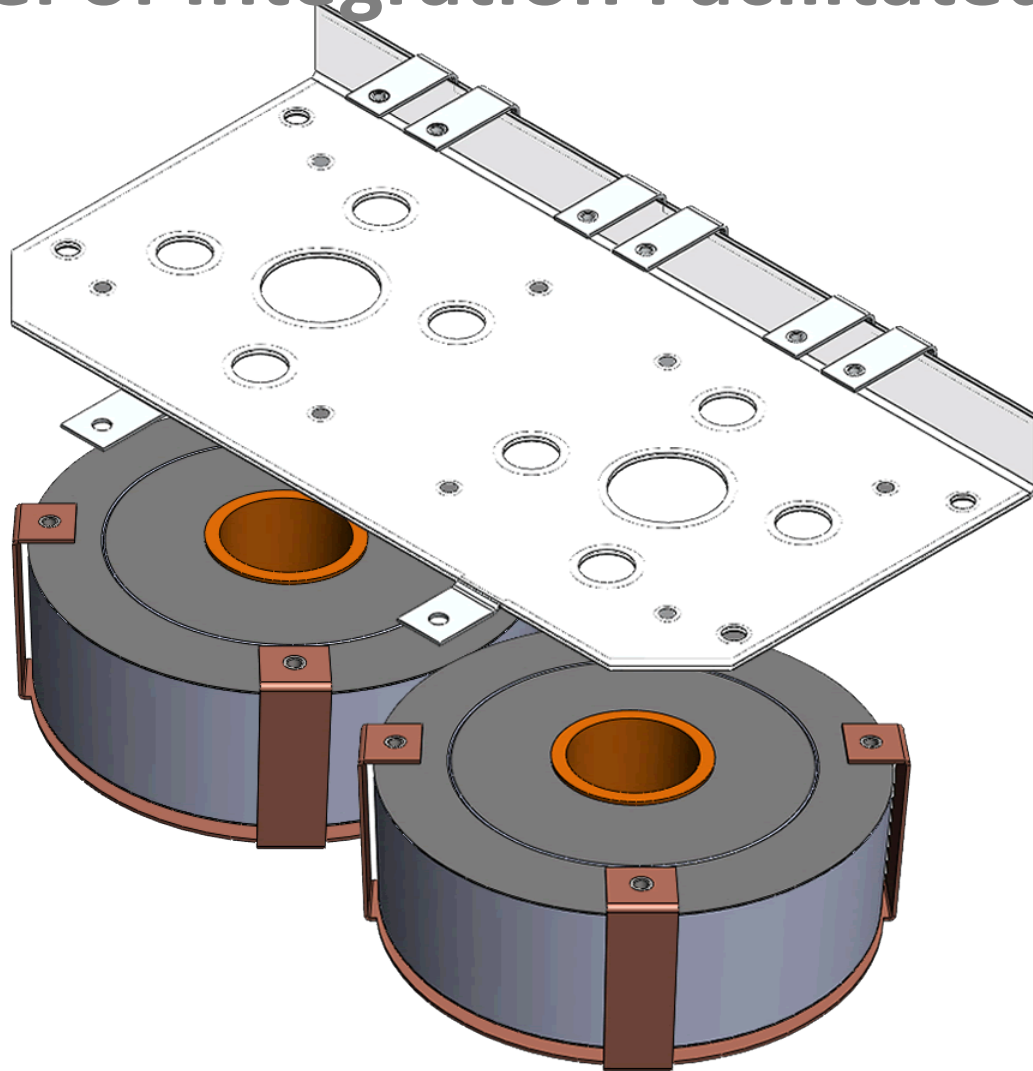
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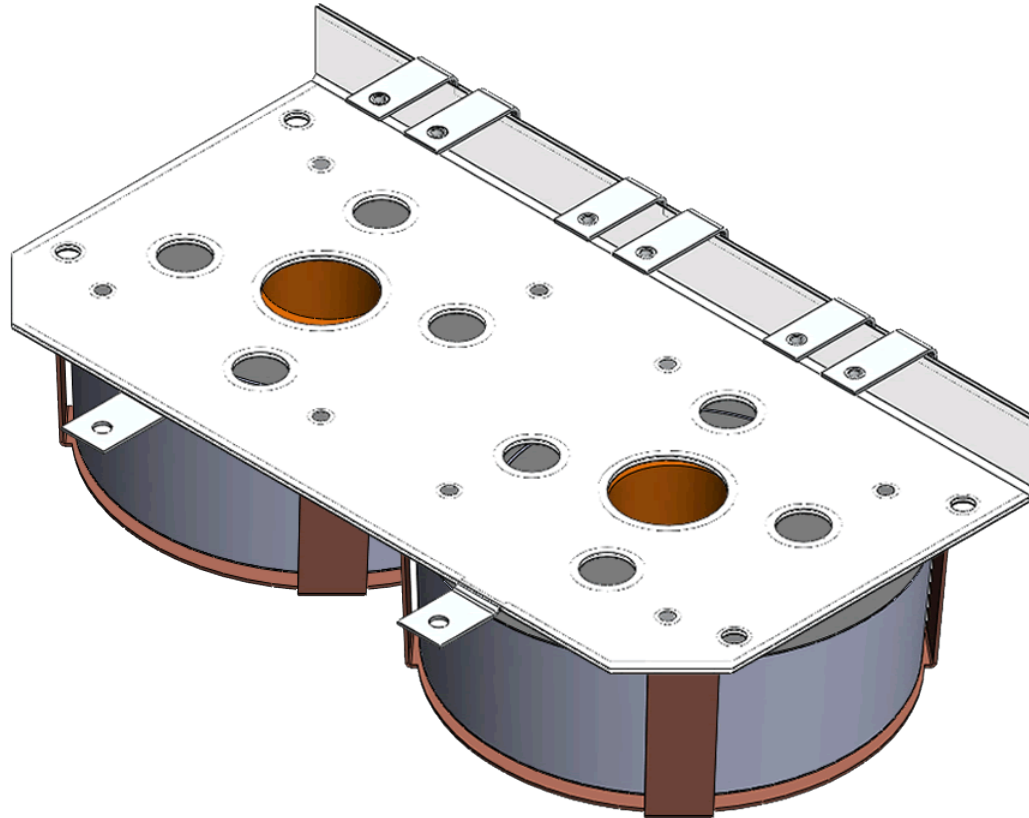
Next level of Integration Facilitated by SBE



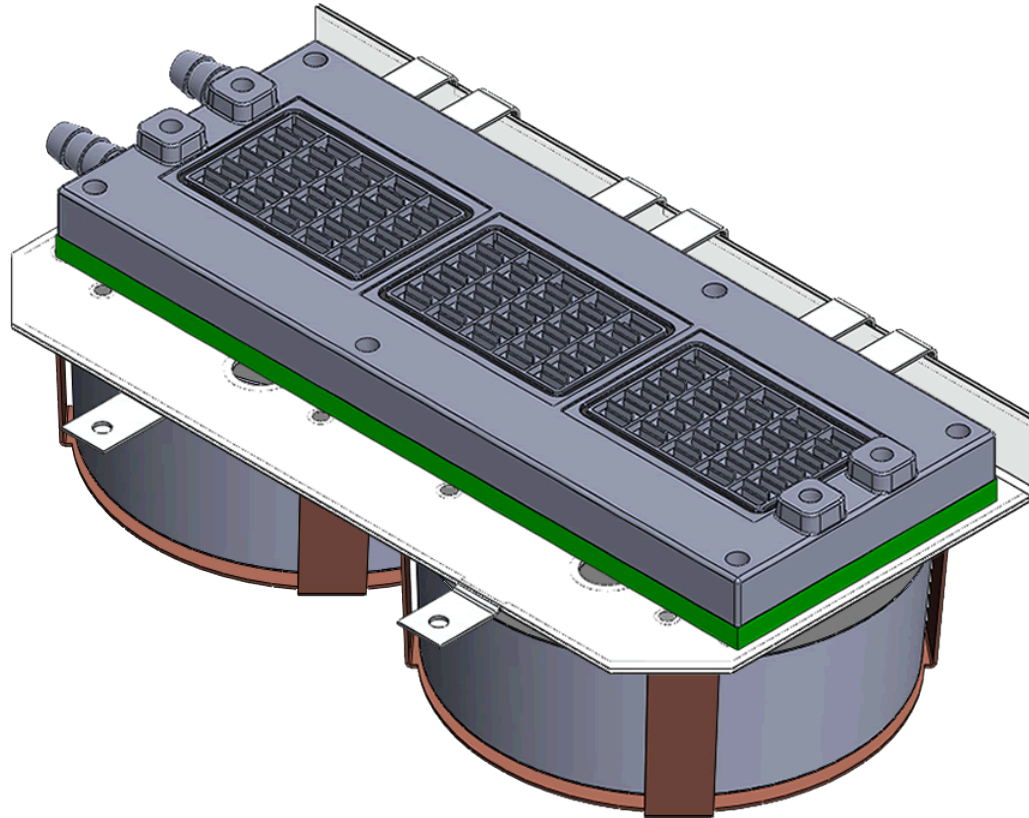
