MILD-HYBRID 48 V DC DESIGN
混合動力車用48伏直流電源設計
APRIL, TAIPEI 2019
RYAN LIN
BUSINESS DEVELOPMENT ASIA
Market and Technology Leader

Semiconductors
- Low-voltage power MOSFETs
- Power rectifiers
- Infrared components
- TVS avalanche breakdown diodes

Passive Components
- Thin film SMD resistors
- Power inductors and custom magnetics
- Wirewound and other power resistors
- Wet and conformal-coated tantalum capacitors
- Capacitors for power electronics
- Leaded film resistors

### STRATEGIC ACQUISITIONS

<table>
<thead>
<tr>
<th>Year</th>
<th>Company</th>
<th>Year</th>
<th>Company</th>
</tr>
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<tbody>
<tr>
<td>2018</td>
<td>UltraSource</td>
<td>2000</td>
<td>Cera-Mite</td>
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<tr>
<td>2014</td>
<td>Capella Microsystems</td>
<td>1988</td>
<td>Electro-Films</td>
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<td></td>
<td>Holy Stone Polytech</td>
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<td>Spectrol</td>
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<td>2013</td>
<td>MCB Industrie</td>
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<td>Siliconix</td>
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<td>2012</td>
<td>HiRel Systems</td>
<td>1994</td>
<td>Telefunken</td>
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<td>Huntington Electric: Resistor businesses</td>
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<td>2007</td>
<td>International Rectifier: PCS business</td>
<td>1987</td>
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<td>2002</td>
<td>BCcomponents</td>
<td>1985</td>
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<td>Dale</td>
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<td>Infineon: Infrared components business</td>
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<td>Mallory (NACC)</td>
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<td>Tansitor</td>
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</table>
BALANCED PRODUCT PORTFOLIO

Vishay Revenues 2018
BROAD MARKET PENETRATION

28% AUTOMOTIVE
38% INDUSTRIAL
6% CONSUMER
5% POWER SUPPLIES
7% COMPUTING
5% MILITARY/AERO
7% TELECOM
4% MEDICAL

END MARKETS

39% ASIA
57% DISTRIBUTION
36% EUROPE
25% AMERICAS
7% EMS
36% OEM

GEOGRAPHY

SALES CHANNELS

Vishay Revenues 2018
48 V BOARDNET

- Key products for Bi-Directional DC/DC Converters 48 V / 12 V up to 3.5 kW and different topologies solutions (Cost and performance targets)
  - MOSFET
  - INDUCTOR
  - RESISTOR

- Electrical Machine Inverters 48 V up to 25 kW with Vishay power-stage solutions
  - CAPACITOR
  - SINTER MODULE
    - MOSFET
    - DIODES
    - NTC
48 V DUAL BOARDNET COMPONENTS

- 3.5kW Bi-Directional DC/DC
- DC/DC 12V Loads (< 600W) + 12V Battery Charging
- GND31
- TRM 30

48V Battery

- Term 40
- Term 41
- GND 41
- BMS

BMS

- DC
- INVERTER 48V / 15kW

48V Loads (>500W)

- E-Compressor (Supercharger)
- Active Chassis Control / Roll stabilization
- Engine Water pump
- Windscreen deicing
- Climate Compressor
- Engine Cooling
- Starter

Combustion Engine (ICE)
PMSM/GENERATOR BELT DRIVEN
48 V / 12 V DC/DC CONVERTER

- 6-PHASE, 3.5 KW
48 V / 12 V DC/DC CONVERTER

- 6-PHASE, 3.5 KW
# DC/DC 48 V / 12 V CONVERTER KEY COMPONENTS

<table>
<thead>
<tr>
<th>Part number</th>
<th>Division</th>
<th>Description and bullets</th>
</tr>
</thead>
</table>
| SQJQ112E    | MOSFET         | • HS Buck Boost Switch 100 V PowerPAK® 8x8L  
• Optimized for balanced conduction and switching losses in PWM applications  
• Very low output capacitance for high frequency operation                   |
| WSLP3921    | Resistors DALE | • Low Side Phase Current Sense Resistor  
• Low Ωic value; down to 0.0005  
• High Power with small footprint                                          |
| MAL218397805E3 | Aluminum Caps       | • LC Filter 48V Terminal  
• Low ESR high ripple current  
• High temperature (up to 125°C)  
• Low ESR (down to 20 mΩ)                                                              |
| IHDM1008BC  | DALE Magnetic   | • Input EMI (PI) Filter Inductor  
• Iron Powder, low DCR.  
• High current handling capability.  
• Low DCR loss and high saturation  
• Output Storage Inductors                                                           |
| IHDM1412BCSA | DALE Magnetic   | • Extremely Low DCR  
• High current handling capability                                                  |
Key products for Bi-Directional DC/DC Converters 48 V / 12 V up to 3.5 kW and different topologies solutions (Cost and performance targets)
- MOSFET
- INDUCTOR
- RESISTOR

