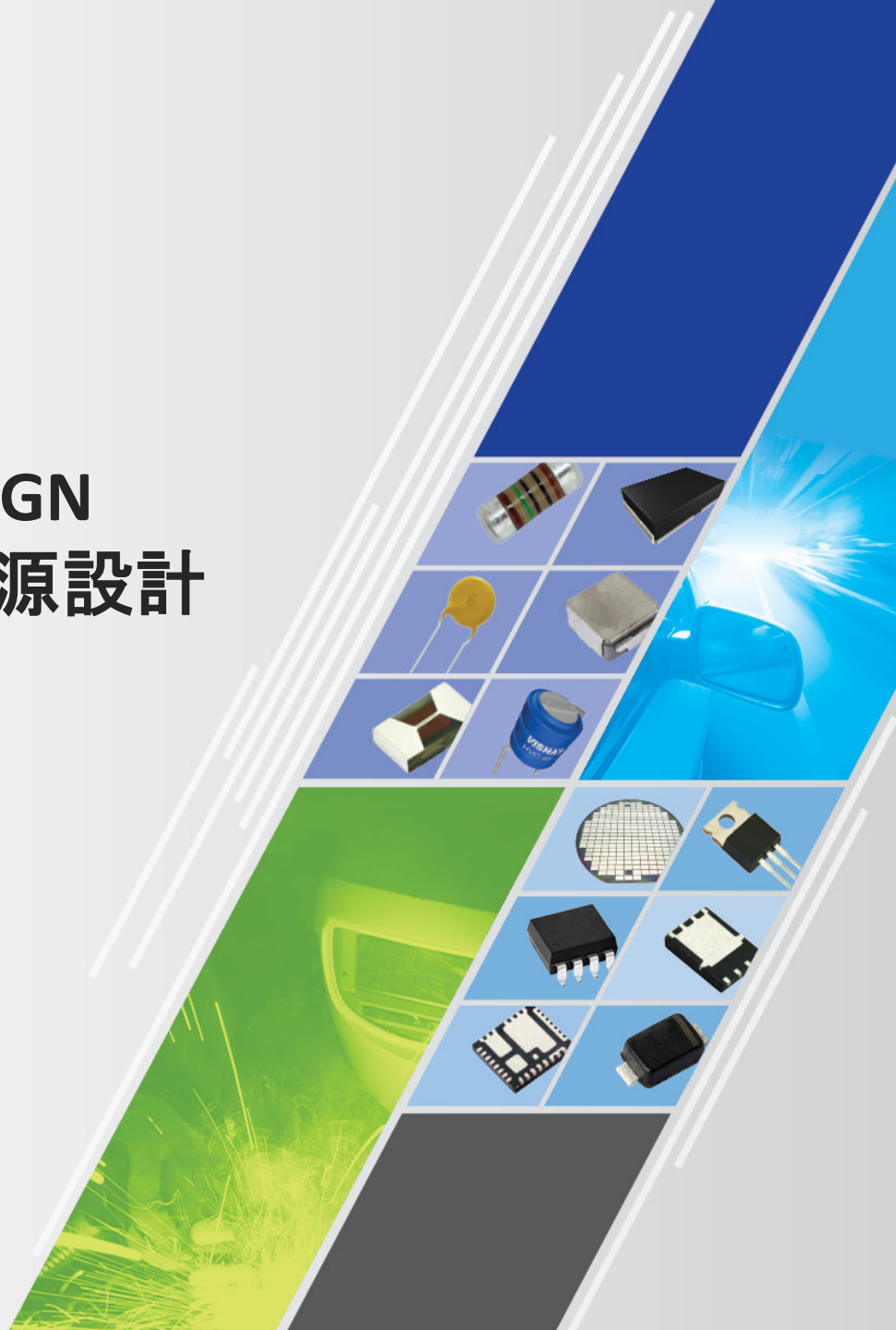
# MILD-HYBRID 48 V DC DESIGN
# 混合動力車用48伏直流電源設計

## APRIL, TAIPEI 2019


## RYAN LIN

## BUSINESS DEVELOPMENT ASIA

A WORLD OF SOLUTIONS™

# Market and Technology Leader

## Semiconductors

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

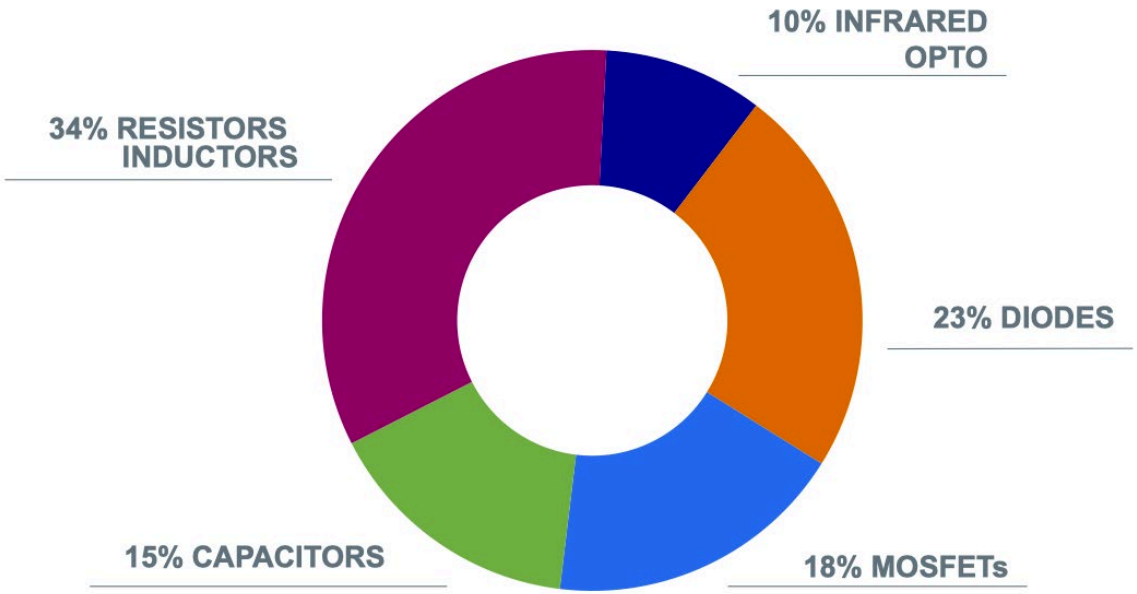
## Passive Components

- 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

| | |
|---|---|
| 2018 | UltraSource |
| 2014 | Capella Microsystems<br>Holy Stone Polytech |
| 2013 | MCB Industrie |
| 2012 | HiRel Systems |
| 2011 | Huntington Electric: Resistor businesses |
| 2008 | KEMET: Wet tantalum capacitor business |
| 2007 | International Rectifier: PCS business |
| 2002 | BCcomponents<br>Beyschlag |
| 2001 | General Semiconductor<br>Infineon: Infrared components business<br>Mallory (NACC)<br>Tansitor |
| 2000 | Cera-Mite<br>Electro-Films<br>Spectrol |
| 1998 | Siliconix<br>Telefunken |
| 1994 | Vitramon |
| 1993 | Roederstein |
| 1992 | Sprague |
| 1988 | Sfernice |
| 1987 | Draloric |
| 1985 | Dale |