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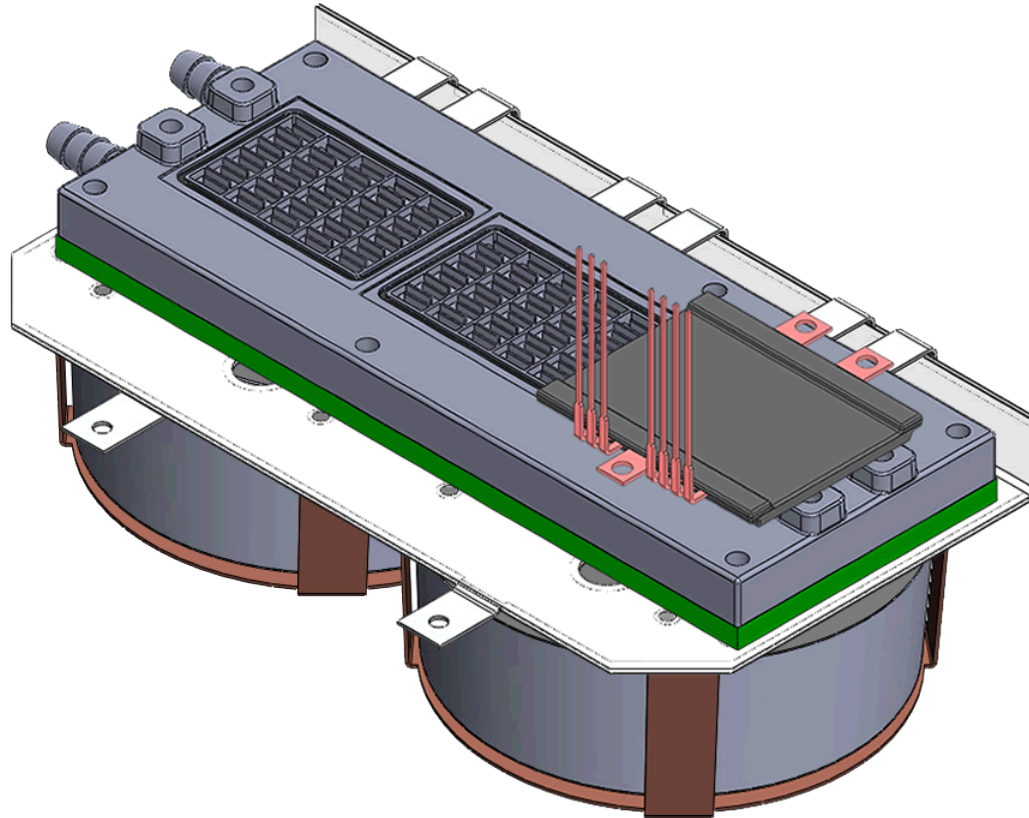
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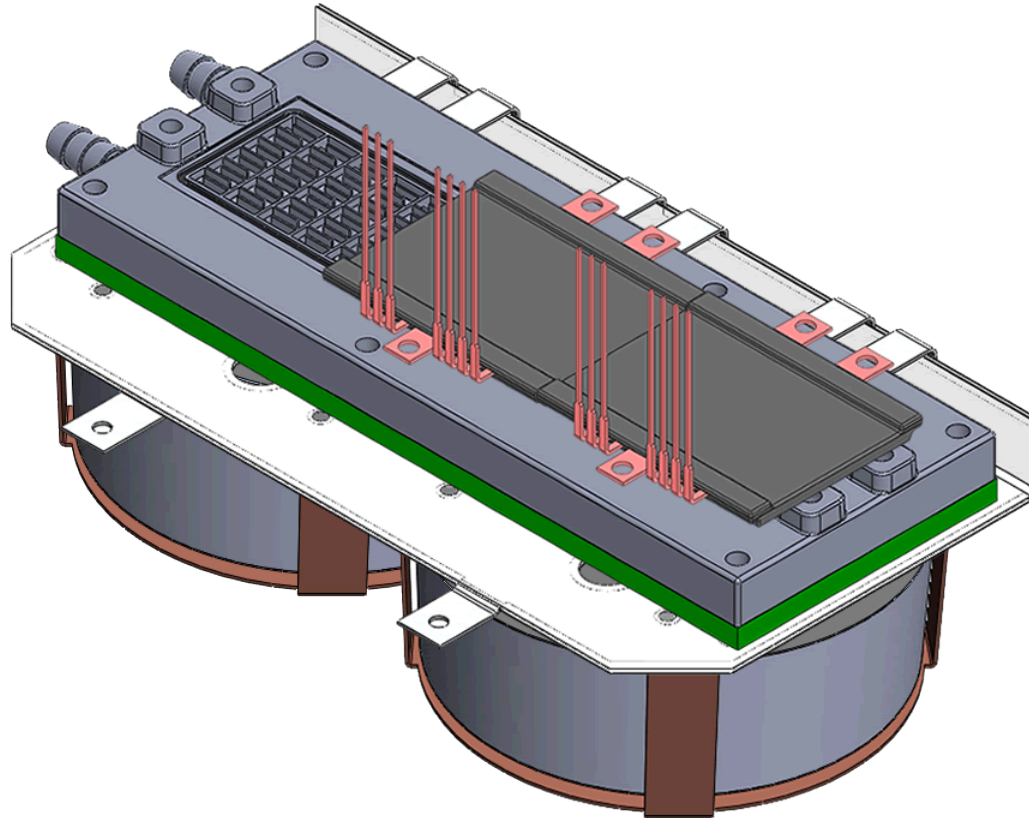
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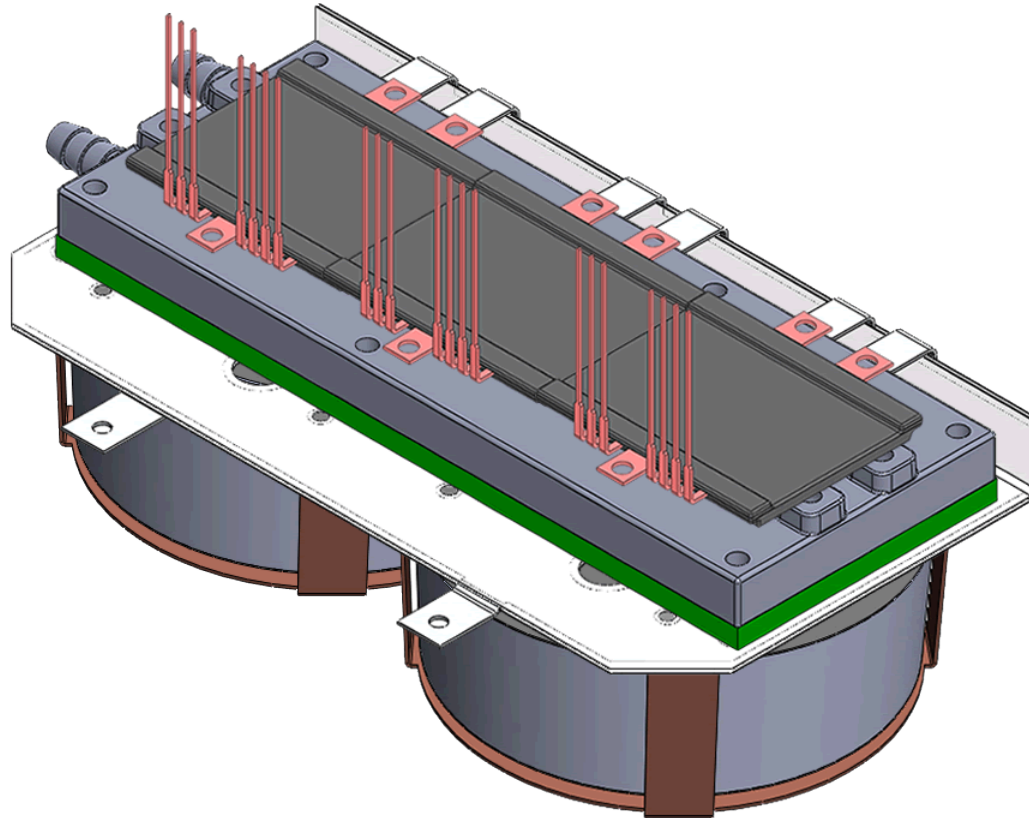