Electrical Machine Inverters 48 V up to 25 kW with Vishay power-stage solutions
- CAPACITOR
- SINTER MODULE
  - MOSFET
  - DIODES
  - NTC
**POWER TRENCH MOSFETS**

- **Automotive Grade Gen 4 Split Gate Platform** in production from 30 V – 100 V
- **Roadmap for continuous optimization and improved efficiency** focuses on:
  - $R_{DS(ON)}$, $Q_g$, $Q_{oss}$, $Q_{rr}$

<table>
<thead>
<tr>
<th>Year</th>
<th>30V</th>
<th>40V</th>
<th>60V</th>
<th>80V</th>
<th>100V</th>
<th>150V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Now</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>Gen IV 30V 800MC 5mΩmm²</td>
<td>Gen IV 40V 530MC 7.6mΩmm²</td>
<td>Gen IV 60V, 134MC 20mΩmm²</td>
<td>Gen IV 80V 250MC 26mΩmm²</td>
<td>Gen IV 100V 250MC 40mΩmm²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gen V 80V Low $Q_g$ 20mΩmm²</td>
<td>Gen IV 80V 250MC 26mΩmm²</td>
<td>Gen IV 80V 250MC 26mΩmm²</td>
<td>Gen IV 100V Low $Q_g$ 30mΩmm²</td>
<td>Gen IV 150V 90mΩmm²</td>
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</tr>
</tbody>
</table>

- **Automotive Bond wireless package technology** released.

**New Material Set and lead frame design**
- Low Resistance
- Large Die Capability
- Robust BLR

**PowerPAK® SO8L**
Package Released
- 40 V 1.2 mΩ max – SQJA36EP
- 80 V 3.7 mΩ max – SQJ180EP

**PowerPAK® 8x8L**
Package Release Sep 2018
- 40 V 0.65 mΩ max – SQJQ140E
- 80 V 1.5 mΩ max – SQJQ184E

**PowerPAK® 8x8LR**
Reverse Concept. Sample July
Top Side Cooling Only
- 80 V 1.5 mΩ max – SQJQ184ER
# AUTOMOTIVE MOSFETS PACKAGE EVOLUTION

## Increased $I_{D\text{MAX}}$ (%)

<table>
<thead>
<tr>
<th>Package</th>
<th>Size</th>
<th>Increased $I_{D\text{MAX}}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOT23, TSOP6</td>
<td>(2.46mm x 2.7mm)</td>
<td>25%</td>
</tr>
<tr>
<td>SO-8</td>
<td>(4.9mm x 6mm)</td>
<td>100% (With BWL)</td>
</tr>
<tr>
<td>DPAK</td>
<td>(6.5mm x 10mm)</td>
<td>100%</td>
</tr>
<tr>
<td>D2PAK</td>
<td>(10mm x 15mm)</td>
<td>50%</td>
</tr>
<tr>
<td>D2PAK 7ld</td>
<td>(10mm x 15mm)</td>
<td>100%</td>
</tr>
<tr>
<td>PowerPAK SC70</td>
<td>(2.05mm x 2.05mm)</td>
<td></td>
</tr>
<tr>
<td>PowerPAK 1212W</td>
<td>(3.3mm x 3.3mm)</td>
<td></td>
</tr>
<tr>
<td>PowerPAK SO8L</td>
<td>(5.13mm x 6.15mm)</td>
<td></td>
</tr>
<tr>
<td>PowerPAK 8x8L</td>
<td>(8.0x8.1mm)</td>
<td></td>
</tr>
<tr>
<td>PowerPAK 8x8L BWL</td>
<td>PowerPAK 10x12?</td>
<td></td>
</tr>
</tbody>
</table>
## POWERPAK® SO-8L PACKAGE PORTFOLIO