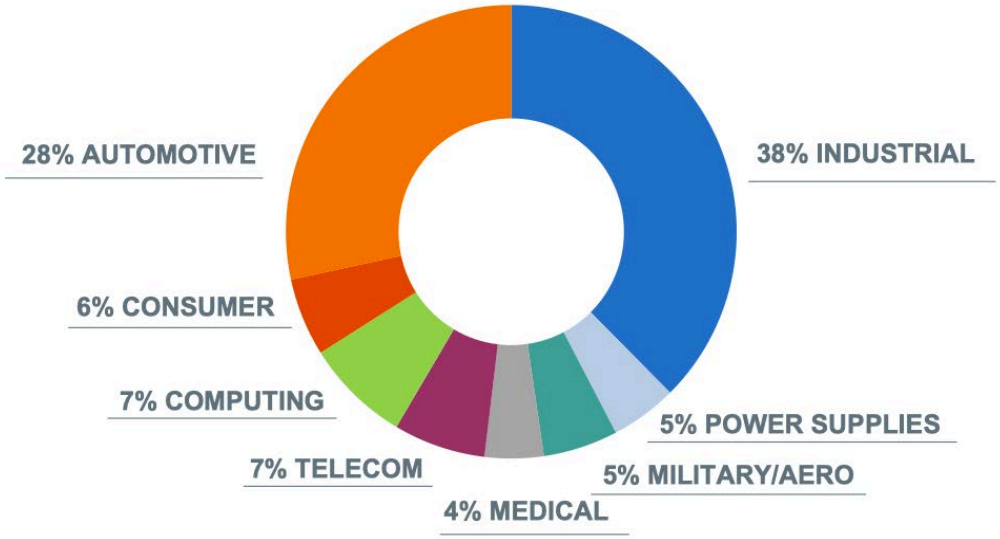
# BALANCED PRODUCT PORTFOLIO

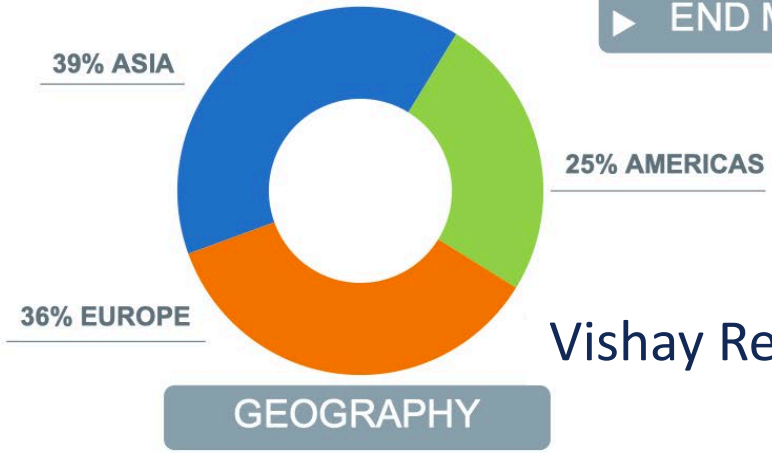


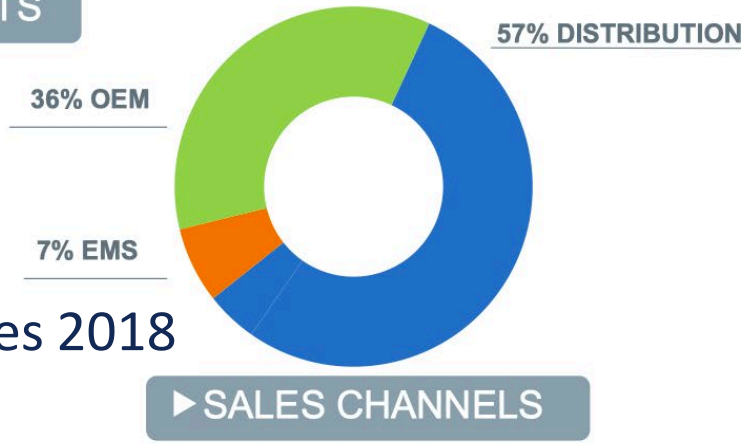

| 49% | PASSIVES | 51% | SEMICONDUCTORS |
|---|---|---|---|

Vishay Revenues 2018

# BROAD MARKET PENETRATION



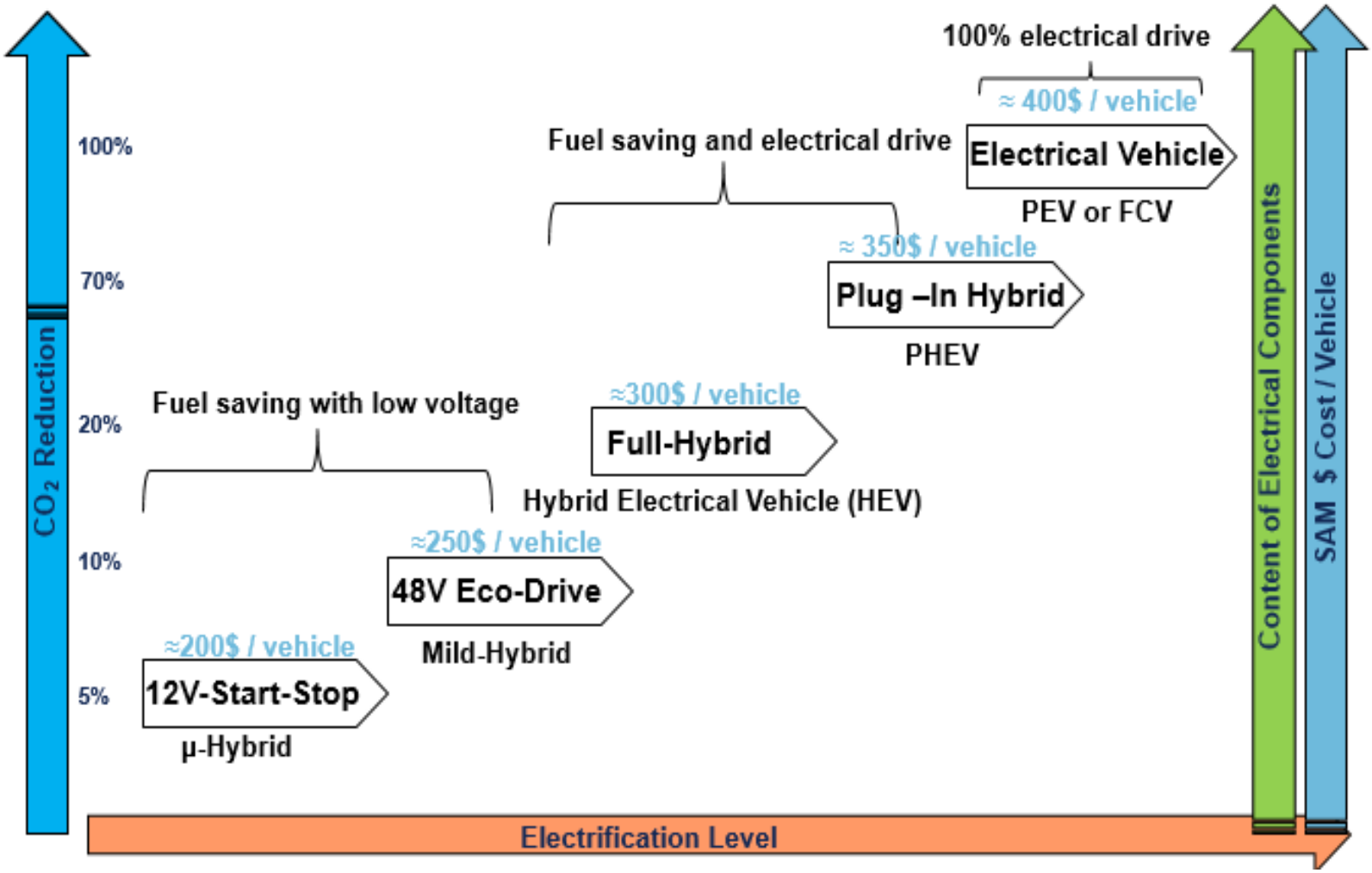

Vishay Revenues 2018

# 48 V BOARDNET

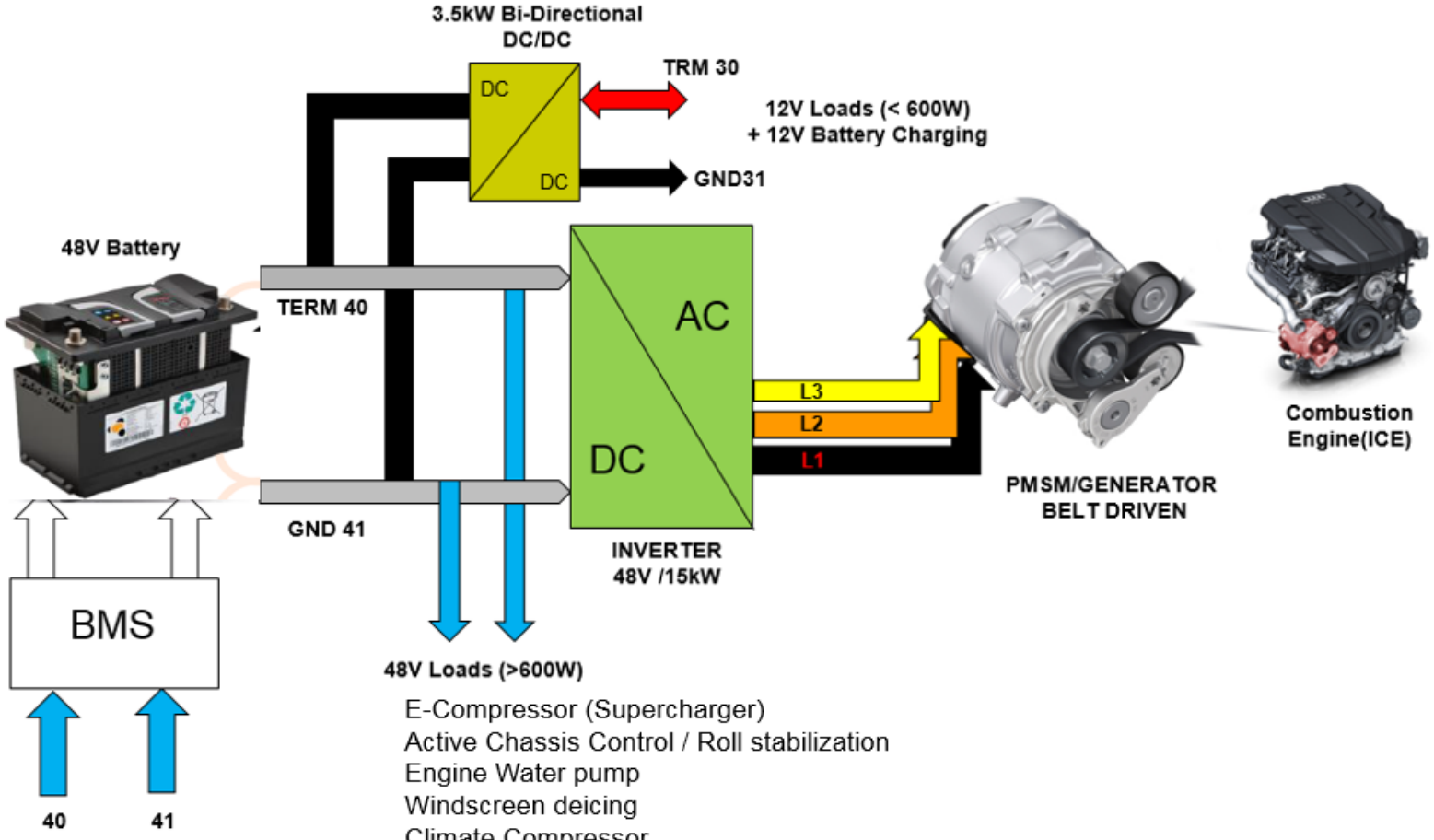
- **Key products for Bi-Directional DC/DC Converters 48 V / 12 V up to 3.5 kW and different topologies solutions (Cost and performance targets)**
  - **MOSFET**
  - **INDUCTOR**
  - **RESISTOR**

