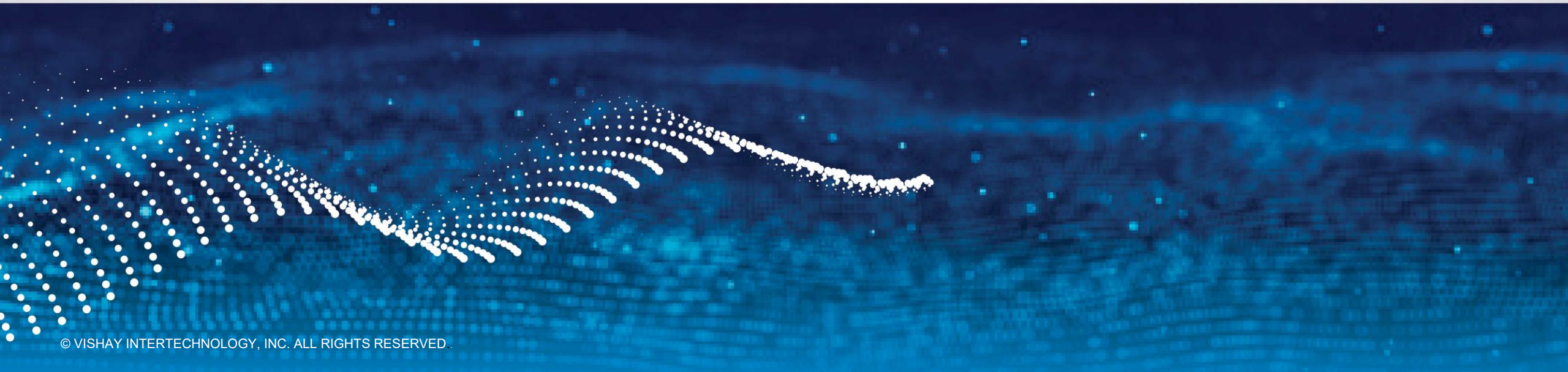
# Redefine EV Power Distribution With eFuses

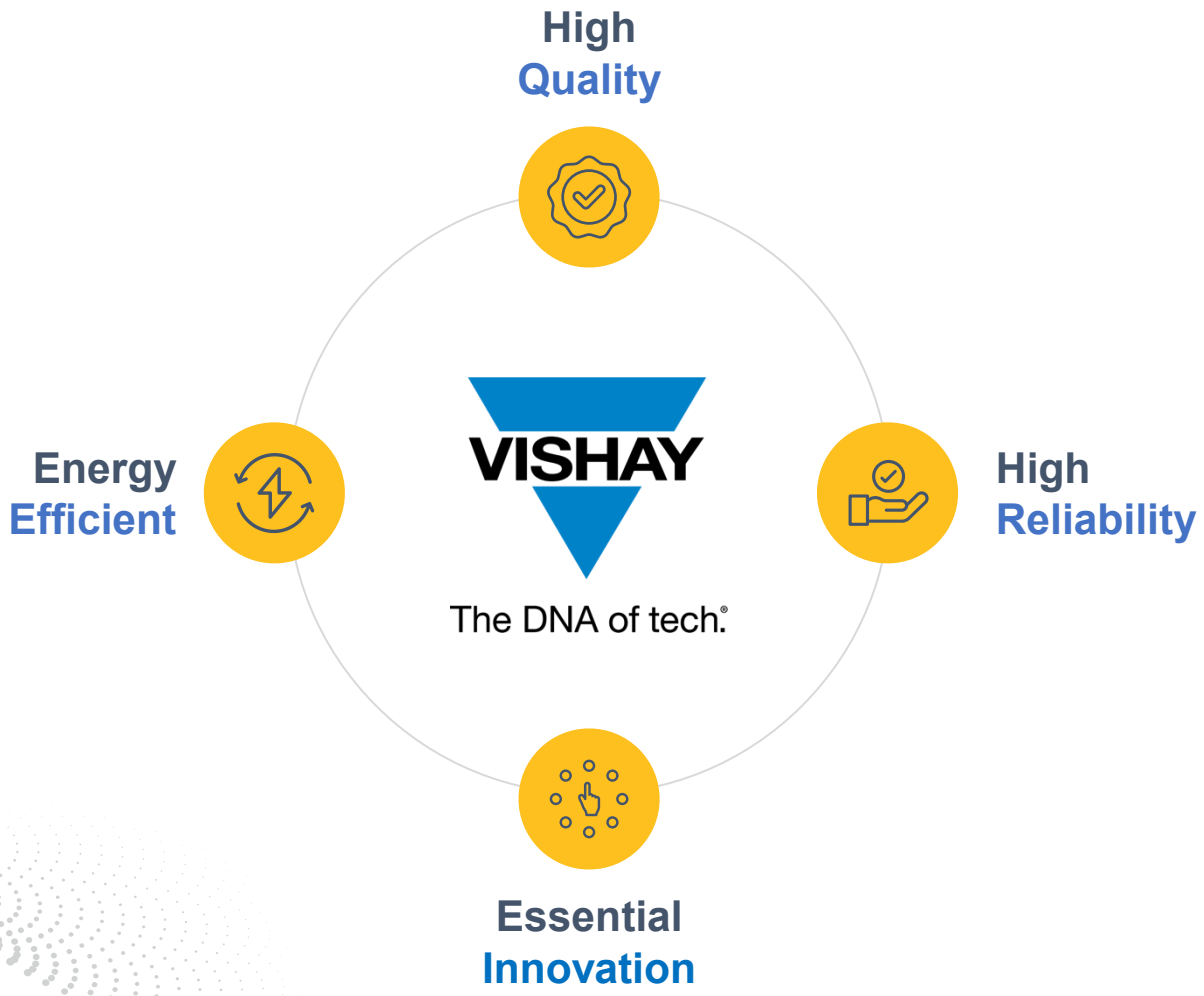
Sam Han, Sep. 2025

Business Development Automotive



# We manufacture one of the world's largest portfolios

of discrete semiconductors and passive electronic components



We are proud to be the go-to manufacturer for engineers to innovate with ease and confidence that **The DNA of tech.®** is behind them all the way.

DISCRETE SEMICONDUCTORS ▶ PASSIVE COMPONENTS

LOWEST VOLTAGE DIODE ▶ HIGHEST ENERGY CAPACITOR

In power applications, we can supply

# ~ 80 %

**of your BOM**

VISHAY

The DNA of tech.®

# Vishay Automotive Grade

AUTOMOTIVE GRADE

## PROGRAM DESCRIPTION

Vishay has incorporated key automotive industry quality initiatives into an Automotive Grade Product line. The goal is zero defects. The requirements cover design, qualification, and manufacturing, and are used to continuously improve Vishay products and processes. Products fulfilling the Vishay Automotive Grade requirements, described below, earn our Automotive Grade stamp on their datasheets.