<table>
<thead>
<tr>
<th>V_{DS} (V)</th>
<th>Part Number</th>
<th>V_{GS} (V)</th>
<th>R_{DS(ON)} 10V (mΩ)</th>
<th>R_{DS(ON)} 4.5V (mΩ)</th>
<th>Q_{th} (nC) Typ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>SQJ191EP</td>
<td>±20</td>
<td>210</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-100</td>
<td>SQJ111ELP</td>
<td>±20</td>
<td>24</td>
<td>34</td>
<td>51</td>
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<tr>
<td>-40</td>
<td>SQJ141ELP</td>
<td>±20</td>
<td>4.8</td>
<td>6.9</td>
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<tr>
<td>-30</td>
<td>SQJ131ELP</td>
<td>±20</td>
<td>2.8</td>
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<td>30</td>
<td>SQJA26EP</td>
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<td>0.55</td>
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<td>40</td>
<td>SQJA36EP</td>
<td>±20</td>
<td>1</td>
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<td>60</td>
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<td>±20</td>
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<td>80</td>
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<td>100</td>
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<td>5.2</td>
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<td>150</td>
<td>SQJ172EP</td>
<td>±20</td>
<td>32</td>
<td>40</td>
<td>12</td>
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**POWERPAK® 8X8L PACKAGE PORTFOLIO**

<table>
<thead>
<tr>
<th>P/N</th>
<th>Configuration</th>
<th>Package</th>
<th>Channel</th>
<th>VDS</th>
<th>VGS</th>
<th>IDMax. (A)</th>
<th>RDS(on)@10V</th>
<th>Qg@10V (nC)</th>
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<tbody>
<tr>
<td>SQJQ904E</td>
<td>Dual</td>
<td>PowerPAK 8 x 8L</td>
<td>N</td>
<td>40</td>
<td>20</td>
<td>100</td>
<td>0.0034</td>
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<td>PowerPAK 8 x 8L</td>
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<td>20</td>
<td>100</td>
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<td>PowerPAK 8 x 8L</td>
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<td>60</td>
<td>20</td>
<td>63</td>
<td>0.009</td>
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<td>SQJQ980EL</td>
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<td>20</td>
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<td>20</td>
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<td>0.0015</td>
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<td>20</td>
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<td>20</td>
<td>135</td>
<td>0.0034</td>
<td>97</td>
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</tbody>
</table>

*Production Version
Package Resistance: ~0.4 mΩ
Current Rating: 400 A*
48 V BOARDNET

- Key products for Bi-Directional DC/DC Converters 48 V / 12 V up to 3.5 kW and different topologies solutions (Cost and performance targets)
  - MOSFET
  - INDUCTOR
  - RESISTOR

- Electrical Machine Inverters 48 V up to 25 kW with Vishay power-stage solutions
  - CAPACITOR
  - SINTER MODULE
    - MOSFET
    - DIODES
    - NTC
When symmetrical coupled inductor is used, each inductor current has better shared phase current compared with asymmetrical coupled inductor.
CONCLUSION:

Symmetrical as well as asymmetrical coupled inductors are known to offer advantages in applications requiring fast response — they allow reducing ripple current while keeping the leakage inductance, which determines transient response, constant. In applications where transient response is not important, low leakage inductance is also advantageous, because it corresponds to low energy storage, and thus smaller less expensive inductors. We have experimentally demonstrated good performance with coupled inductors in an automotive multi-phase dc-dc converter, using symmetrical coupled inductors. Improved performance would be possible with better winding construction and/or custom designed solutions.
48 V / 12 V CONVERTER SOLUTIONS

- **Three Phase** with 3 single Output Inductors
- Three Phase **symmetrical coupled** Inductor solutions
- Three-Phase **non symmetrical coupled** Inductor solution
- **Six Phase** single Inductor
- **Four Phase** single Inductor

Using coupled inductor the ripple current is smaller than using non coupled inductor, and moreover with increasing coupled factor the ripple current can be reduced with significant degrade scaling.
IHDM INDUCTORS FOR STORAGE AND FILTERING

• Customized power Inductors for 48 V Filtering and Storage
  - Voltage Breakdown: 700 V to 1500 V
  - Temperature range: 200 – 220°C
  - Terminal: Fla Wire / Customized
  - Core material: Composite / Iron-Powder