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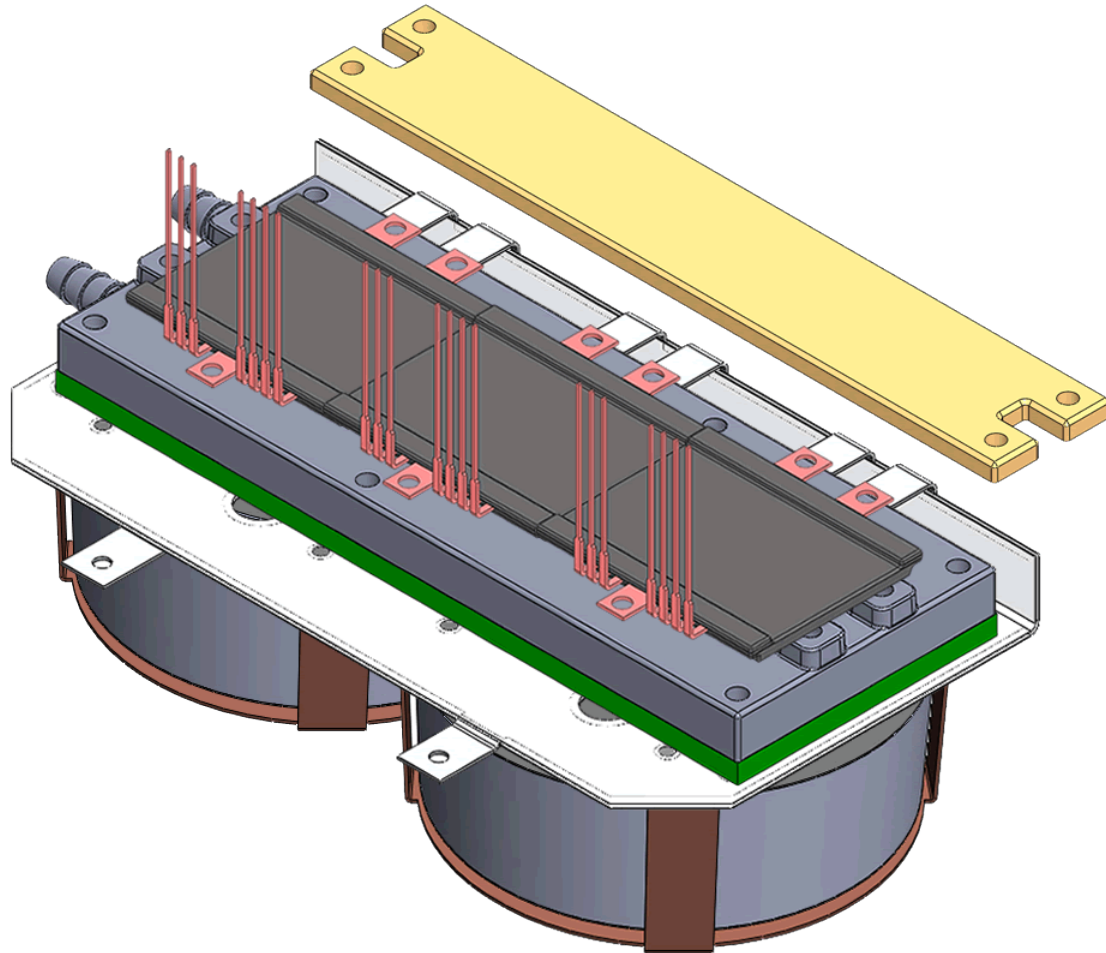
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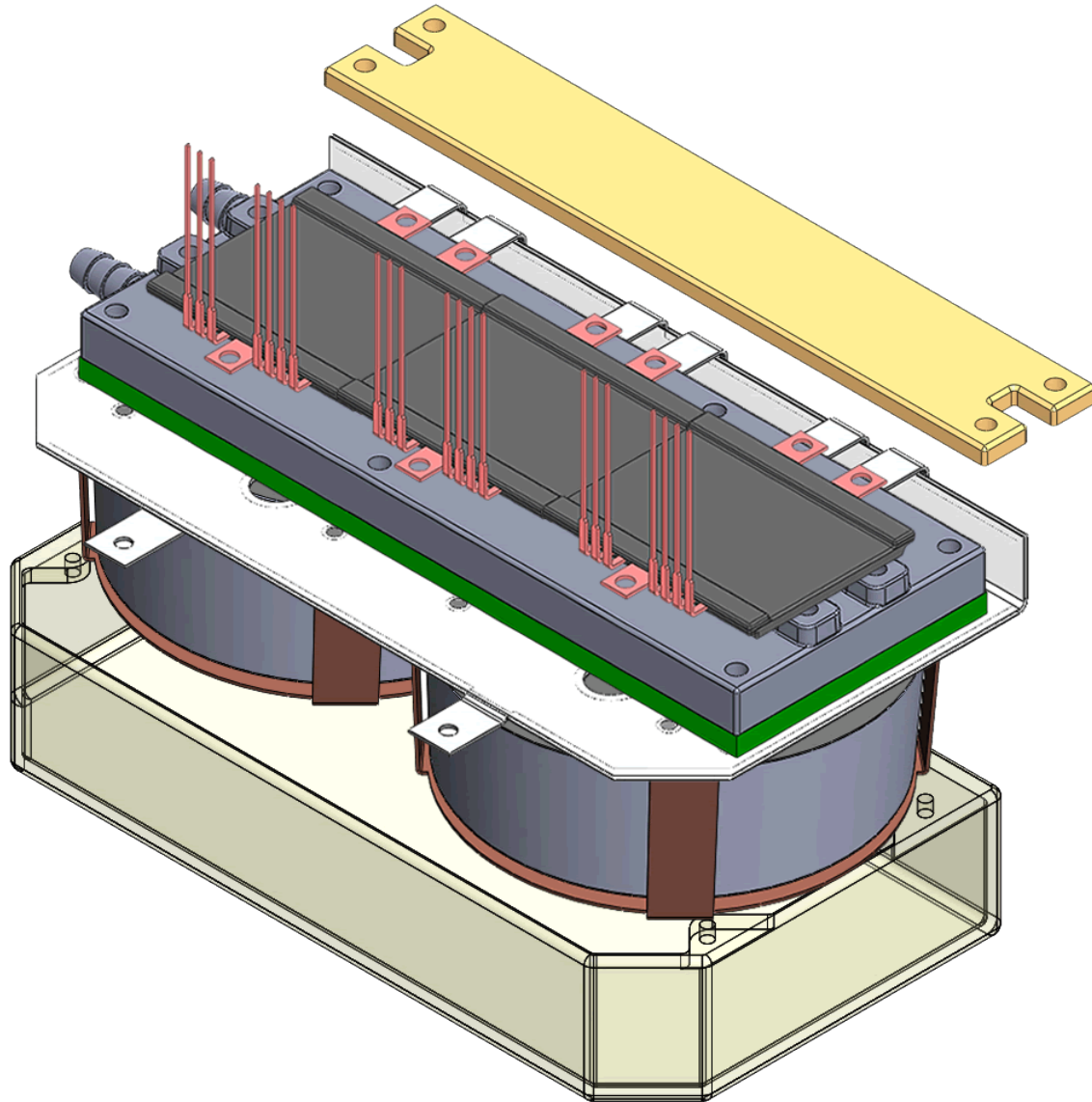
Next level of Integration Facilitated by SBE