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

# ELECTRIFICATION



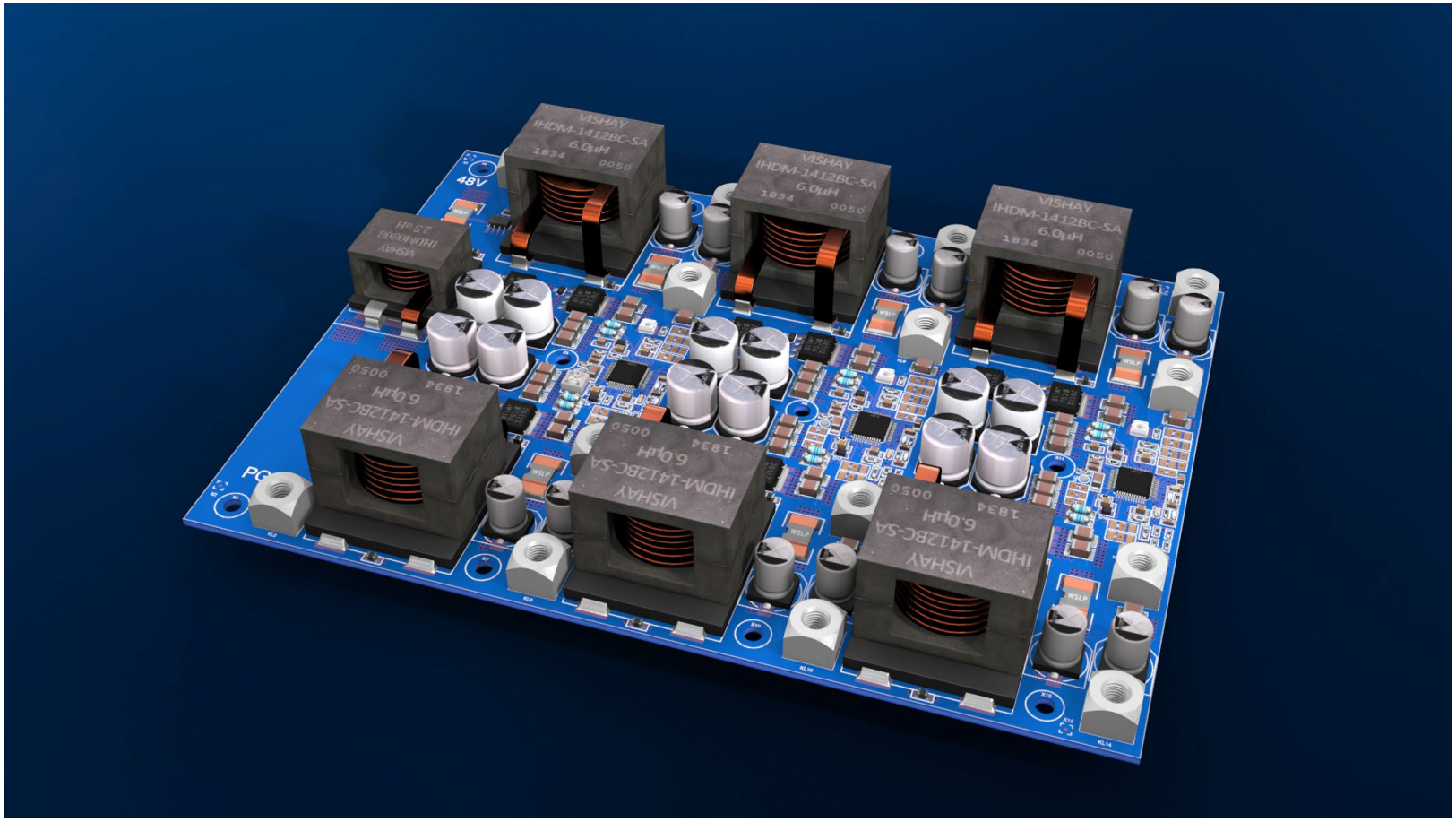
# 48 V DUAL BOARDNET COMPONENTS




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

# 48 V / 12 V DC/DC CONVERTER

- 6-PHASE, 3.5 KW



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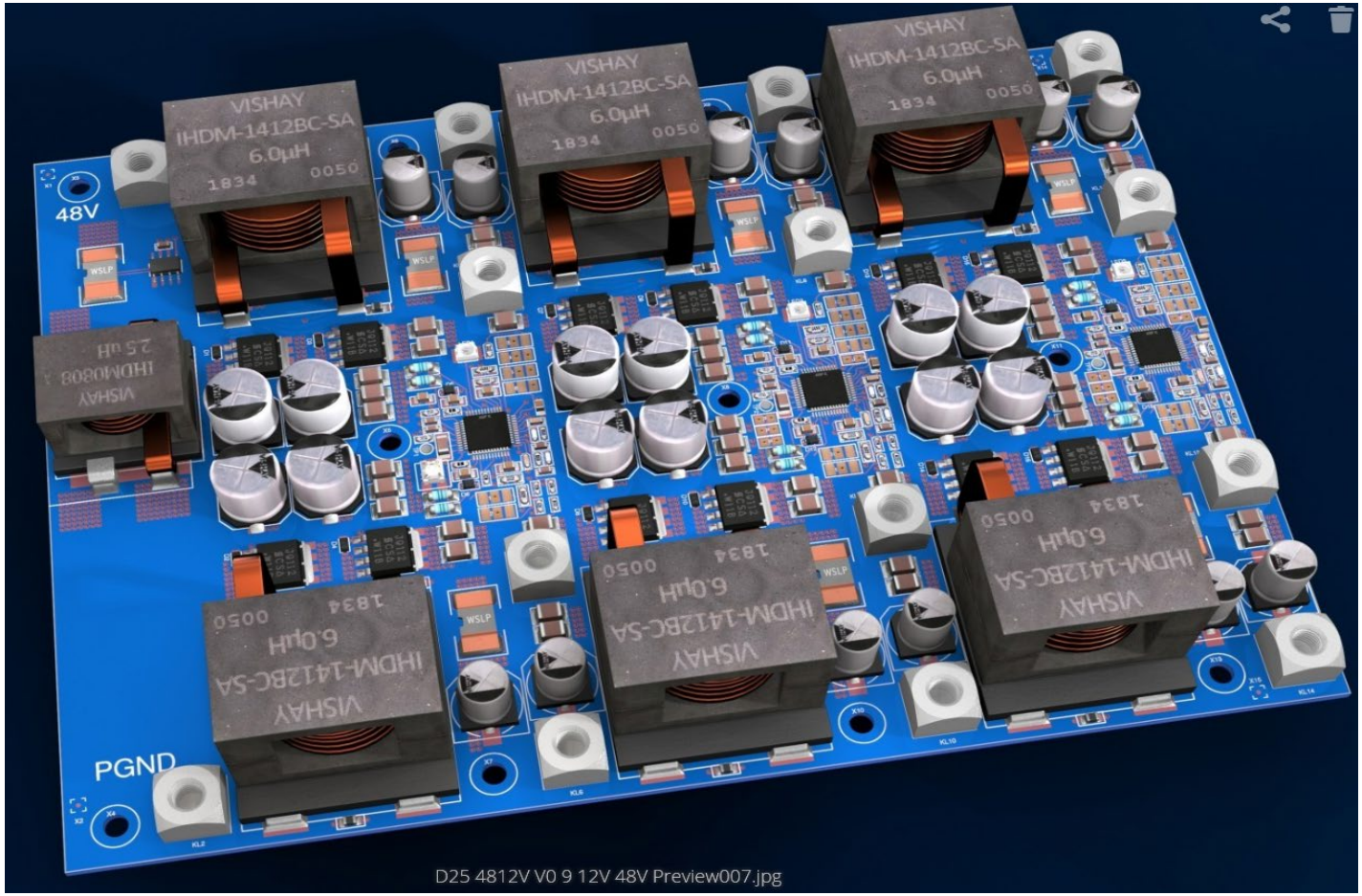

# DC/DC 48 V / 12 V CONVERTER KEY COMPONENTS

| Part number | Division | Description and bullets |
|---|---|---|
| SQJQ112E | MOSFET | •HS Buck Boost Switch 100 V PowerPAK® 8x8L<br>•Optimized for balanced conduction and switching losses in PWM applications<br>•Very low output capacitance for high frequency operation |
| WSLP3921 | Resistors DALE | •Low Side Phase Current Sense Resistor<br>•Low Ωic value; down to 0.0005<br>•High Power with small footprint |
| MAL218397805E3 | Aluminum Caps | •LC Filter 48V Terminal<br>•Low ESR high ripple current<br>•High temperature (up to 125℃)<br>•Low ESR (down to 20 mΩ) |
| IHDM1008BC | DALE Magnetic | •Input EMI (PI) Filter Inductor<br>•Iron Powder, low DCR.<br>•High current handling capability.<br>•Low DCR loss and high saturation |
| IHDM1412BCSA | DALE Magnetic | •Output Storage Inductors<br>•Extremely Low DCR<br>•High current handling capability |

# 48 V BOARDNET

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  - **MOSFET**
  - INDUCTOR
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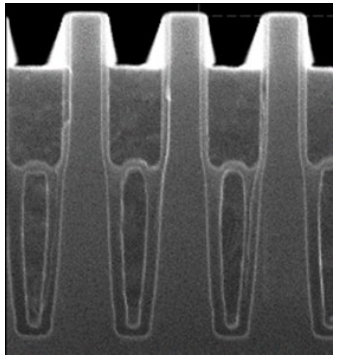
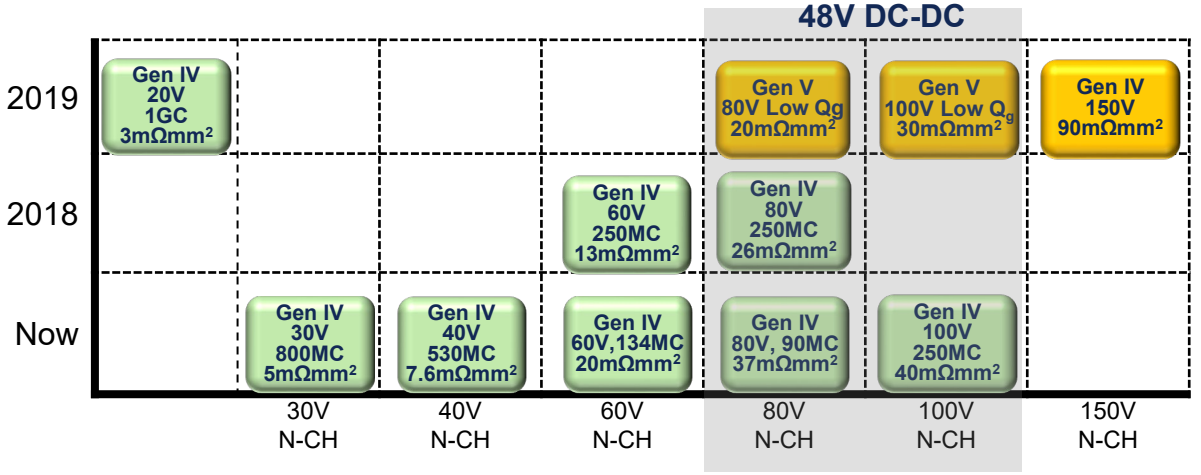
  - CAPACITOR
  - SINTER MODULE
    - MOSFET
    - DIODES
    - NTC

# POWER TRENCH MOSFETS

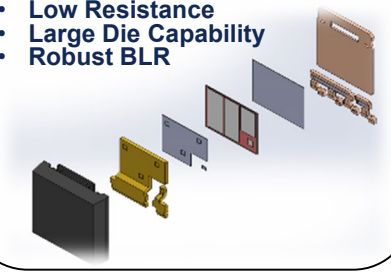
- Automotive Grade Gen 4 Split Gate Platform in production from 30 V – 100 V
- Roadmap for continuous optimization and improved efficiency focusses on:
  - $R_{DS(ON)}$, Qg, Qoss, Qrr





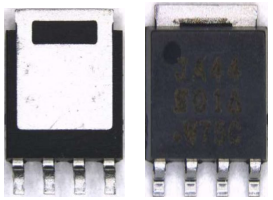

- **Automotive Bond wireless package technology released.**

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



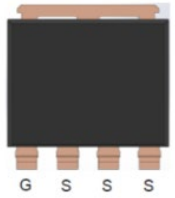
⇨

**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**

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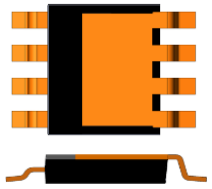
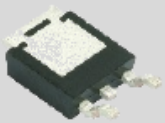
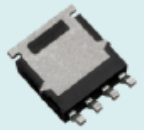
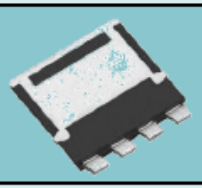
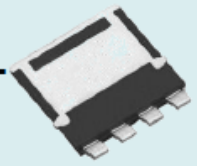
**PowerPAK® 8x8LR**
**Reverse Concept. Sample July**
**Top Side Cooling Only**
**80 V 1.5 mΩ max – SQJQ184ER**



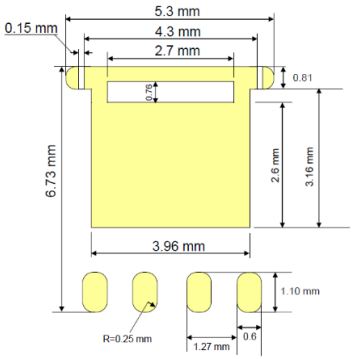
# AUTOMOTIVE MOSFETS PACKAGE EVOLUTION

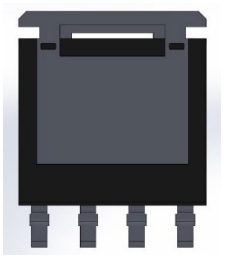
## Increased $I_{DMAX}$ (%)

| | | | |
|---|---|---|---|
| SOT23, TSOP6 (2.46mm x 2.7mm)  | 25% | | PowerPAK SC70 (2.05mm x 2.05mm)  |
| SO-8 (4.9mm x 6mm)  | 100% (With BWL) | | PowerPAK 1212W (3.3mm x 3.3mm)  |
| DPAK (6.5mm x 10mm)  | 100% | | PowerPAK SO8L (5.13mm x 6.15mm)  |
| D2PAK (10mm x 15mm)  | 50% | | PowerPAK 8x8L (8.0x8.1mm)  |
| D2PAK 7ld (10mm x 15mm)  | 100% | | PowerPAK 8x8L BWL PowerPAK 10x12?  |

# POWERPAK® SO-8L PACKAGE PORTFOLIO

| $V_{DS}$ (V) | Part Number | $V_{GS}$ (V) | $R_{DS(ON)}$ 10V (mΩ) | | $R_{DS(ON)}$ 4.5V (mΩ) | | $Q_g$ (nC) Typ. | |
|---|---|---|---|---|---|---|---|---|
| | | | Typ. | Max | Typ. | Max | 10$V_{GS}$ | 4.5$V_{GS}$ |
| -200 | SQJ191EP | ±20 | | 210 | | | | |
| -100 | SQJ111ELP | ±20 | 20 | 24 | 28 | 34 | 51 | 25 |
| -40 | SQJ141ELP | ±20 | | 4.8 | | 6.9 | 169 | 90 |
| -30 | SQJ131ELP | ±20 | | 2.8 | | 5.1 | 169 | 90 |
| 30 | SQJA26EP | ±20 | 0.55 | 0.7 | 0.95 | 1.15 | 125 | 56 |
| 40 | SQJA36EP | ±20 | 1 | 1.2 | - | - | 86 | - |
| 60 | SQJ160EP | ±20 | 1.7 | 2 | - | - | 57 | - |
| 80 | SQJ180EP | ±20 | 2.5 | 3 | - | - | 60 | - |
| 100 | SQJ110EP | ±20 | 4.3 | 5.2 | - | - | 60 | - |
| 150 | SQJ172EP | ±20 | 32 | 40 | - | - | 12 | - |

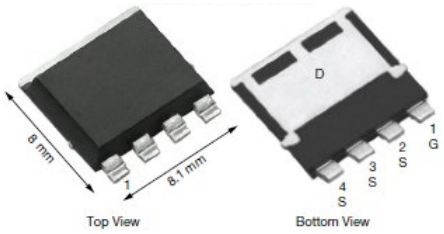


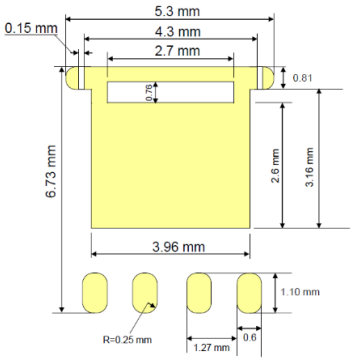



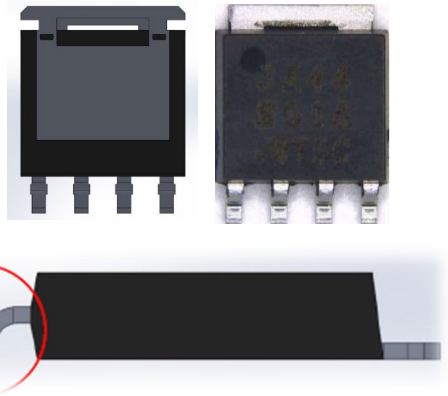
# POWERPAK® 8X8L PACKAGE PORTFOLIO

| P/N | Configuration | Package | Channel | VDS | VGS | IDMax. (A) | RDS(on)@10V | Qg@10V (nC) |
|---|---|---|---|---|---|---|---|---|
| SQJQ904E | Dual | PowerPAK 8 x 8L | N | 40 | 20 | 100 | 0.0034 | 60 |
| SQJQ900E | Dual | PowerPAK 8 x 8L | N | 40 | 20 | 100 | 0.0039 | 85 |
| SQJQ960EL | Dual | PowerPAK 8 x 8L | N | 60 | 20 | 63 | 0.009 | 19 |
| SQJQ980EL | Dual | PowerPAK 8 x 8L | N | 80 | 20 | 36 | 0.0135 | 26 |
| SQJQ910EL | Dual | PowerPAK 8 x 8L | N | 100 | 20 | 70 | 0.0086 | 46 |
| SQJQ100E | Single | PowerPAK 8 x 8L | N | 40 | 20 | 200 | 0.0015 | 125 |
| SQJQ404E | Single | PowerPAK 8 x 8L | N | 40 | 20 | 200 | 0.00172 | 175 |
| SQJQ100EL | Single | PowerPAK 8 x 8L | N | 40 | 20 | 200 | 0.0012 | 140 |
| SQJQ402E | Single | PowerPAK 8 x 8L | N | 40 | 20 | 200 | 0.0017 | 169 |
| SQJQ466E | Single | PowerPAK 8 x 8L | N | 60 | 20 | 200 | 0.0019 | 135 |
| SQJQ480E | Single | PowerPAK 8 x 8L | N | 80 | 20 | 150 | 0.003 | 82 |
| SQJQ410EL | Single | PowerPAK 8 x 8L | N | 100 | 20 | 135 | 0.0034 | 97 |