We have different termination options available:

- SMD with or without stabilization
- THT with or without header
- Press Fit Pins ... or custom solution

IHDM: Stable inductance over temperature
Ferrite: Current rating went down by ca. 13 A
48 V / 12 V DC/DC CONVERTER OUTPUT STORAGE INDUCTOR IHDM1008BZEB6R4MVA

3.5 kW Output Storage Inductor 6.4 µH

**ELECTRICAL SPECIFICATIONS:**

Inductance (µH)

\[ L_{0x} = 6.4\,\mu\text{H} \pm 20\% \]

**Estimated Core Loss:** 80kHz

\[ I_{rip} = 20A_{pk-pk} : 2.2\text{W nominal} \]

\[ I_{rip} = 10A_{pk-pk} : 0.8\text{W nominal} \]

**Temperature rise**

\[ \Delta T = 40^\circ\text{C} @ 45ADC \]

**Saturation Current**

\[ L = 3.5\,\mu\text{H min.} @ 85A \]

**AC Copper Loss**

\[ I_{rip} = 20A_{pk-pk} : 0.4W nominal \]

\[ I_{rip} = 10A_{pk-pk} : 0.1W nominal \]

**Material**

Core: Powdered Iron Alloy

Solder: Hot-dipped Sn.

Wire: 200°C Polyimide-amide insulation

**Resistance**

\[ R_{DC} = 1\,\text{mΩ nominal} \]

\[ R_{DC} = 1.2\,\text{mΩ max} \]

**Operating Temperature**

-40°C ~ 180°C

Including Self-Heating
IHSR6767GZ-5A 12 V OUTPUT FILTER HIGH CURRENT @130 A

Instead of 2 pcs

220nH

**STANDARD ELECTRICAL SPECIFICATIONS**

<table>
<thead>
<tr>
<th>L&lt;sub&gt;0&lt;/sub&gt;</th>
<th>DCR mΩ rms</th>
<th>TYPICAL 25°C</th>
<th>MAX 25°C</th>
<th>HEAT RATING CURRENT DC AMPS</th>
<th>TYPICAL 20%</th>
<th>SATURATION CURRENT DC AMPS</th>
<th>TYPICAL 100%</th>
<th>SATURATION CURRENT DC AMPS</th>
<th>TYPICAL 1200%</th>
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</thead>
<tbody>
<tr>
<td>0.100</td>
<td>0.09</td>
<td>0.09</td>
<td>0.16</td>
<td>165</td>
<td>120</td>
<td>80</td>
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<tr>
<td>0.120</td>
<td>0.10</td>
<td>0.14</td>
<td>0.17</td>
<td>175</td>
<td>115</td>
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<td>0.150</td>
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<td>0.16</td>
<td>0.18</td>
<td>165</td>
<td>112</td>
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<td>0.180</td>
<td>0.19</td>
<td>0.20</td>
<td>0.20</td>
<td>144</td>
<td>110</td>
<td>50</td>
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<tr>
<td>0.200</td>
<td>0.23</td>
<td>0.25</td>
<td>0.25</td>
<td>132</td>
<td>107</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**
1. All test data is referenced to 25°C ambient.
2. Operating Temperature Range: -55°C to +155°C
3. DC current (A) that will cause an approximate T of 40°C.
4. DC current (A) that will cause Lo to drop approximately 20%
5. DC current (A) that will cause Lo to drop approximately 30%
6. The part temperature (ambient + temp rise) should not exceed 155°C under worst case operating conditions. Circuit design, component placement, PWB trace size and thickness, airflow and other cooling provisions all affect the part temperature. Part temperature should be verified in the end application.
48 V / 12 V DC/DC CONVERTER IHDM INPUT FILTER 48 V
IHDM0907AHEB1R7MVA

1.7 μH Differential Mode EMI Filter Inductor

**DIMENSIONAL OUTLINE (mm)**

**ELECTRICAL SPECIFICATIONS:**
- Inductance (μH)
  \( L_{0A} = 1.7\,\mu\text{H} \pm 20\% \)
- Resistance
  \( R_{DC} = 0.40\,\Omega \pm 15\% \) at 25°C
- Operating Temperature
  -40°C to 180°C Including Self-Heating