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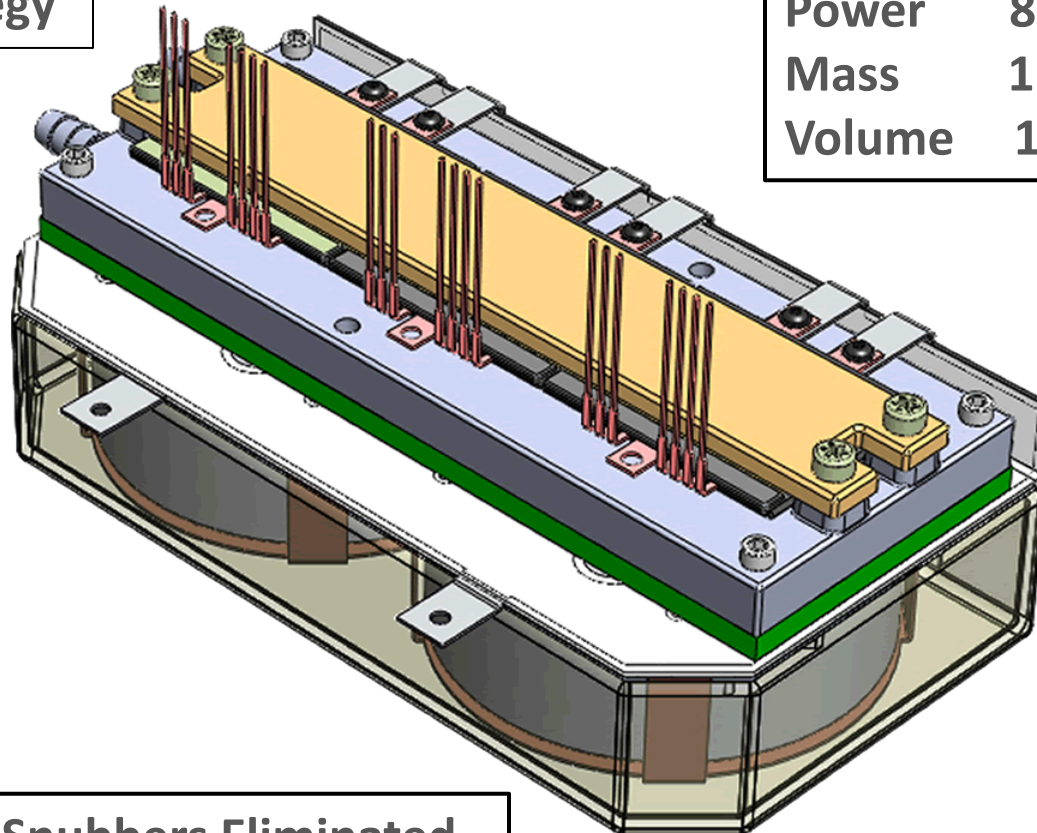


Next Level of Integration Facilitated by SBE



Next level of Integration Facilitated by SBE

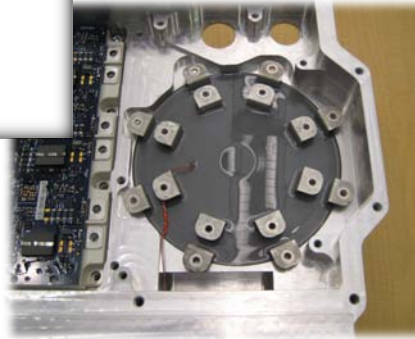
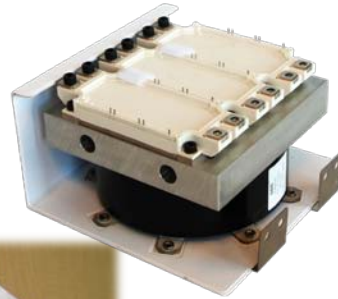