### DESIGN

- Robust Design Policy: new and modified products are designed using design rules, DFMEA, and lessons learned. The design rules ensure Automotive Grade Products are robust through manufacturing and assembly. Testing to failure confirms that design margins meet the demands of automotive use
- Safe Launch: Vishay's Safe Launch Policy ensures that everything from design through production roll-out happens according to plan. Process corner evaluation, yield analysis, process capability review, and reliability testing are all incorporated into this program

### QUALIFICATION

- AEC-Q100, AEC-Q101, AEC-Q200 Qualified: Automotive Grade Products are qualified to the latest AEC qualification standards and presented for approval using PPAP

### MANUFACTURING

- IATF 16949 Facility: all Automotive Grade Products are produced in facilities certified to IATF 16949
- Maverick Lot Program: the Maverick lot program employs part average testing (PAT), statistical yield limit (SYL), and statistical bin limit (SBL) according to AEC-Q001 and AEC-Q002 to identify statistically different parts and lots
- Periodic Verification to AEC Requirements (Reliability Monitoring): product families are verified to AEC stress test qualification standards every two years

### CONTINUOUS IMPROVEMENT

- Error Proofing: error proofing is performed during the entire process to identify and eliminate potential causes of defects
- Lessons Learned / Look Across: all continual improvement actions are linked to lessons learned and look across programs to ensure improvement everywhere in the company

# eMobilityLAB

## Rugged SiC and Low TCR Shunts Enabling Solid-State Power Distribution Units

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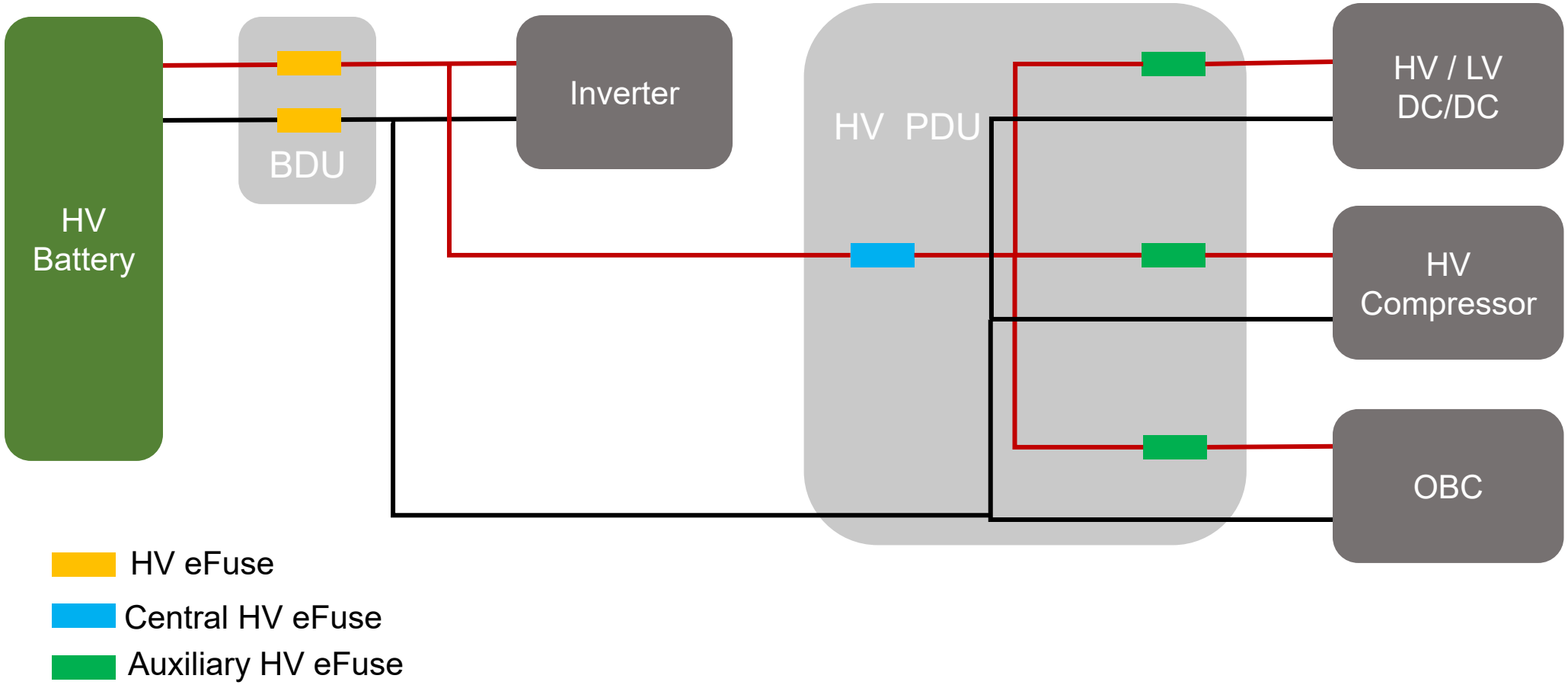
# HV Power Distribution

**Trend:** eFuses are necessary for electrification and E/E architectures
**Benefits:** easy maintenance, configurable, easy diagnostics and protection, resettable, arc-free

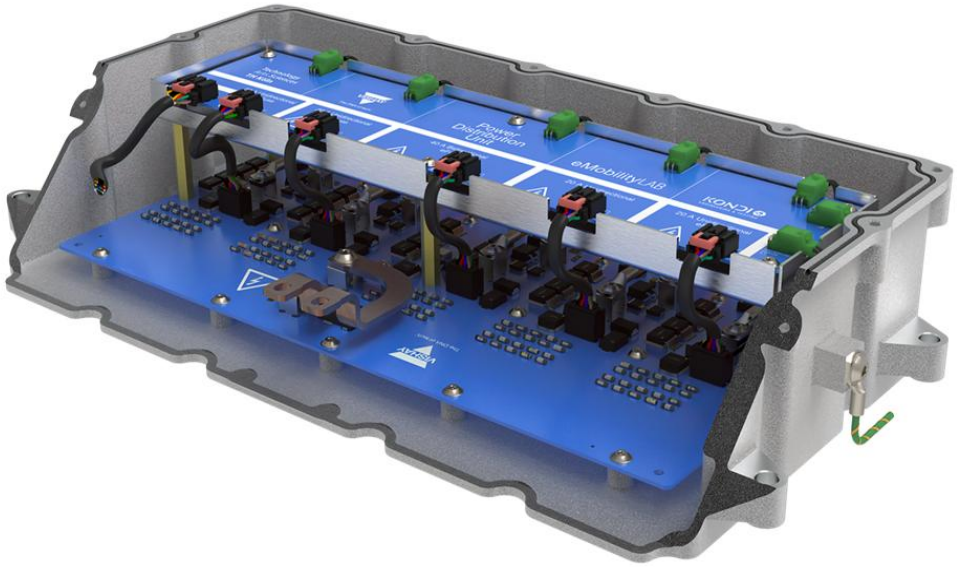


# Power Distribution System

- **Solid-state relay technology:** our robust SiC switches enable eFuses and solid-state relays (SSRs), which provide fast, reliable switching and superior durability and response times in demanding environments

- **Fast overcurrent detection:** Vishay's low TCR current shunt resistors enable precise, high speed overcurrent detection (< 1 µs) and intelligent fuse management, ensuring near instantaneous isolation of faulty circuits to prevent system damage and reduce downtime