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



# 48 V BOARDNET

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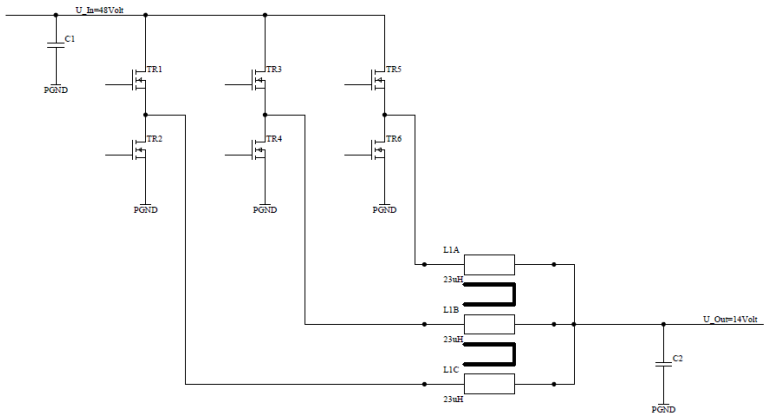
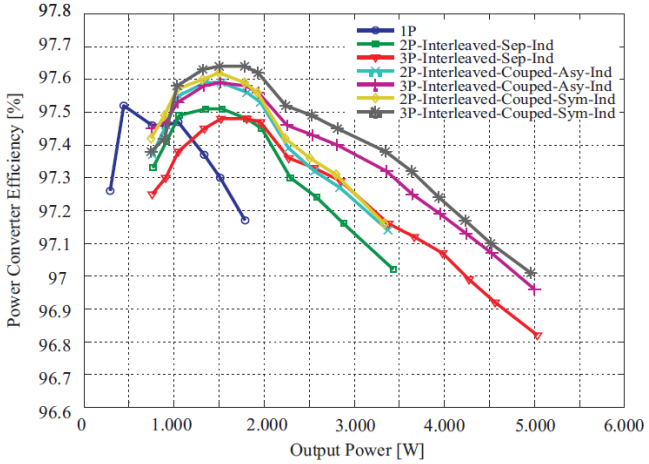
  - MOSFET
  - **INDUCTOR**
  - RESISTOR

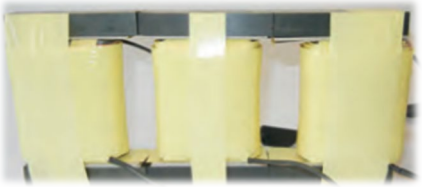
- Electrical Machine Inverters 48 V up to 25 kW with Vishay power-stage solutions
  - CAPACITOR
  - SINTER MODULE
    - MOSFET
    - DIODES
    - NTC

# 48 V / 12 V BI-DIRECTIONAL CONVERTER WITH SYMMETRICAL COUPLED INDUCTOR



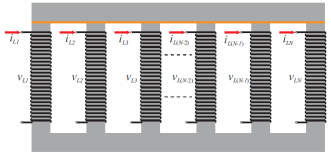

- **When symmetrical coupled inductor is used, each inductor current has better shared phase current compared with asymmetrical coupled inductor.**



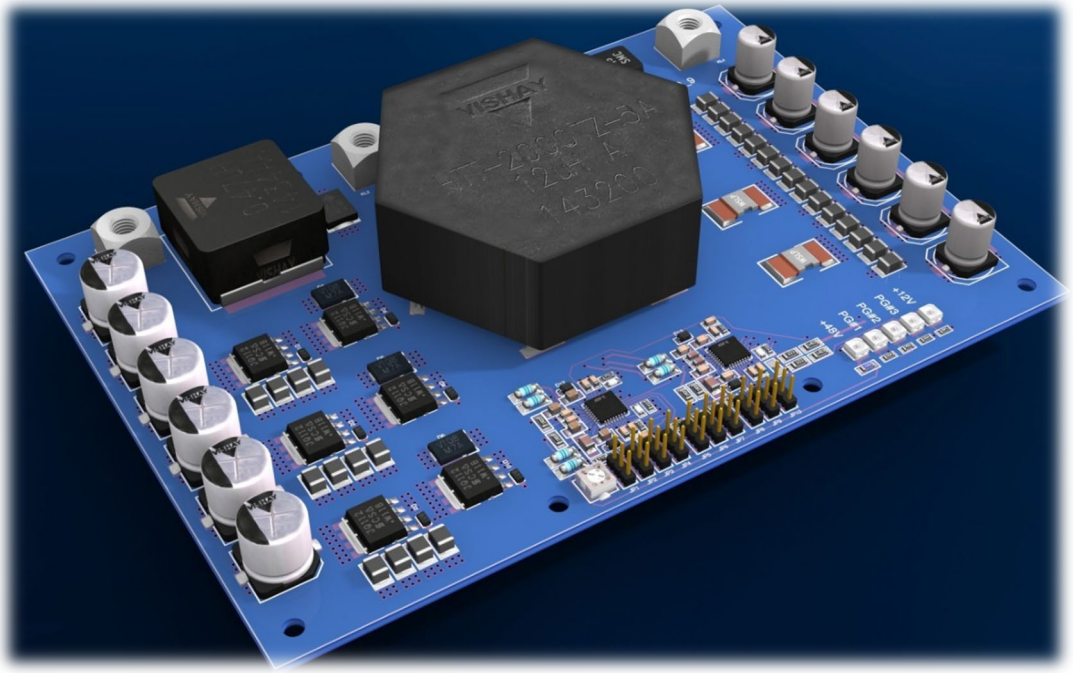



**Asymmetrical Coupled 3-Phase**

**Symmetrical Coupled 3-Phase**



# 48 V / 12 V DC/DC WITH SYMMETRICAL COUPLED INDUCTOR IHTT-200TZ-5A CONVERTER



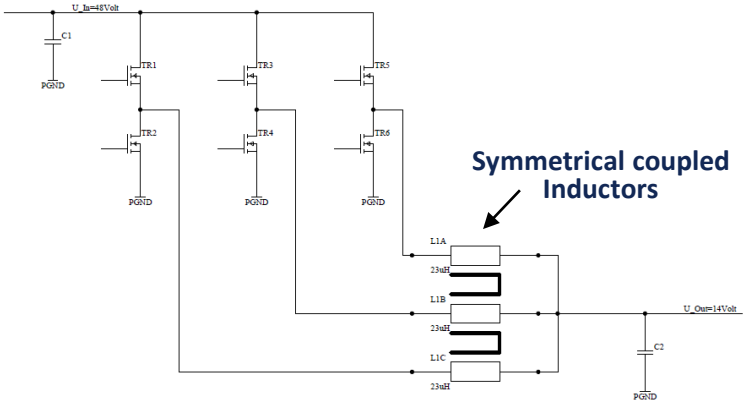
Symmetrical Coupled
3-Phase

## CONCLUSION:

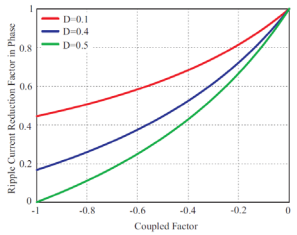
**Symmetrical as a well as asymmetrical coupled inductors are known to offer advantages in applications requiring fast response — they allow reducing ripple current while keeping the leakage inductance, which determines transient response, constant. In applications where transient response is not important, 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.**

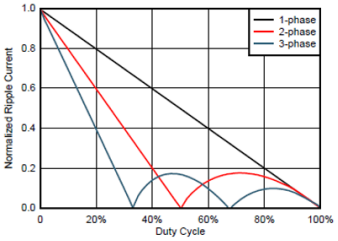
# 48 V / 12 V CONVERTER SOLUTIONS

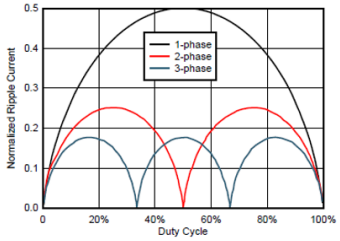
- **Three Phase** with 3 single Output Inductors
- Three Phase **symmetrical coupled** Inductor solutions
- Three-Phase **non symmetrical coupled** Inductor solution
- **Six** Phase **single Inductor**
- **Four** Phase single Inductor

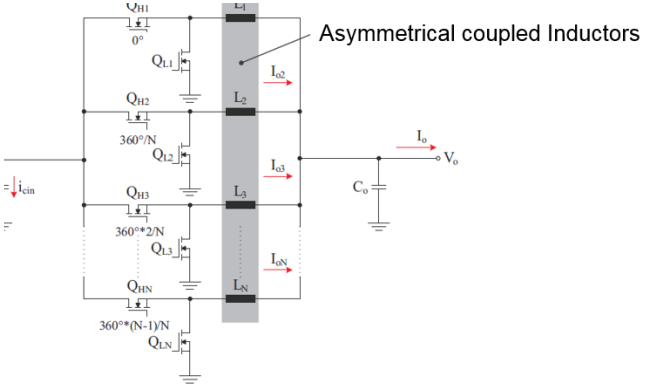



**Using coupled inductor the ripple current is smaller than using non coupled inductor, and moreover with increasing coupled factor the ripple current can be reduced with significant degrade scaling.**



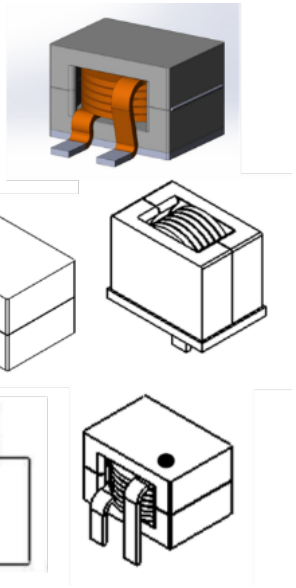



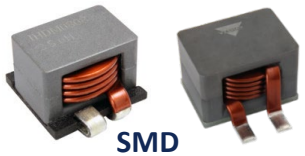
# IHDM INDUCTORS FOR STORAGE AND FILTERING

- **Customized power Inductors for 48 V Filtering and Storage**

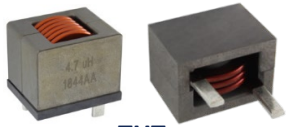
  - **Voltage Breakdown: 700 V to 1500 V**
  - **Temperature range: 200 – 220°C**
  - **Terminal: Fla Wire / Customized**
  - **Core material: Composite / Iron-Powder**