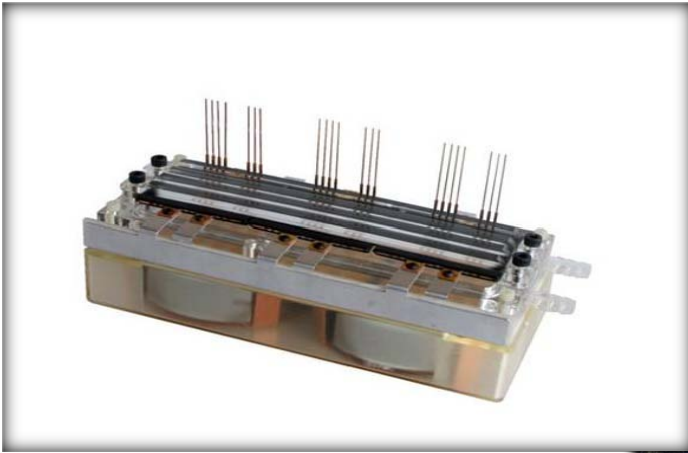
3D Design Strategy



| | |
|--------|--------|
| Power | 80 kw |
| Mass | 1.1 kg |
| Volume | 1.9 l |

Parts Reduced ,Snubbers Eliminated
~30% Mass & Volume Savings
~20 % Cost Savings

Power Ring Enables Flexible 3D Packaging



SBE Power Ring Capacitor

Design Simplification and Up-Integration Benefits

- **Now - Inverters**
 - Compact 3D Designs, Integration Parts Eliminated/Reduced
 - Power Densities up to 70 kw/kg and 40 kw/l
 - Mass and Size reductions of up to 30%
 - Snubber Components Eliminated
 - Cost Reduction up to 20%
- **Next - Electric Drives (Inverter & Motor) 105°C Operation**
 - Hybrid Vehicles
 - Eliminates dedicated thermal system and cost
 - Share engine cooling loop or direct mount in transmission
 - Electric Vehicles
 - Reduced size and cost of heat exchanger
 - Higher quality of heat for occupant compartment
 - Fuel Cell Vehicles
 - Eliminates dedicated thermal system and cost
 - Share cooling loop with fuel cell stack