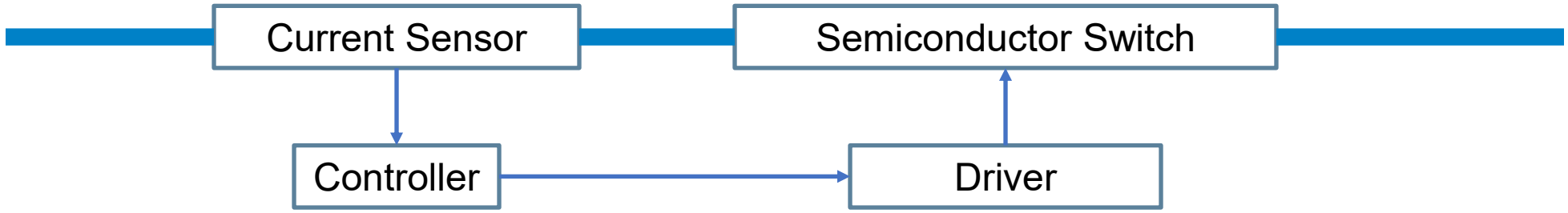
- **Pre-charge circuit:** based on high power, pulse-proof resistors alongside rugged semiconductor switches and gate drivers, our portfolio includes everything needed to construct low cost, reliable pre-charge solutions for capacitive loads



# Why 800 V eFuses?

- Thermal fuses are slow and non-resettable
- Mismatch between durational current and short circuit protection
- Traditional circuit breakers use a combination of:
  - Magnetic device + mechanical switch for short circuit protection
    (arcing => lifetime and arc prevention => big and heavy solutions, DC)
  - Fuse for thermal protection
    (non-resettable)

- eFuses: use semiconductor switches for fast, resettable, non-arcing current breaking

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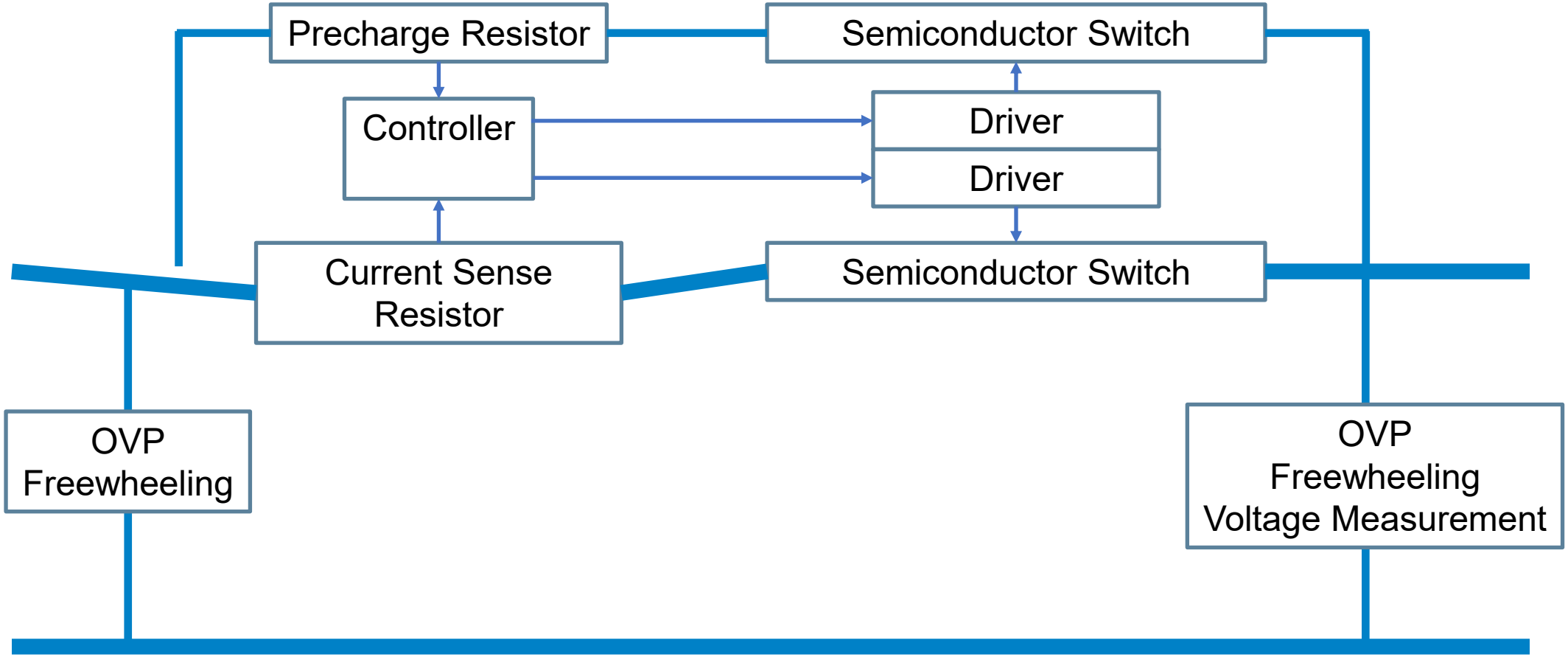
# eFuse in a DC System

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# Where Can the Use of eFuses Bring Advantages?

In HV DC applications, fast-acting, controllable, or resettable fuses are needed:

- Overcurrent protection of SiC MOSFETs, where other solutions are not guaranteed to break the short circuit current within the short circuit withstand time of the SiC device (HV-DC, fast)
- DC grids (switching many times under full current, controllable current limit)
- Electric vehicle charging equipment (switching high DC current, thermal protection of cables)
- Software-defined vehicles  (light, controllable, resettable, and fast if used to protect components such as SiC inverters) such as in a power distribution unit for auxiliary power



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# How to Size an 800 V EV PDU

- **800 V roll stabilization (unidirectional eFuse)**
  800 V / 5 kW peak: 3.5 A peak
- **800 V PTC heater (unidirectional eFuse)**
  800 V / 3 kW to 10 kW: 5 A to 17 A
- **800 V heat pump (unidirectional eFuse)**
  7 kW durational, 10 kW peak: 12 A durational, 17 A peak
- **800 V air curtain compressor (unidirectional eFuse)**
  800 V / 4 kW: 7 A
- **800 V OBC (bidirectional eFuse)**
  800 V, 11 kW / 22 kW; 20 A / 40 A