**We have different termination options available:**

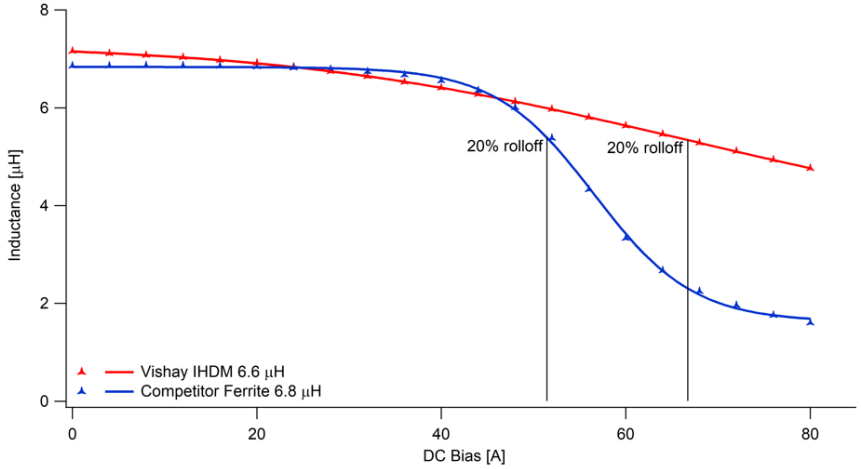


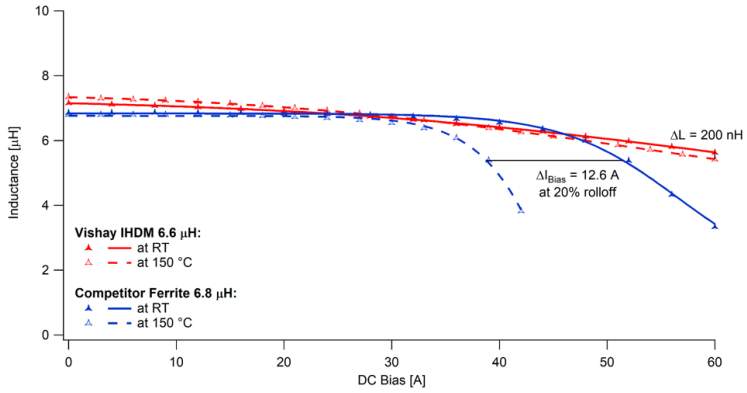
**SMD**
**with or without stabilization**



**THT**
**with or without header**

**Press Fit Pins**
**... or custom solution**

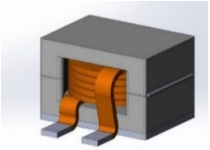


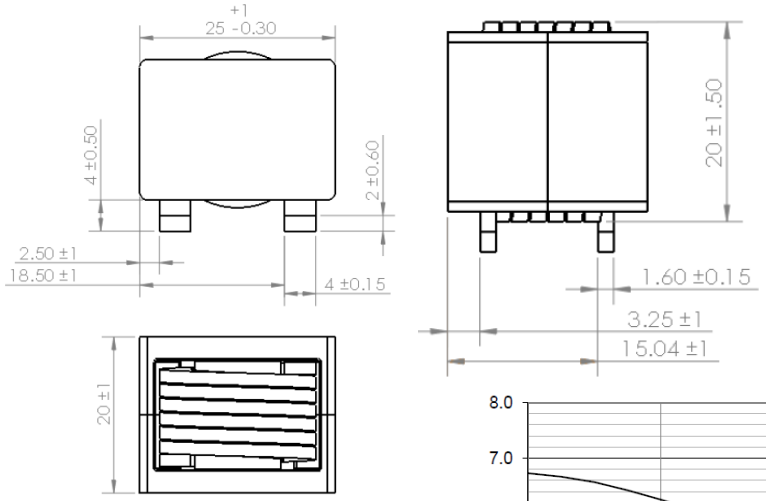

**IHDM:** **Stable inductance over temperature**

**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

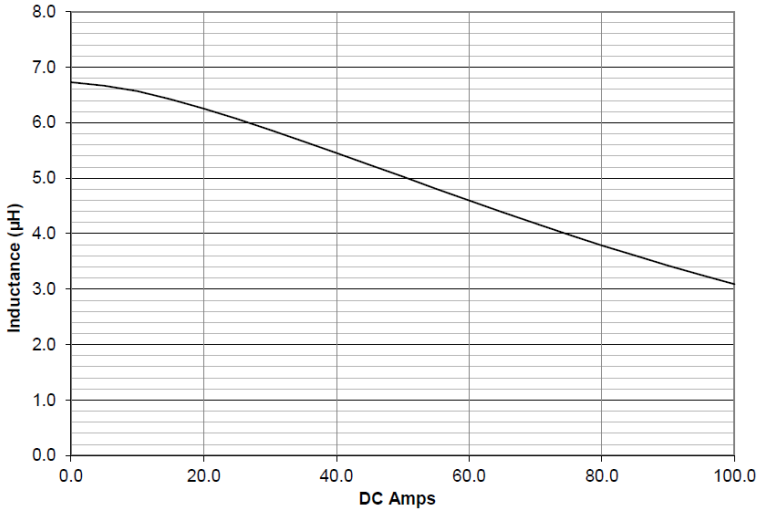



**ELECTRICAL SPECIFICATIONS:**

**Inductance (µH)**
$L_{0A}$ = 6.4µH ± 20%

**Estimated Core Loss: 80kHz**
$I_{rip} = 20A_{pk-pk}$ : 2.2W nominal
$I_{rip} = 10A_{pk-pk}$ : 0.8W nominal

**Temperature rise***
ΔT = 40°C @ 45ADC




**Saturation Current**
L = 3.5µH min. @ 85A

**AC Copper Loss**
$I_{rip} = 20A_{pk-pk}$ : 0.4W nominal
$I_{rip} = 10A_{pk-pk}$ : 0.1W nominal

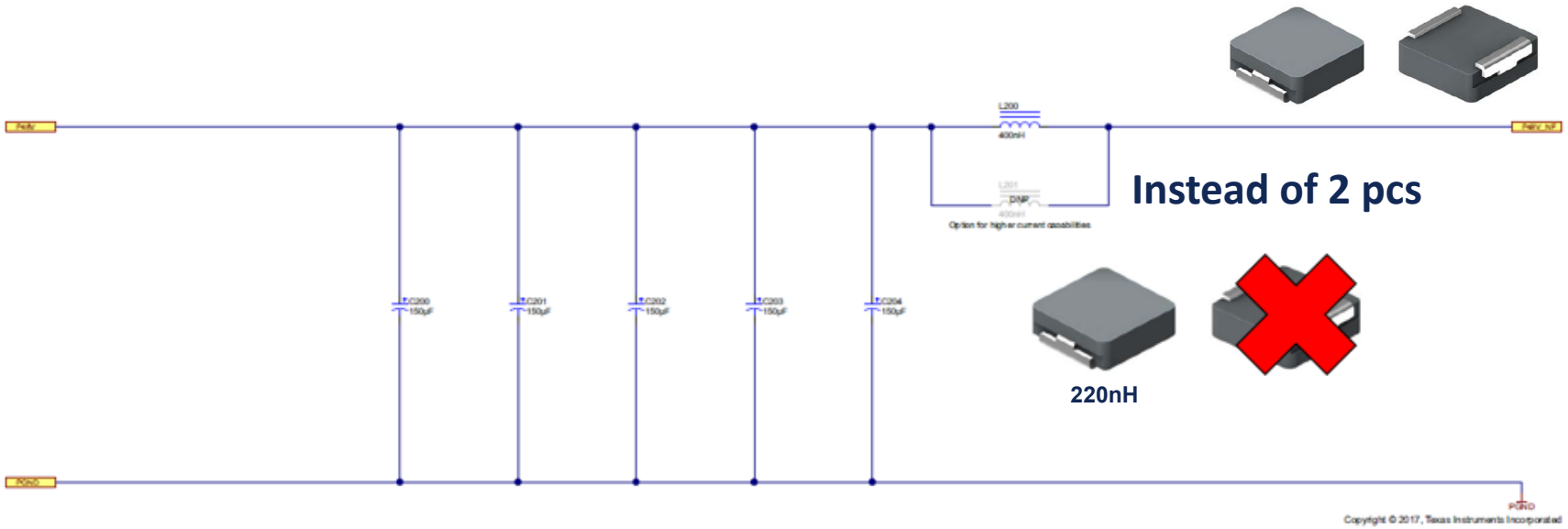
**Material**
Core: Powdered Iron Alloy
Solder: Hot-dipped Sn.
Wire: 200°C Polyimide-amide insulation

**Resistance**
$R_{DC}$ = 1 mΩ nominal
$R_{DC}$ = 1.2 mΩ max

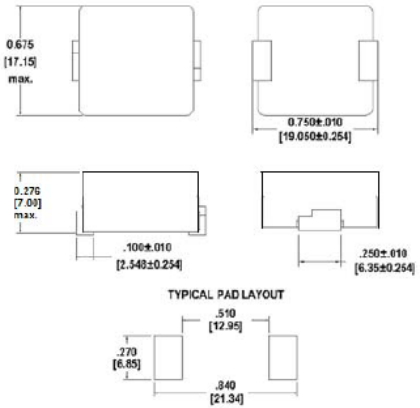
**Operating Temperature**
- 40°C – 180°C
Including Self-Heating

**SCHEMATIC**

# IHSR6767GZ-5A 12 V OUTPUT FILTER HIGH CURRENT @130 A

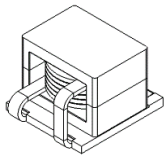



| STANDARD ELECTRICAL SPECIFICATIONS | | | | | |
|---|---|---|---|---|---|
| Lo INDUCTANCE µH ±20% @100KHz, .25V, 0A | DCR mOhms TYPICAL 25°C | DCR mOhms MAX 25°C | HEAT RATING CURRENT DC AMPS3 TYPICAL | SATURATION CURRENT DC AMPS4 TYPICAL | SATURATION CURRENT DC AMPS5 TYPICAL |
| 0.100 | 0.09 | 0.09 | 185 | 120 | 180 |
| 0.120 | 0.13 | 0.14 | 175 | 115 | 161 |
| 0.150 | 0.15 | 0.16 | 165 | 112 | 161 |
| 0.180 | 0.19 | 0.20 | 144 | 110 | 159 |
| 0.220 | 0.24 | 0.25 | 132 | 107 | 155 |



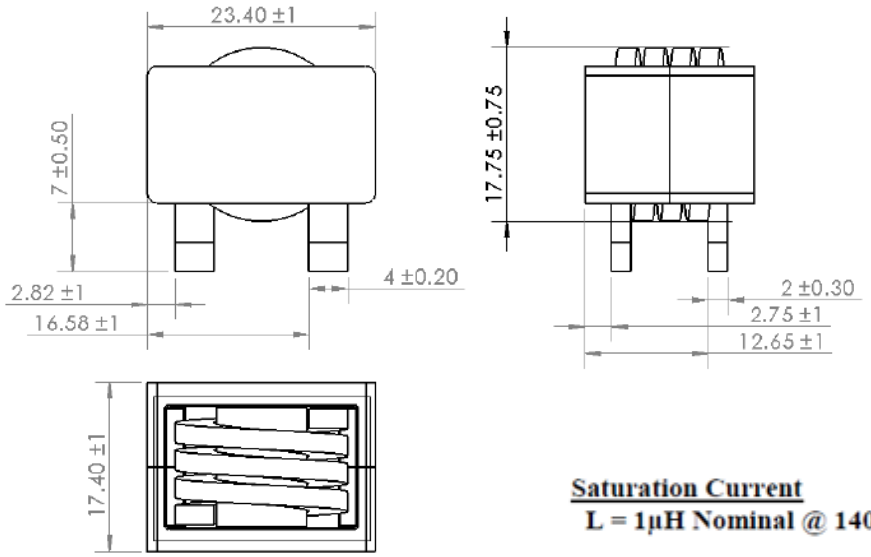

**NOTES:**
1. All test data is referenced to 25°C ambient.
2. Operating Temperature Range - 55°C to + 155°C
3. DC current (A) that will cause an approximate ΔT of 40°C.
4. DC current (A) that will cause Lo to drop approximately 20%
5. DC current (A) that will cause Lo to drop approximately 30%
6. The 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