**Saturation Current**
\[ L = 1\,\mu\text{H Nominal} @ 140\,\text{ADC} \]

**Material**
- Core: Powdered Iron Alloy
- Wire: 200°C, PAI Insulated
- Solder: Hot Dipped Tin

**Temp Rise**
\[ \Delta T = 40°C @ 60\,\text{ADC} \]

**Weight**
35g Nominal
48 V BOARDNET

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  - MOSFET
  - INDUCTOR
  - RESISTOR

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  - CAPACITOR
  - SINTER MODULE
    - MOSFET
    - DIODES
    - NTC
48 V DUAL BOARDNET SOLUTIONS CURRENT SENSE RESISTORS

Power Stage

DERATING - TERMINAL TEMPERATURE

DERATING - TERMINAL TEMPERATURE

STANDARD ELECTRICAL SPECIFICATIONS

GLOBAL MODEL | SIZE | POWER RATING Pwr [W] | TOLERANCE ± % | RESISTANCE VALUE RANGE [Ω] | WEIGHT (typical) g/1000 pieces
--- | --- | --- | --- | --- | ---
WSK1216 | 1216 | 3.0 | 1.0 | 1Ω | 4.26
WSK1216 | 1216 | 6.0 | 1.0 | 0.5m | 4.26

DIMENSIONS in millimeters

| MODEL | W | L | H | R (REF.) | S | U | N |
--- | --- | --- | --- | --- | --- | --- | --- |
WSK1216 | 0.122 ± 0.014 | 0.150 ± 0.012 | 0.075 ± 0.014 | 0.106 | 0.020 ± 0.004 | 0.031 ± 0.012 | 0.024 ± 0.006 |

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CAPACITORS • DIODES • INDUCTORS • MOSFETs • OPTOELECTRONICS • RESISTORS
CURRENT SENSE TECHNOLOGY
HIGH POWER, LOW RESISTANCE

Multiple Package Sizes (0603 to 5931)

<table>
<thead>
<tr>
<th>Resistive</th>
<th>Hall Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly linear</td>
<td>Low linearity</td>
</tr>
<tr>
<td>Stable over temperature</td>
<td>High variation with temperature</td>
</tr>
<tr>
<td>No measurement latency</td>
<td>May have excessive measurement latency</td>
</tr>
<tr>
<td>No saturation</td>
<td>Saturation mode when current range is exceeded</td>
</tr>
<tr>
<td>No additional power supply</td>
<td>Additional power supply required</td>
</tr>
<tr>
<td>Low cost</td>
<td>Higher cost</td>
</tr>
</tbody>
</table>

WSBS8518 Custom Shunts, high power, 50 µΩ - 500 µΩ
SHUNT RESISTOR

**WSLP0603**
- 0.4 WATT
- 10mΩ to 100mΩ

**WSLP0805**
- 0.5 WATT
- 5mΩ to 50mΩ

**WSLP1206**
- 1 WATT
- 1mΩ to 50mΩ

**WSLP2010**
- 2 WATT
- 1mΩ to 30mΩ

**WSLP2512**
- 3 WATT
- 0.5mΩ to 10mΩ

**WSLF2512**
- 0.3mΩ to 0.5mΩ
- 3mΩ

**WSLP3921**
- 0.2mΩ to 1mΩ
- 0.5mΩ to 1mΩ

**WSLP5931**
- 0.2mΩ to 0.5mΩ
- 1mΩ to 3mΩ

**WSLP2726**
- 0.3mΩ to 1mΩ
- 2.0 mΩ to 4 mΩ

**WSLP4026**
- 0.3mΩ to 1mΩ
- 2 mΩ to 4 mΩ
48 V BOARDNET

- Key products for Bi-Directional DC/DC Converters 48 V / 12 V up to 3.5 kW and different topologies solutions (Cost and performance targets)
  - MOSFET
  - INDUCTOR
  - RESISTOR

- Electrical Machine Inverters 48 V up to 25 kW with Vishay power-stage solutions
  - CAPACITOR
  - SINTER MODULE
    - MOSFET
    - DIODES
    - NTC
48 V INVERTER SOLUTIONS

P0: The e-motor is installed in the belt drive system of combustion engine (ICS)