Plan for eFuse with
~ 3 A to 20 A and ~ 40 A

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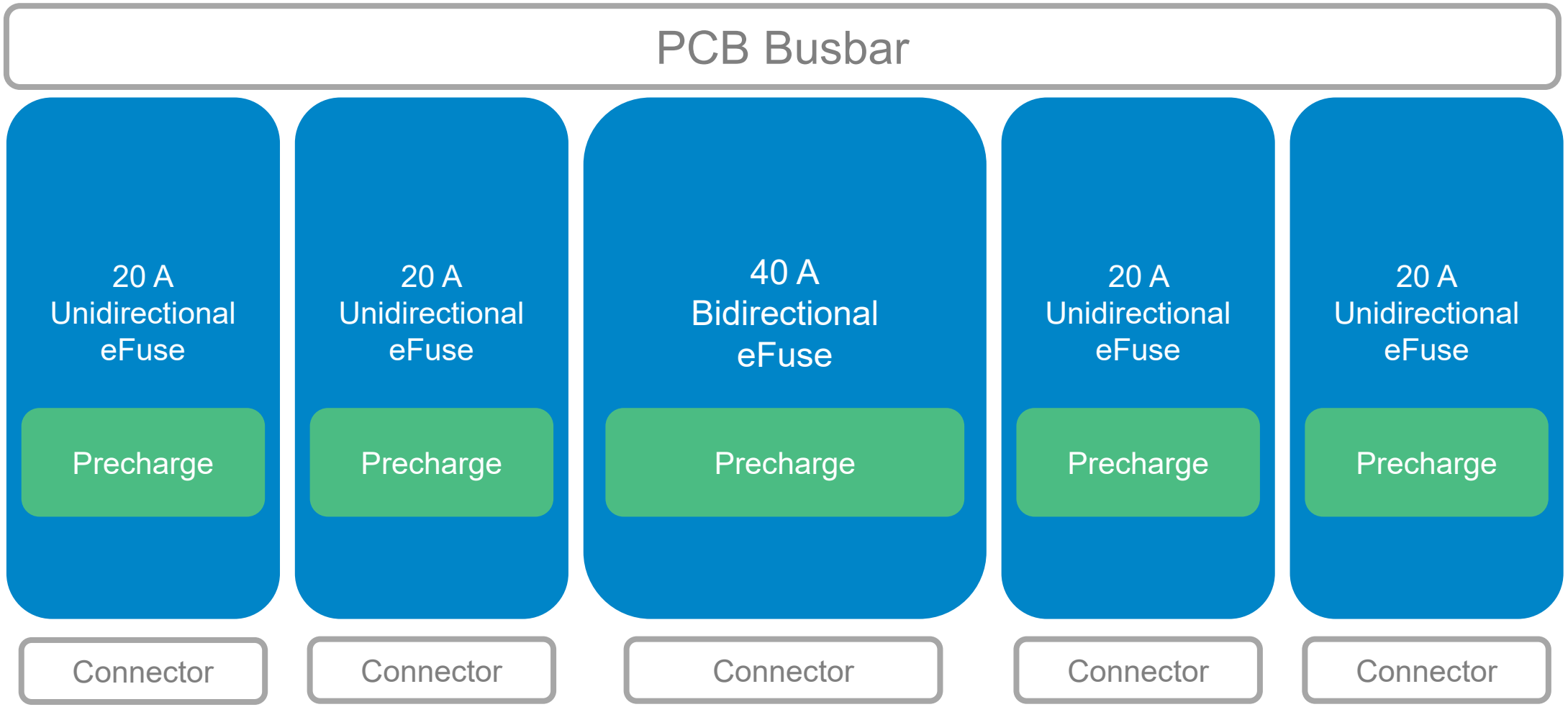
# Power Distribution Unit – Architecture

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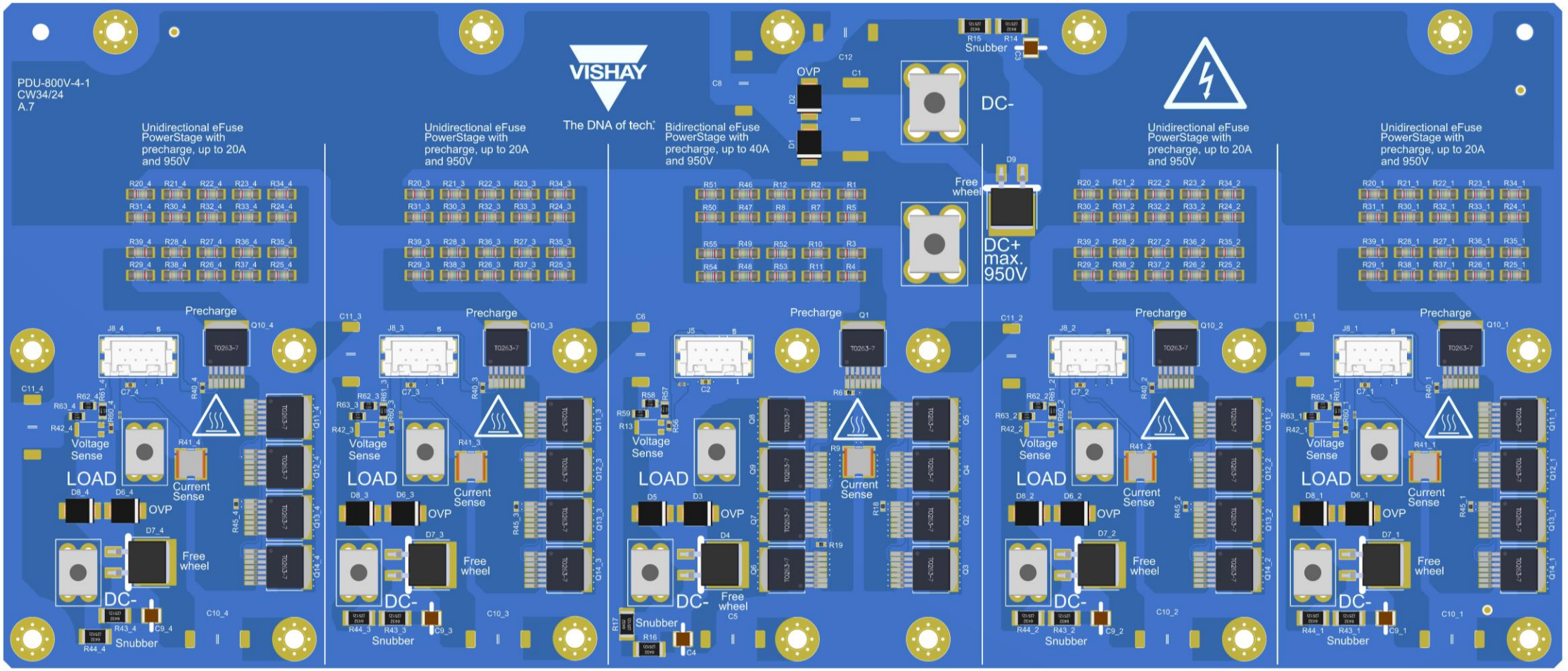
# PDU Power Stage (Based on the MXP120A45FE)