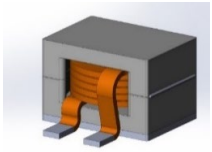


## 1.7 µH Differential Mode EMI Filter Inductor

**DIMENSIONAL OUTLINE (mm)**




**SCHEMATIC**



**ELECTRICAL SPECIFICATIONS:**

**Inductance (µH)**
$L_{0A}$ = 1.7µH ± 20%

**Resistance**
$R_{DC}$ = 0.40mΩ ± 15% @25°C

**Operating Temperature -40°C to 180°C**
**Including Self-Heating**

**Saturation Current**
L = 1µH Nominal @ 140ADC

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

**DWV: Core-Coil Isolation**
300VDC

**Temp Rise***
ΔT = 40°C @ 60ADC

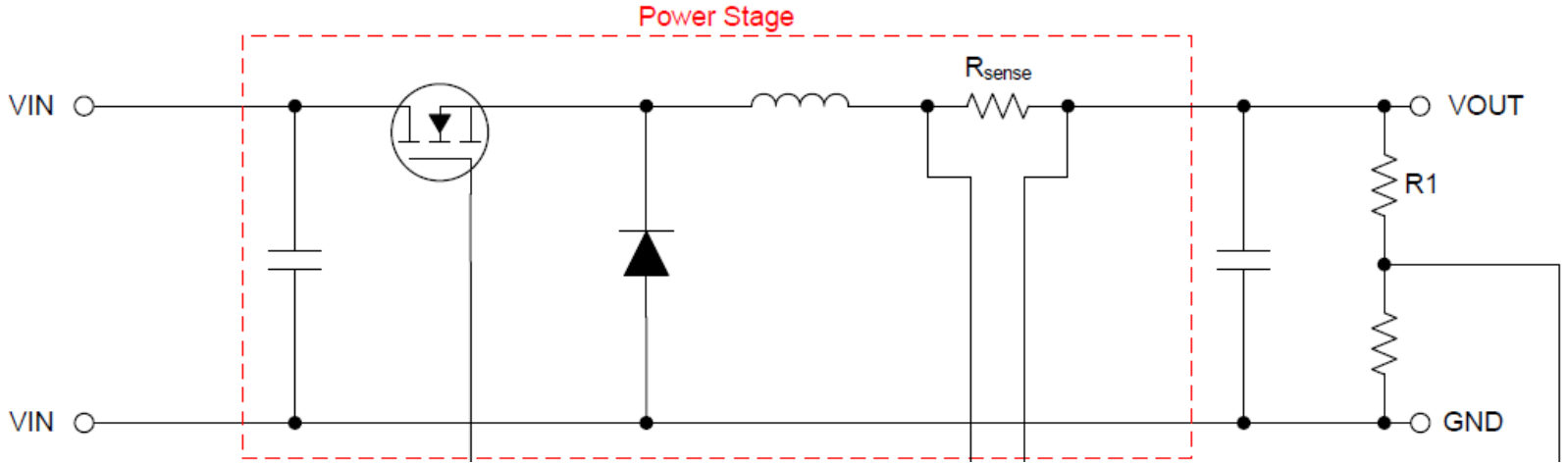
**Weight**
35g Nominal

# 48 V BOARDNET

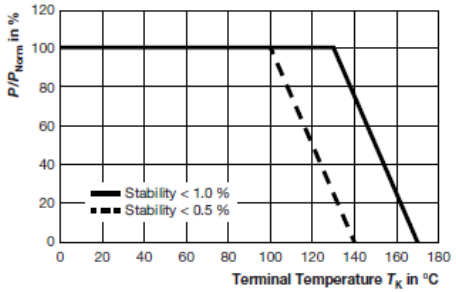
- **Key products for Bi-Directional DC/DC Converters 48 V / 12 V up to 3.5 kW and different topologies solutions (Cost and performance targets)**
  - MOSFET
  - INDUCTOR
  - **RESISTOR**

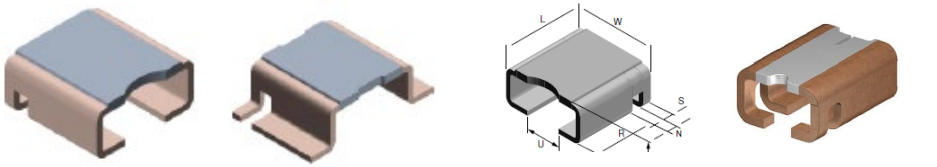
- Electrical Machine Inverters 48V up to 25kW with Vishay power-stage solutions
  - CAPACITOR
  - SINTER MODULE
    - MOSFET
    - DIODES
    - NTC

# 48 V DUAL BOARDNET SOLUTIONS CURRENT SENSE RESISTORS




## DERATING - TERMINAL TEMPERATURE



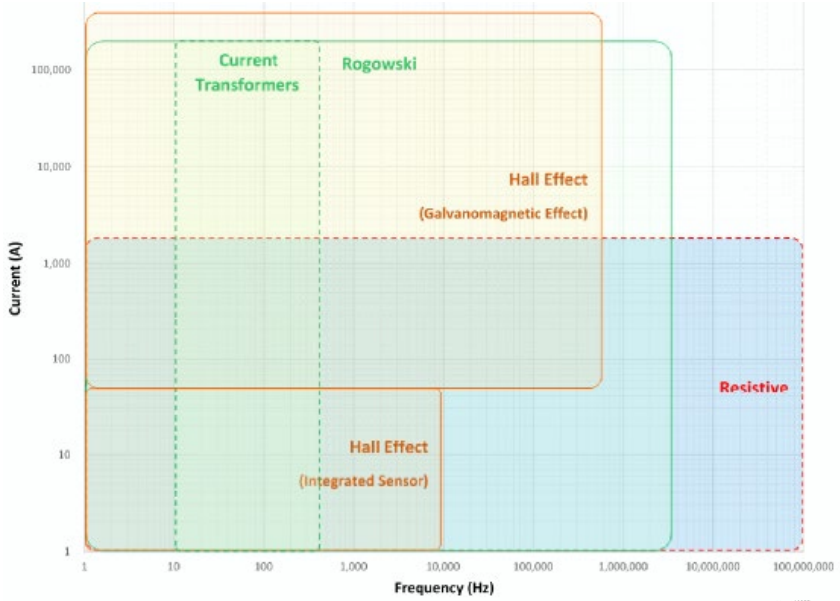



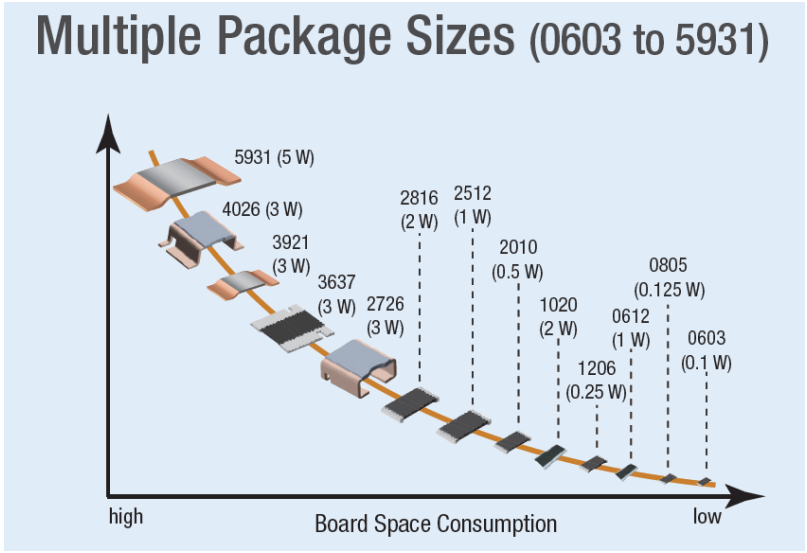

| MODEL | DIMENSIONS in inches (millimeters) | | | | | | |
|---|---|---|---|---|---|---|---|
| | W | L | H | R (REF.) | S | U | N |
| WSK1216 | 0.122 - 0.014 (3.1 - 0.35) | 0.150 ± 0.012 (3.81 ± 0.3) | 0.075 - 0.014 (1.9 - 0.35) | 0.106 (2.70) | 0.020 ± 0.004 (0.5 ± 0.1) | 0.031 + 0.012 (0.8 + 0.3) | 0.024 + 0.006 (0.6 + 0.15) |

| STANDARD ELECTRICAL SPECIFICATIONS | | | | | |
|---|---|---|---|---|---|
| GLOBAL MODEL | SIZE | POWER RATING $P_{70\,°C}$ W | TOLERANCE ± % | RESISTANCE VALUE RANGE (1) Ω | WEIGHT (typical) g/1000 pieces |
| WSK1216 | 1216 | 3.0 | 1.0 | 1m | 420 |
| WSK1216 | 1216 | 5.0 | 1.0 | 0.5m | 420 |

| MODEL | RESISTANCE VALUE (mΩ) | THERMAL RESISTANCE | ELEMENT MATERIAL |
|---|---|---|---|
| WSK1216 | 0.5 | 14.5 | MnCuSn |
| | 1.0 | 7.3 | MnCu |

# CURRENT SENSE TECHNOLOGY
# HIGH POWER, LOW RESISTANCE




**WSBS8518 Custom Shunts, high power, 50 µΩ - 500 µΩ**

| Resistive | Hall Effect |
|---|---|
| Highly linear | Low linearity |
| Stable over temperature | High variation with temperature |
| No measurement latency | May have excessive measurement latency |
| No saturation | Saturation mode when current range is exceeded |
| No additional power supply | Additional power supply required |
| Low cost | Higher cost |

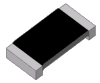
# SHUNT RESISTOR

## WSLP0603

**0.4 WATT**

10mΩ to 100mΩ

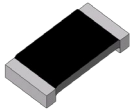
## WSLP0805



**0.5 WATT**

5mΩ to 50mΩ

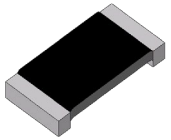
## WSLP1206



**1 WATT**

1mΩ to 50mΩ

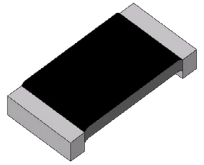
## WSLP2010



**2 WATT**

1mΩ to 30mΩ

## WSLP2512



**3 WATT**

0.5mΩ to 10mΩ

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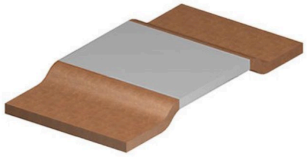
## WSLF2512



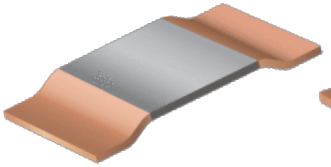
**WSLF2512, 6 W**

0.3mΩ to 0.5mΩ

**WSLF2512, 4 W**

3mΩ

## WSLP3921



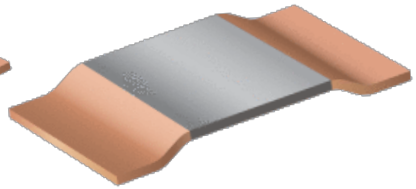
**WSLP3921, 9 W**

0.2mΩ to 1mΩ

**WSLP3921, 5 W**

2mΩ to 4mΩ

## WSLP5931



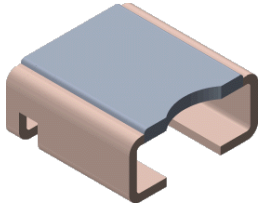
**WSLP5931, 10 W**

0.2mΩ to 0.5mΩ

**WSLP5931, 7 W**

1 mΩ to 3 mΩ

## WSLP2726



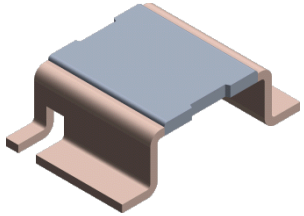
**WSLP2726, 7 W**

0.3mΩ to 1mΩ

**WSLP2726, 5 W**

2.0 mΩ to 4 mΩ

## WSLP4026



**WSLP4026, 7 W**

0.3mΩ to 1mΩ

**WSLP4026, 5 W**

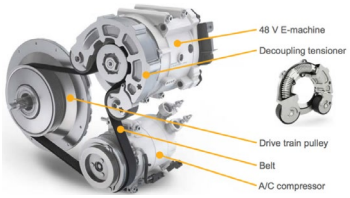
2 mΩ to 4 mΩ

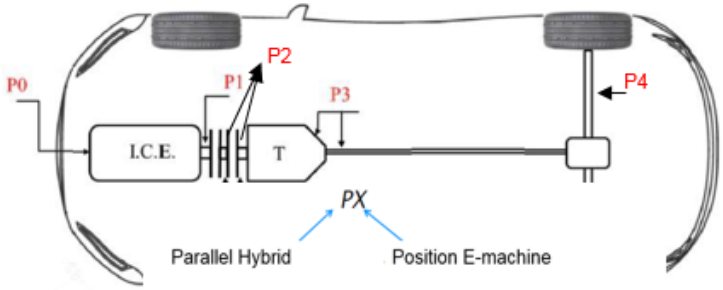
# 48 V BOARDNET

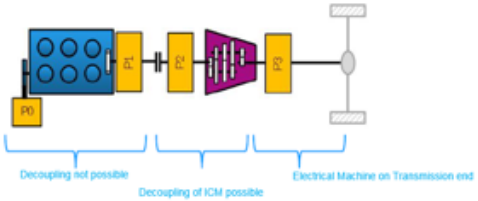
- Key products for Bi-Directional DC/DC Converters 48 V / 12 V up to 3.5 kW and different topologies solutions (Cost and performance targets)
  - MOSFET
  - INDUCTOR
  - RESISTOR