P1: The e-motor is fixed to the crankshaft of the combustion engine

P2: The e-motor is installed between combustion engine and transmission

P3: The e-motor is located between transmission and differential

P4: The E-Motor torque directly on axle drive

P0: Max. cont. power 3.5 kW (peak 14 kW)
Discrete solution possible, Sintering better

P1: Max. cont. power is 5-8 kW (peak 18 kW):
Sintering Module

P2: Max. cont. power is up to 13kW (peak 21 kW):
Sintering Module

P3: Max. cont. power up to 15-18kW (peak 25 kW)
Sintering Module

P4: Max. power for LSEV 25 kW
Sintering Module
CUSTOMIZED MKT DC-LINK FILM CAPACITORS

**48 V Applications Highlights**

- AEC-Q200 Rev D approved –Automotive Grade
- High Temperature Capabilities: especially designed for 48V Board Net high temperature operations, 125°C continuously and up to 150°C for a limited time
- Capacitance range: up to 1000 μF
- Low inductance, low ESR
- High continuous ripple currents
- Self healing properties during operation
- Bus bar connections in line with customer needs

<table>
<thead>
<tr>
<th>48V Board Net</th>
<th>DC/DC Converter</th>
<th>DC-LINK</th>
<th>MKT1820</th>
</tr>
</thead>
<tbody>
<tr>
<td>eBooster</td>
<td>DC-FILTER</td>
<td>MKP1848</td>
<td></td>
</tr>
<tr>
<td>Starter Generator</td>
<td>DC-LINK</td>
<td>MKT1820</td>
<td></td>
</tr>
</tbody>
</table>

**MKT1820**
- Capacitance up to 560μF
- High temperature operation up to 150°C
- Customization possible

**MKP1848**
- Standard capacitance value up to 400μF
- High Ripple current capabilities / Low ESR
- Long Lifetime
Attached to the DC-side of the inverter is a DC-link Capacitor whose main functions include filtering of the DC-side voltage and attenuation of the ripple currents that are drawn from the DC-link by the inverter. DC-link capacitors do not only fill a very important role in the operation of a typical MHEV & EV driveline but are most often bulky and heavy and can contribute to a significant portion of the total inverter volume and weight. Minimizing the parasitic elements such as the stray inductances inside the inverter and the DC-link capacitor is another way to try and decrease the resulting switching transients. Studies have also shown that the values of the parasitic elements, e.g. capacitor and cable series resistance and inductance can greatly impact both current and voltage ripple.
CUSTOMIZED DC-LINK FILM CAPACITORS

- **Basic properties customized designs**
  - Nominal voltage: 63 V series
  - Design is based on 1,4μm metallized polyester, special profile for high temperature and low ESR
  - Standard bus bar connection

- **Voltage:**
  - 48 V up to 105 °C < 15,000h
  - 48 V up to 125 °C < 6,000h
  - 48 V up to 140 °C < 150h

### Typical Values

<table>
<thead>
<tr>
<th>Capacitance</th>
<th>Film</th>
<th>Volume</th>
<th>μF/cm³</th>
<th>ESL (nH)</th>
<th>ESR</th>
<th>I_{rms}</th>
<th>hot spot</th>
<th>Pd</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PET</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>330</td>
<td>1,4</td>
<td>68</td>
<td>4,8</td>
<td>10</td>
<td>1,5</td>
<td>70</td>
<td>125</td>
<td>7,4</td>
</tr>
<tr>
<td>470</td>
<td>1,4</td>
<td>104</td>
<td>4,5</td>
<td>10</td>
<td>1,0</td>
<td>85</td>
<td>125</td>
<td>7,2</td>
</tr>
<tr>
<td>1000</td>
<td>1,4</td>
<td>225</td>
<td>4,4</td>
<td>10</td>
<td>0,6</td>
<td>110</td>
<td>125</td>
<td>7,3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>if PP</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>2,4</td>
<td>972</td>
<td>1,0</td>
<td>5</td>
<td>0,40</td>
<td>300</td>
<td>105</td>
<td>34,4</td>
</tr>
<tr>
<td>1000</td>
<td>1,9</td>
<td>700</td>
<td>1,4</td>
<td>5</td>
<td>0,55</td>
<td>250</td>
<td>105</td>
<td>34,4</td>
</tr>
</tbody>
</table>