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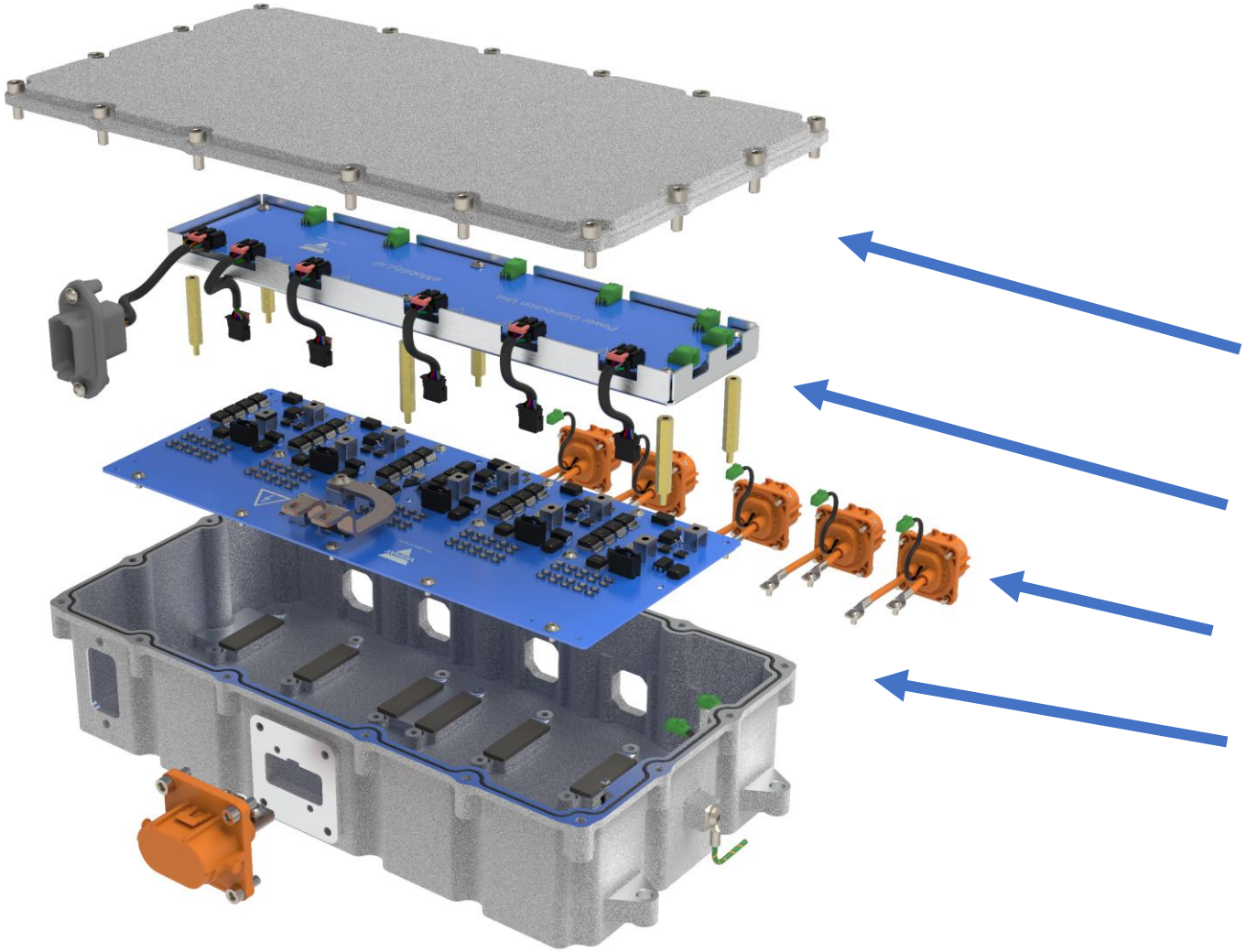
# Proof of Concept



Housing developed with automotive standards in mind

Shielded control PCB

Industry-standard connectors

Power stage close to 100 % Vishay

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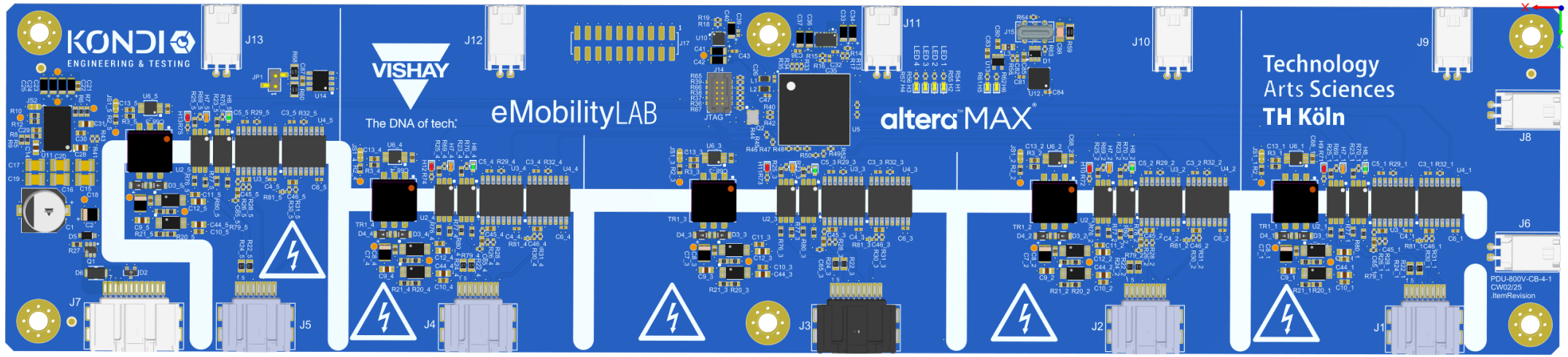
# Logic / Control Board




Show low latency overcurrent detection and SiC FET driving.

All five channels are controlled from a single Altera FPGA.
Resistive current sensing is facilitated via isolated SD-ADCs.
Gate drivers are optically isolated.

Isolated design allows for easy connection to VCU.

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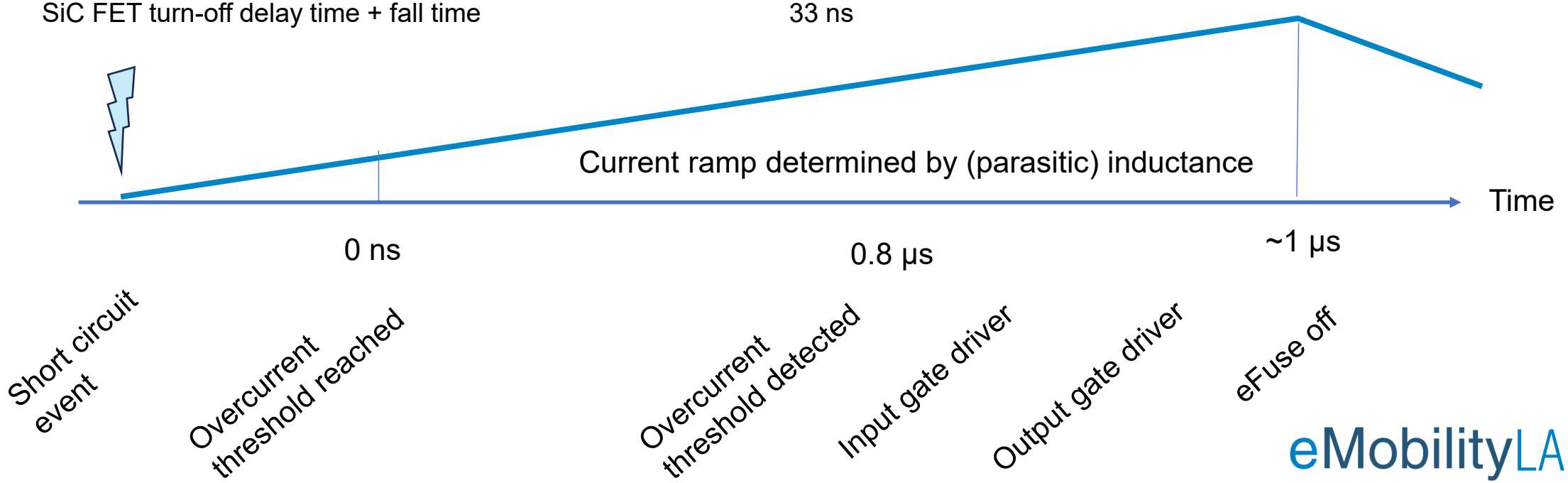
# What Happens to the Current in the Event of a Short?