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

# 48 V INVERTER SOLUTIONS



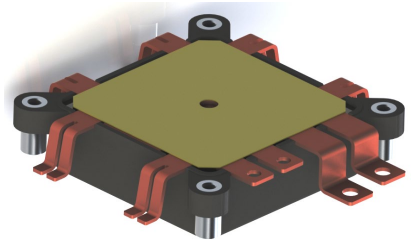




| | |
|---|---|
| **P0:** | **The e-motor is installed in the belt drive system of combustion engine (ICS)** |
| **P1: the** | **The e-motor is fixed to the crankshaft of combustion engine** |
| **P2:** | **The e-motor is installed between combustion engine and transmission** |
| **P3:** | **The e-motor 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: kW)** | **Max. cont. power up to 15-18kW (peak 25** |
| | **Sintering Module** |
| **P4:** | **Max. power for LSEV 25 kW Sintering Module** |

# CUSTOMIZED MKT DC-LINK FILM CAPACITORS

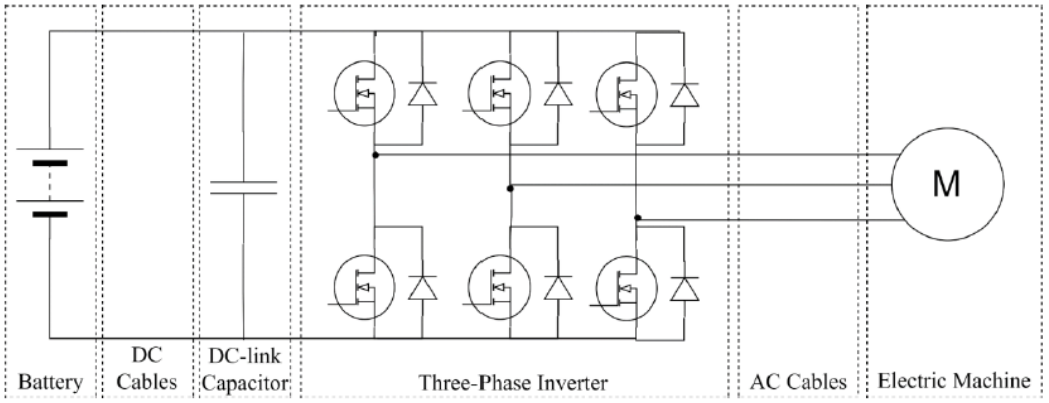
- **48 V Applications Highlights**
  - AEC-Q200 Rev D approved –Automotive Grade
  - High Temperature Capabilities: especially designed for 48V Board Net high temperature operations, 125℃ continuously and up to 150℃ for a limited time
  - Capacitance range: up to 1000 µF
  - Low inductance, low ESR
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

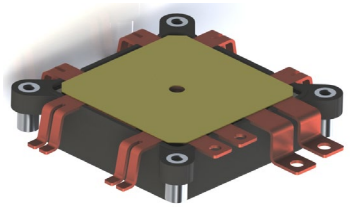


| 48V Board Net | | | |
|---|---|---|---|
| | DC/DC Converter | DC-LINK | MKT1820 / MKP1848 |
| | eBooster | DC-FILTER | MKT1820 |
| | Starter Generator | DC-LINK | MKT1820 |

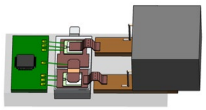
| | |
|---|---|
| MKT1820 | •Capacitance up to 560µF<br>•High temperature operation up to 150°C *<br>•Customization possible |
| MKP1848 | •Standard capacitance value up to 400µF<br>•High Ripple current capabilities / Low ESR<br>•Long Lifetime |

# DC-LINK CAPACITOR FOR 48 V INVERTER P0-P4 INVERTERS



**SINTERING MODULES WITH EACH LEG OWN DC-LINK**
**Reduces size and cost!!**



**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 does 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

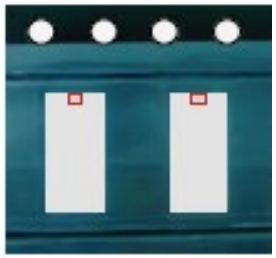
- **Basic properties customized designs**
  - Nominal voltage : 63 V series
  - Design is based on 1,4µm metallized polyester, special profile for high temperature and low ESR
  - Standard bus bar connection

- **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 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Capacitance | Film | Volume | µF/cm³ | ESL (nH) | ESR | $I_{rms}$ * | hot spot | Pd |
| | µF | µm | cm³ | | nH | mΩ | $A_{rms}$ | ° C | W |
| PET | 330 | 1,4 | 68 | 4,8 | 10 | 1,5 | 70 | 125 | 7,4 |
| | 470 | 1,4 | 104 | 4,5 | 10 | 1,0 | 85 | 125 | 7,2 |
| | 1000 | 1,4 | 225 | 4,4 | 10 | 0,6 | 110 | 125 | 7,3 |
| *if PP* | *1000* | *2,4* | *972* | *1,0* | *5* | *0,40* | *300* | *105* | *36,0* |
| *if PP* | *1000* | *1,9* | *700* | *1,4* | *5* | *0,55* | *250* | *105* | *34,4* |

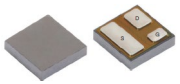
* with cooling

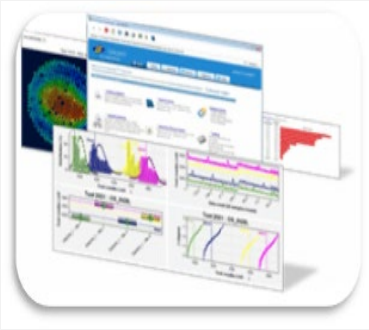
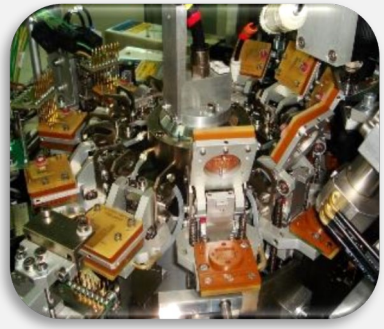
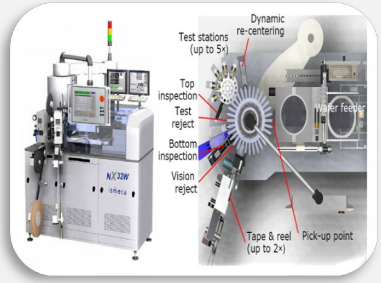
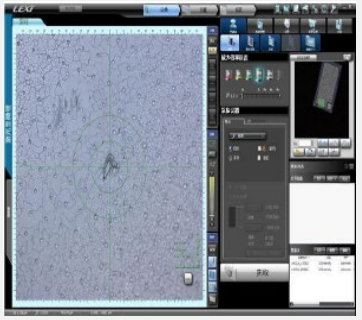
# POWER TRENCH MOSFETS FOR 48 V STARTER GENERATOR KGD 100 V



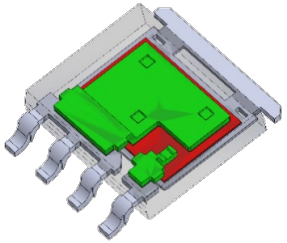
## Known Good Die (KGD)

- 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



| Wafer Test & Galaxy PAT Map | KGD Test Site Technology | Testing & In Line Visual Inspection | Olympus 3D Probe Inspection |
|---|---|---|---|
|  |  |  |  |
| • Wafers are PAT tested at elevated Temperature (85deg)<br>• Dynamic PAT (6 sigma) and SYA (3 sigma) testing | • 10 high precision sockets with built-in die re-centering<br>• Full-Kelvin testing for accurate Rds(on) down to sub-mΩ | • Testing stations up to 5 sites.<br>• Multiple vision inspection to ensure detection of any mechanical defects | • Real-time Probe mark (depth and size) inspection tool to control the probe mark |

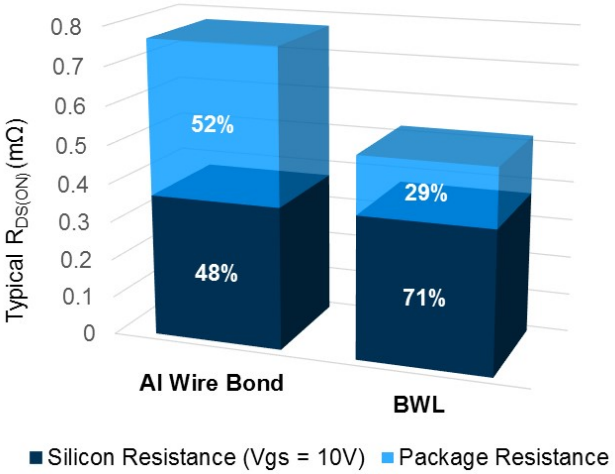
# 48 V CONVERTER AND INVERTER MOSFETS BOND-WIRELESS (COPPER CLIP)

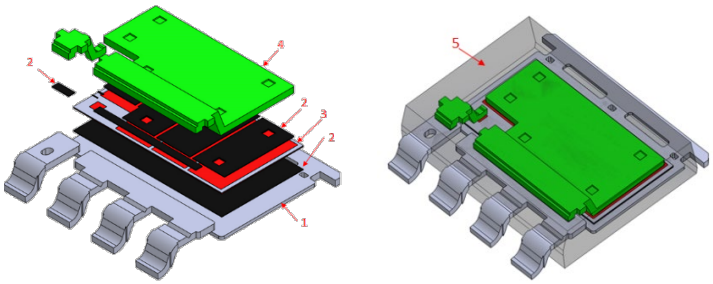


PowerPAK® SO-8L

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

***Resistive Elements for 40V***



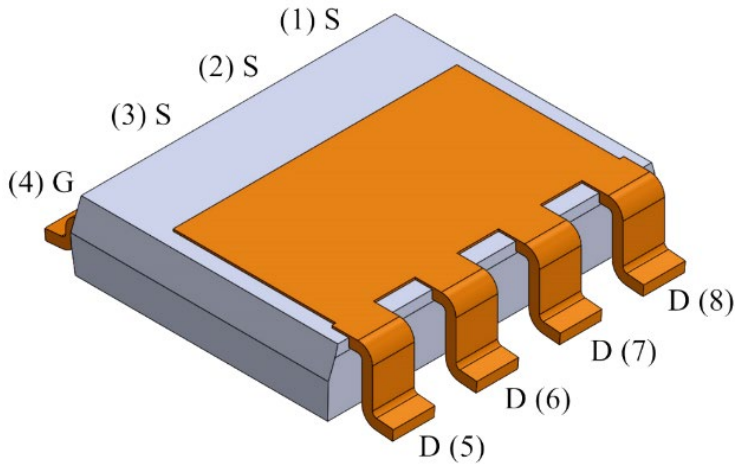



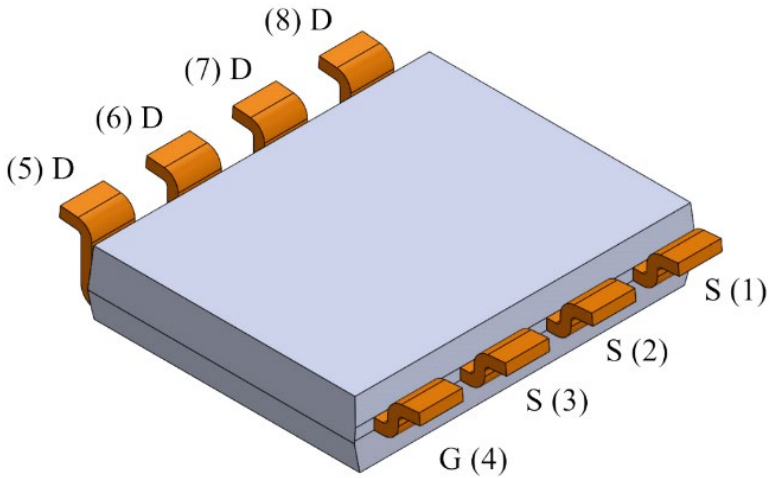
PowerPAK® 8x8L

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

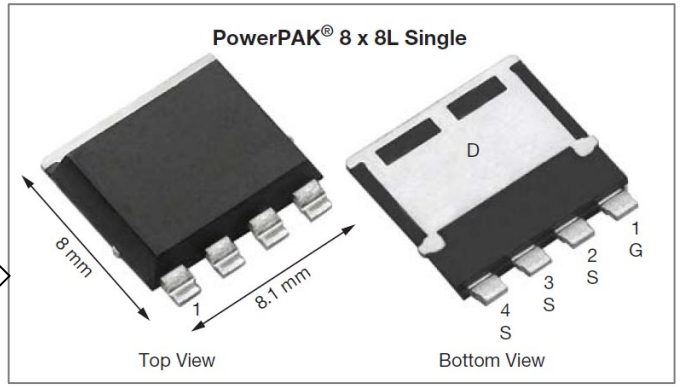
# 48 V INVERTER MOSFET PowerPAK® 8X8L REVERSE LEAD CONCEPT