* with cooling
**POWER TRENCH MOSFETS FOR 48 V STARTER GENERATOR**

**KGD 100 V**

**Known Good Die (KGD)**
- Range of die sizes: 1 mm x 1 mm to 8 mm x 12 mm
- 100 V Gen 4 MOSFET process can provide $R_{DS(on)}$ down to 0.5 mΩ typ @ 10 V
- Typical die thickness: 200 um
- Common Back Metal: TiNiAg 0.14 u/0.4 u/0.3 u – Custom recipes can be defined
- Common Top Metal: AlCu 5u – 2.8u to 6u in production
- Plating for Bond Wireless – NiPdAu
- Cu Pad Plating through third party (Commercial release) 20 u Cu + 20u solder cap

<table>
<thead>
<tr>
<th>Wafer Test &amp; Galaxy PAT Map</th>
<th>KGD Test Site Technology</th>
<th>Testing &amp; In Line Visual Inspection</th>
<th>Olympus 3D Probe Inspection</th>
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</thead>
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<tr>
<td><img src="image1.png" alt="Wafer Test &amp; Galaxy PAT Map" /></td>
<td><img src="image2.png" alt="KGD Test Site Technology" /></td>
<td><img src="image3.png" alt="Testing &amp; In Line Visual Inspection" /></td>
<td><img src="image4.png" alt="Olympus 3D Probe Inspection" /></td>
</tr>
</tbody>
</table>

- Wafers are PAT tested at elevated Temperature (85deg)
- Dynamic PAT (6 sigma) and SYA (3 sigma) testing
- 10 high precision sockets with built-in die re-centering
- Full-Kelvin testing for accurate $R_{ds(on)}$ down to sub-mΩ
- Testing stations up to 5 sites.
- Multiple vision inspection to ensure detection of any mechanical defects
- Real-time Probe mark (depth and size) inspection tool to control the probe mark
48 V CONVERTER AND INVERTER MOSFETS BOND-WIRELESS (COPPER CLIP)

- Cuts Resistance by 50%
- Lower Inductance
- SQJA44EP with 2.1 mΩ (40 V)
- SQJA36EP with 1.2 mΩ (40 V)

PowerPAK® SO-8L

- Reduce Package-Resistance contribution from 52% to 29%
- Lower Inductance
- SQJQ144EL with 0.63 mΩ (40 V)

PowerPAK® 8x8L

Resistive Elements for 40V

- Al Wire Bond
  - Silicon Resistance (Vgs = 10V)
  - Package Resistance

- BWL
  - 52%
  - 29%
  - 48%
  - 71%
For systems where the heat path through the PCB is not effective we are introducing a PowerPAK® 8x8L derivative optimized for Top Side Cooling

- Development Vehicle is the SQJQ184ER – 80V, 1.5mΩ max
- Any device in the conventional package roadmap, (slide 29), can be supported in this reverse package
- Solderable Gull-Wing leads offer highest degree of stress relief for harsh environmental conditions
- Nickel top surface
BLDC MOTOR DRIVE WITH POWERPAK 8X8L FOR HIGHER POWER WITH TOP-COOLING
# MILD HYBRID (BSG / ISG) SINTER MODULES UP TO 25 KW

**CuSiAg** stands for:
- high integration density, load capacity & service life
- an optimized production process
- with reduced system costs

**Sintering instead of soldering**:
- the heat dissipation from the semiconductor is significantly improved by sintering.
- the sintered compound is stable up to the melting point of the silver (962 °C), solder ages thermally from 125 °C.
- reduced chip area with increased ampacity

**Clips instead of bonding wires**:
- the Cu clip leads to an smooth lead of current into the semiconductor, no punctiform load of the chip as with the bonding wire.
- shorter process time
- higher output

**DCB, soldered & bonded**

| R<sub>th</sub> = 1,52 K/W, cost |

**Leadframe, sintered**

| R<sub>th</sub> = 0,74 K/W, cost |
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- Electrical Machine Inverters 48 V up to 25 kW with Vishay power-stage solutions
  - CAPACITOR
  - SINTER MODULE
    - MOSFET
    - DIODES
    - NTC
48 V INVERTER SINTERING MODULES UP TO 25 KW

Worst Case: static 725 A ➔ Tmax = 141°C
SINTER MODULE SOLUTIONS

48 V Battery Safety Switch with Pre-Charging

Vishay Design

800A@ 9x MOS
550A@ 6x MOS
400A@ 4x MOS