| | |
|---|---|
| ADC input filter time constant | 30 ns |
| Processing delay | 200 ns |
| Advanced ADC + FPGA SD algorithm | ~ 500 ns |
| Processing delay | 100 ns |
| VOFD343A turn-off propagation delay | 50 ns to 200 ns |
| SiC FET turn-off delay time + fall time | 33 ns |

Short Circuit Withstand
SiC FET ~ 3 µs

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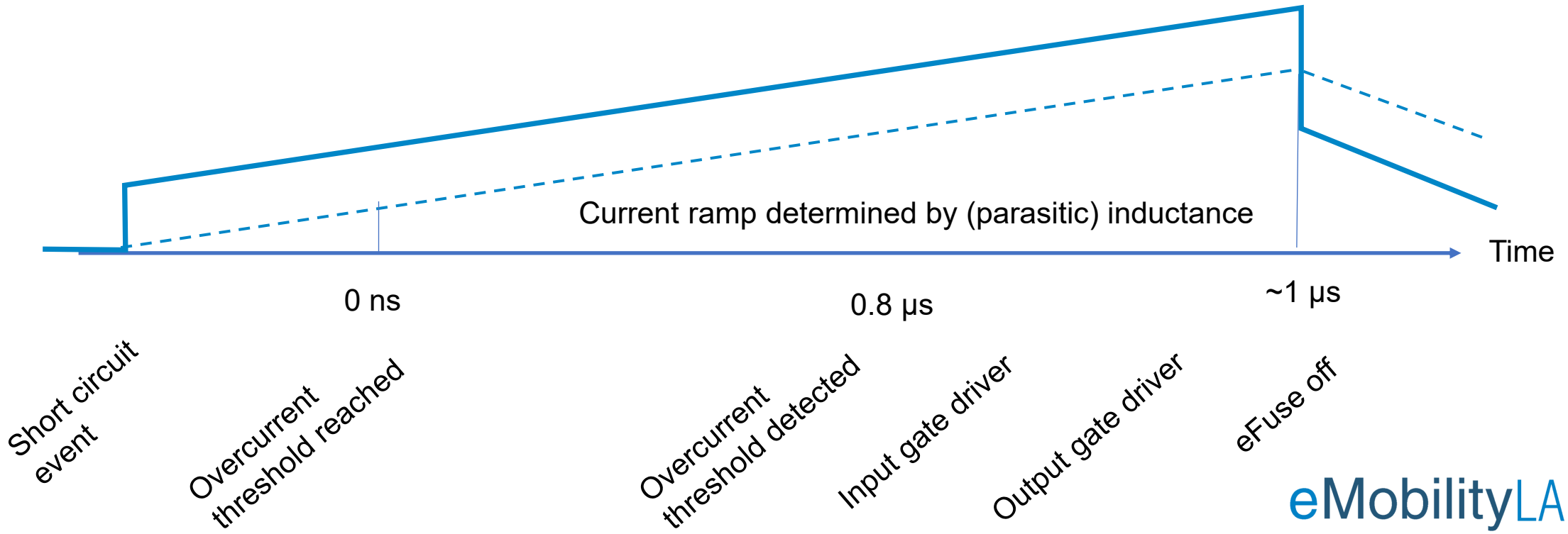
# What Happens to the Shunt Signal During a Short?

J. Laufs-Randerath, J. O. Krah, S. Goodwin and R. Richter, "Fast Electronic Fuse built with SiC MOSFETs, Sigma-Delta-Based Current Sensing and FPGA-based Digital Signal Processing,“ in CPE-POWERENG, Antalya, 2025.

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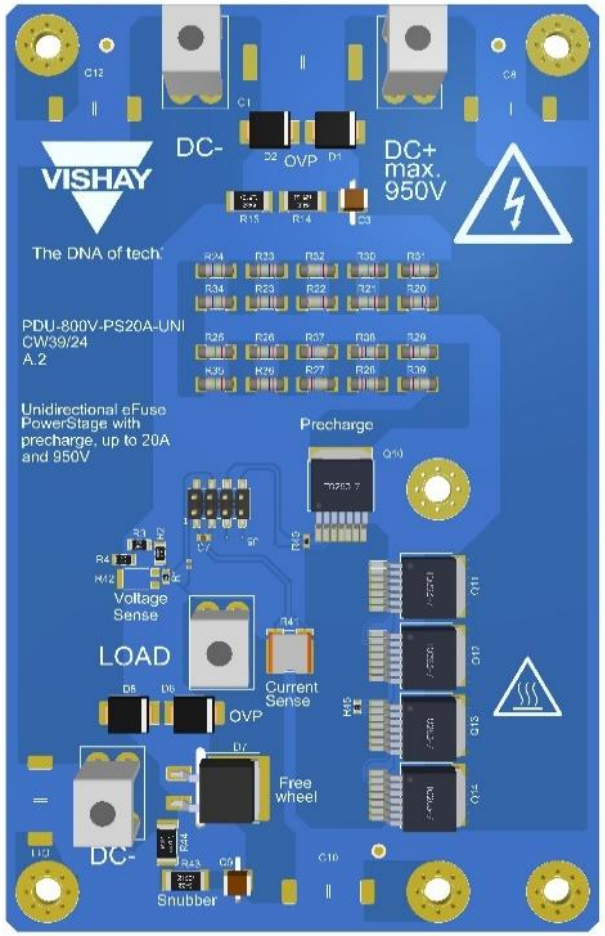
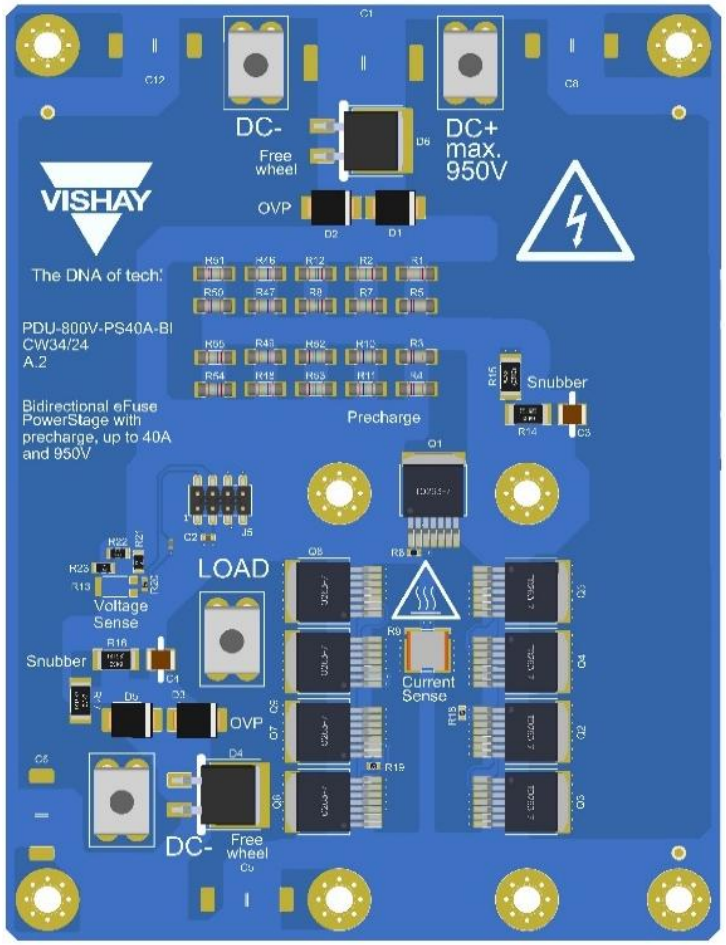
# Single Channel Available as a Development Board