- 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

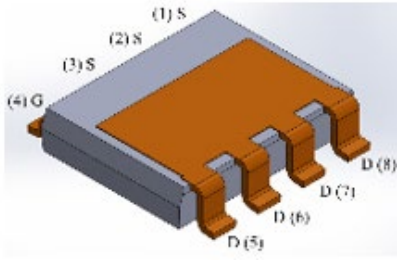


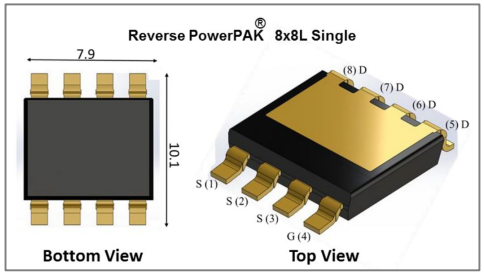



# BLDC MOTOR DRIVE WITH POWERPAK 8X8L FOR HIGHER POWER WITH TOP-COOLING




**Better thermal performance via TOP-Cooling**

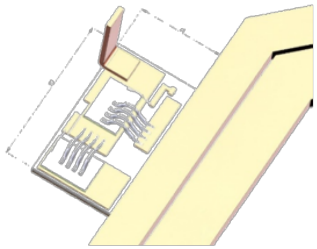
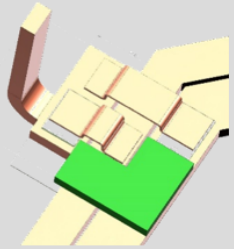


# MILD HYBRID (BSG / ISG) SINTER MODULES UP TO 25 KW

| **CuSiAg** stands for | sintering instead of soldering | clips instead of bonding wires |
|---|---|---|
| ◆ high integration density, load capacity & service life | • the heat dissipation from the semiconductor is significantly improved by sintering.<br>• the sintered compound is stable up to the melting point of the silver (962 °C), solder ages thermally from 125 °C.<br>• reduced chip area with increased ampacity | • the Cu clip leads to an smooth lead of current into the semiconductor, no punctiform load of the chip as with the bonding wire. |
| ◆ an optimized production process | • shorter process time | • higher output |
| ◆ with reduced system costs | • reduced coolant temperature<br>• higher switching frequencies possible<br>• possibly lower DC link capacity | • Very low-inductance connection |

HE SYSTEM ELECTRONIC

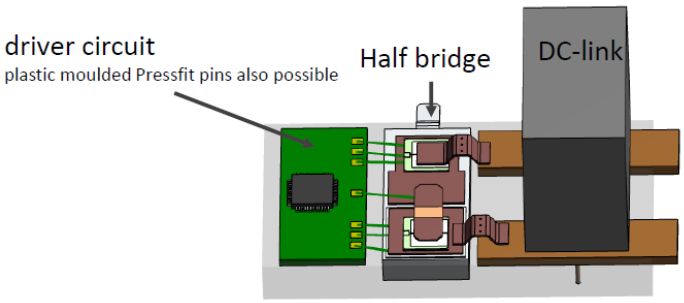
| DCB, soldered & bonded | Leadframe, sintered |
|---|---|
|  |  |
| $R_{th}$ = 1,52 K/W, cost → | $R_{th}$ = 0,74 K/W, cost ↘ |

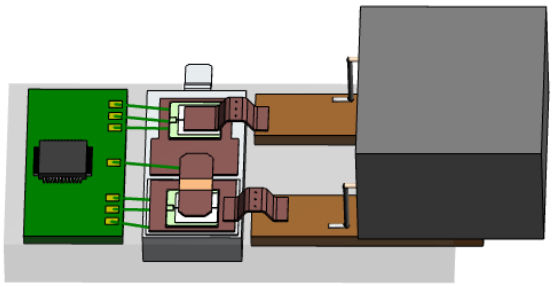
# 48 V BOARDNET

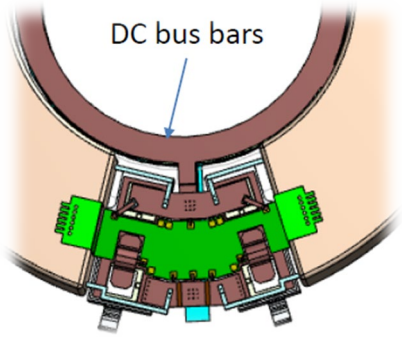
- Key products for Bi-Directional DC/DC Converters 48 V / 12 V up to 3.5 kW and different topologies solutions (Cost and performance targets)
  - MOSFET
  - INDUCTOR
  - RESISTOR

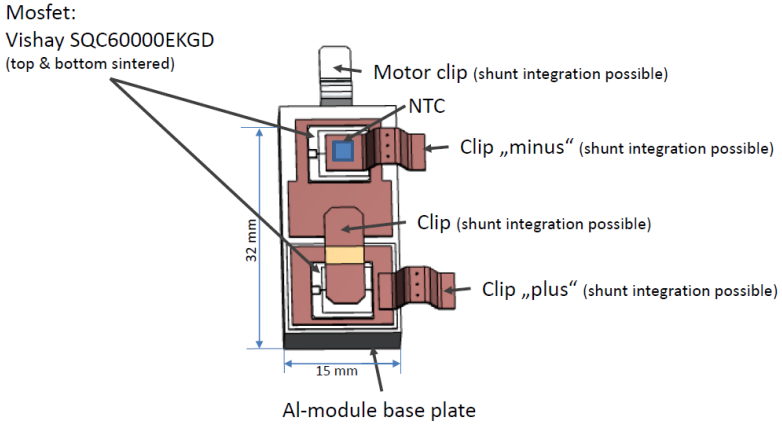
- **Electrical Machine Inverters 48 V up to 25 kW with Vishay power-stage solutions**
  - CAPACITOR
  - **SINTER MODULE**
    - **MOSFET**
    - **DIODES**
    - **NTC**

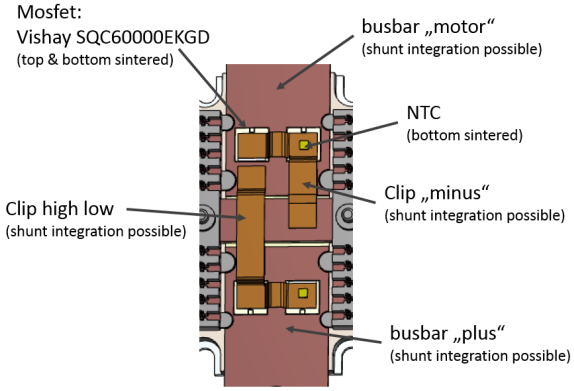
# 48 V INVERTER SINTERING MODULES UP TO 25 KW

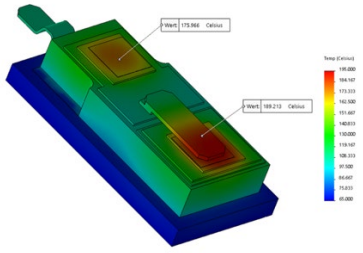


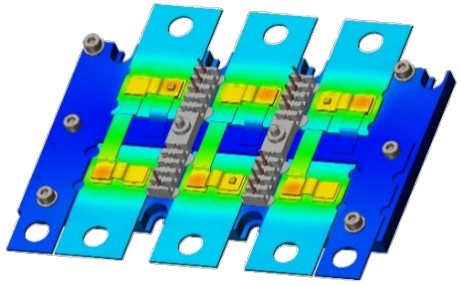





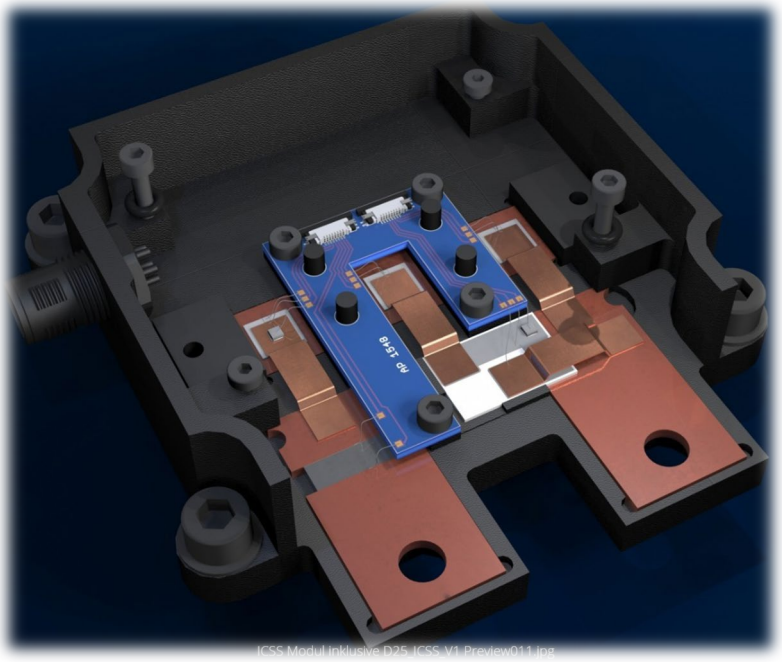



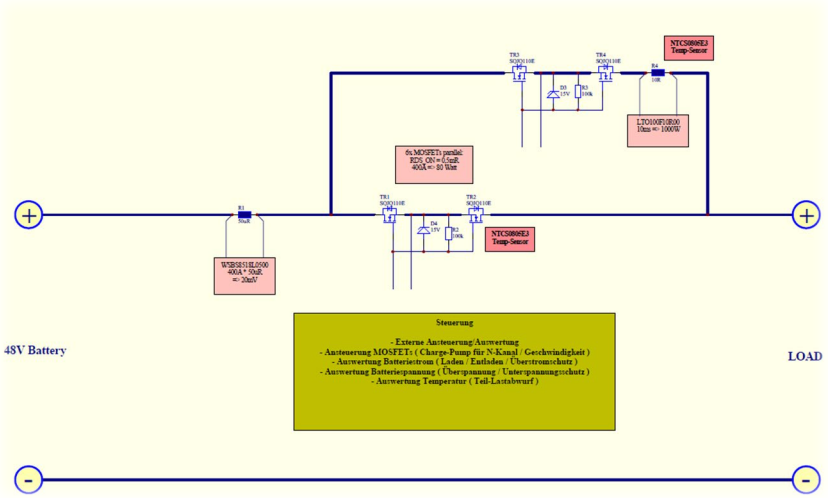


**Worst Case: static 725 A**
**→ Tmax = 141°C**

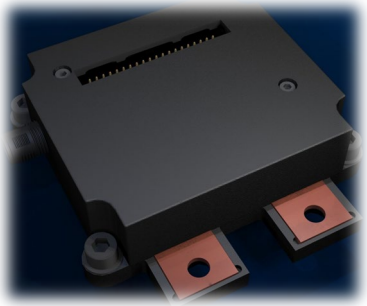
# SINTER MODULE SOLUTIONS

## 48 V Battery Safety Switch with Pre-Charging




Vishay Design



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