- Unidirectional eFuse: 20 A / 40 A




- Bidirectional eFuse: 40 A

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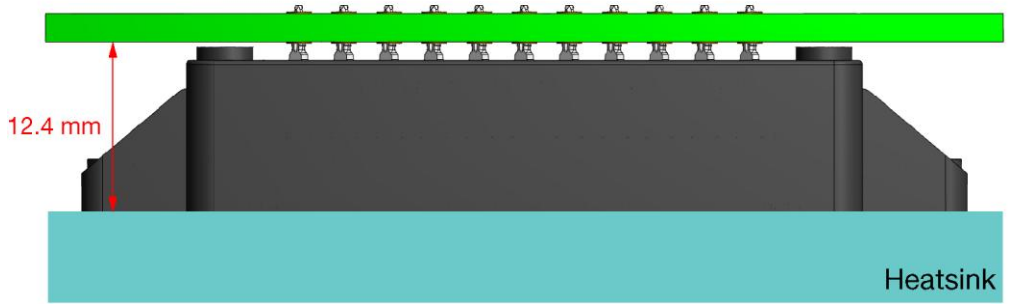
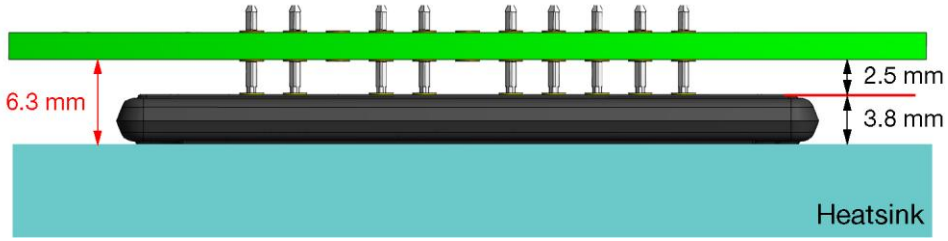
# Outlook: Vishay Custom eFuse Modules

- Integrating low TCR shunts and SiC MOSFETs in compact, easy to use, and robust PressFit modules

EMIPAK 1B




MAACPAK




- Example:

  2x 14 mΩ, 1200 V SiC dies in parallel => 7 mΩ

  1x  low TCR current sense shunt with resistance value as needed by customer

- Optional:

  TVS / OVP …

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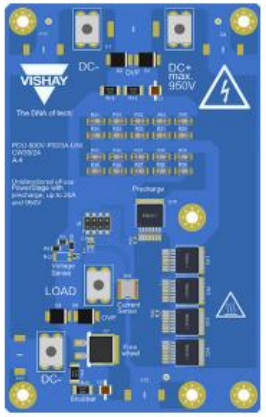
# Reference Design
# SiC MOSFET-Based 800 V, 20 A Unidirectional eFuse




## FEATURES

- Low TCR shunt for precise current measurement
- Low tracking error voltage divider
- Robust I/O port providing ESD protection and freewheel capabilities
- Fast switching speed

## KEY COMPONENTS

- CMB0207 high pulse load carbon film MELF resistor
- MXP120A045FE SiC MOSFET

## LINKS TO ADDITIONAL RESOURCES

- EFUSE-800V20AUNI

## DESCRIPTION

Electronic fuses (eFuses) are crucial in modern applications, especially in automotives. They are used to enhance overall vehicle safety by protecting against overcurrent, voltage spikes, and temperature rise. eFuses often comprise a control board and a power board. Here we focus on providing a complete power board design example that is based on Vishay SiC's MOSFETs.

This power board is capable of handling voltages up to 950 V and 20 A current. The circuit can be easily scaled up for high current ratings. In addition to the eFuse functionality, the circuit benefits from a pre-charge circuit connected in parallel with the main eFuse switch, which avoids inrush currents into external uncharged capacitors. The power circuit is fully equipped with all the required feedback signals, including circuit current - which is measured by a Vishay low TCR shunt resistor - and the circuit voltage, which is measured by a low tracking error voltage divider.

## OVERALL SYSTEM BLOCK DIAGRAM

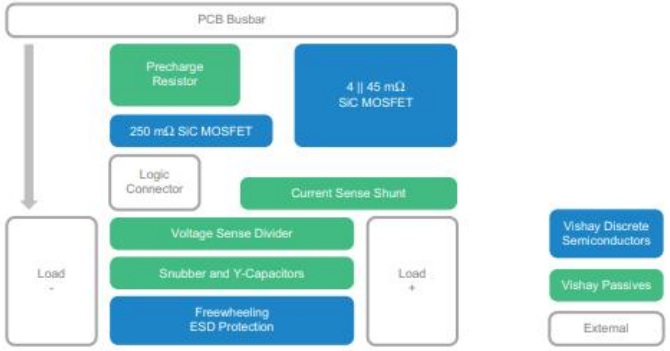
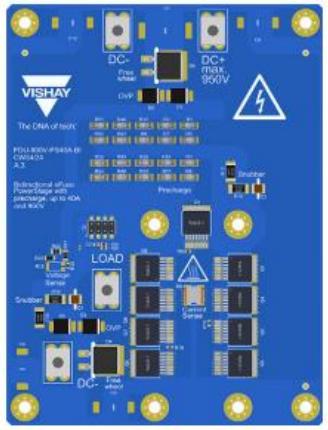



Fig. 1 - Overall System Block Diagram





# Reference Design
# SiC MOSFET-Based 800 V, 40 A Bidirectional eFuse




## FEATURES

- Low TCR shunt for precise current measurement
- Low tracking error voltage divider
- Robust I/O port providing ESD protection and freewheel capabilities
- Fast switching speed

## KEY COMPONENTS

- CMB0207 high pulse load carbon film MELF resistor
- MXP120A045FE SiC MOSFET
- MXP120A250FE SiC MOSFET

## LINKS TO ADDITIONAL RESOURCES

- EFUSE-800V40ABI

## DESCRIPTION

Electronic fuses (eFuses) are crucial in modern applications, especially in automotives. They are used to enhance overall vehicle safety by protecting against overcurrent, voltage spikes, and temperature rise. eFuses often comprise a control board and a power board. Here we focus on providing a complete power board design example that is based on Vishay's SiC MOSFETs.

This power board is capable of handling voltages up to 950 V and 40 A current. The circuit can be easily scaled up for high current ratings. In addition to the eFuse functionality, the circuit benefits from a pre-charge circuit connected in parallel with the main eFuse switch, which avoids inrush currents into external uncharged capacitors.

The power circuit is fully equipped with all the required feedback signals, including the circuit current - which is measured by a Vishay low TCR shunt resistor - and the circuit voltage, which is measured by a low tracking error voltage divider.

## OVERALL SYSTEM BLOCK DIAGRAM

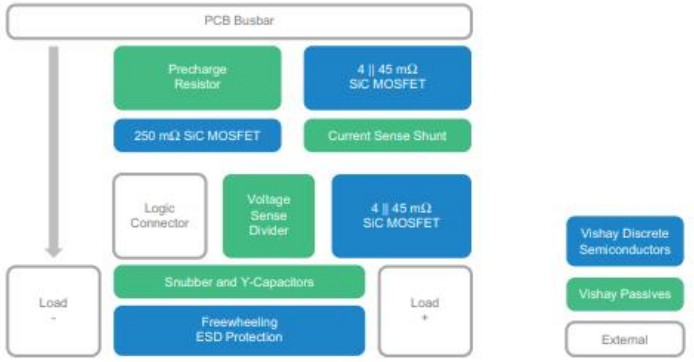



Fig. 1 - Overall System Block Diagram

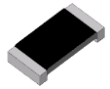
# Shunt Resistor Overview

## WSLP0603

**0.4 W**

10 mΩ to 100 mΩ

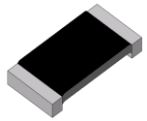
## WSLP0805



**0.5 W**

5 mΩ to 100 mΩ

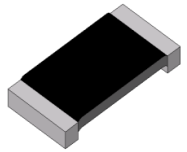
## WSLP1206



**1 W**

0.5 mΩ to 50 mΩ

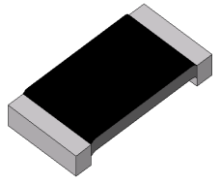
## WSLP2010



**2 W**

1 mΩ to 30 mΩ

## WSLP2512



**3 W**

0.5 mΩ to 10 mΩ

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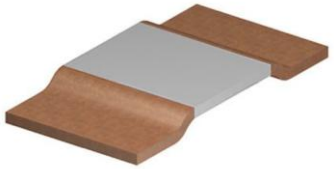
## WSLF2512



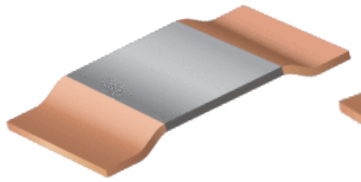
**WSLF2512, 10 W**

0.3 mΩ to 0.5 mΩ

**WSLF2512, 3 W**

4 mΩ

## WSLP3921



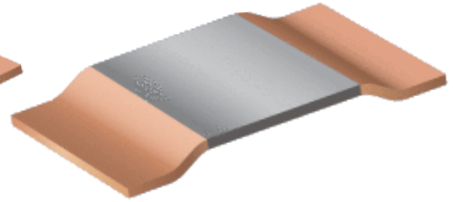
**WSLP3921, 9 W**

0.1 mΩ to 1 mΩ

**WSLP3921, 5 W**

2 mΩ to 4 mΩ

## WSLP5931



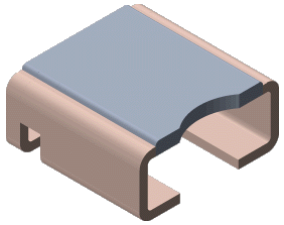
**WSLP5931, 15 W**

0.1 mΩ to 0.5 mΩ

**WSLP5931, 7 W**

1 mΩ to 3 mΩ

## WSLP2726



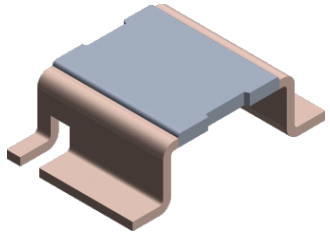
**WSLP2726, 12 W**

0.2 mΩ to 0.5 mΩ

**WSLP2726, 5 W**

1.3 mΩ to 5 mΩ

## WSLP4026



**WSLP4026, 12 W**

0.2 mΩ

**WSLP4026, 5 W**

1.3 mΩ to 5 mΩ

# eMobilityLAB

## Vishay's eMobility Application Laboratory

External support:

Using Vishay components
mostly through design activities

Internal support:
Application-specific questions
and defining new components

Dev / eval board
Reference designs
Turnkey solutions

Documentation
Test PCBs
Application knowledge

(application-centric viewpoint)

(component-centric viewpoint)

eMobilityLAB

# eMobilityLAB Locations

- LAB in Turin, Italy: mostly general technical support
- LAB in Warwik, UK: focuses on HV traction inverter applications

- International team to support design activities: Germany, Mexico, and Switzerland

eMobilityLAB

# Vishay Reference Designs

## VISHAY REFERENCE DESIGNS

To accelerate your development Vishay provides reference designs, highly reliable solutions that leverage the best of our component technology.

All of the resources needed for fast development are easily accessed: schematics, PCB layouts, BOMs, 3D views and Gerber files. View our current designs below.

**Reference Designs:**

**Isolated Busbar / SMD Current Sensor with Analog Output** - *New*

Utilizing WSBE and WSL low TCR shunt resistors, in addition to the VIA0050DD isolation amplifier, this design provides AC current measurement up to 1415 A for high voltage applications.

**Active Discharge Reference Designs**

Our Active Discharge Circuit reference designs provide reliable solutions for discharging stored energy in 400 V and 800 V capacitors. Ideal for automotive applications, they ensure system voltage reaches safe levels within required timeframes set by legal and manufacturer standards.

- Active Discharge Circuit for 400 V Systems - *New*
- Active Discharge Circuit for 800 V Systems - *New*

**High Voltage Intelligent Battery Shunt Reference Designs**

Our series of High Voltage Intelligent Battery Shunt reference designs demonstrate the effectiveness of our low TCR battery shunt technology to minimize the variation of the resistance over the operating temperature range.

- High Voltage Intelligent Battery Shunt Sensor (HV-IBSS-CANFD) - *New*
- High Voltage Intelligent Battery Shunt Single - USB (HV-IBSS-USB)
- High Voltage Intelligent Battery Shunt Redundant (HV-IBSR)

**196 HVC ENYCAP™ Energy Harvesting**

The V-harvester board is a photovoltaic (PV) harvesting stand-alone board charged using TEMD5080X01 micro PV cells or with micro USB.

**1 kW DC/DC Converter 48 V to 12 V**

This 1 kW, 48 V / 12 V buck-boost converter features two module power stages, each rated for 500 W. The converter can automatically switch between buck and boost operation, while its switching frequency of 160 kHz enables a compact form factor.

**Scalable 3 kW, 48 V / 12 V Bidirectional DC/DC Converter**

A complete 3 kW, 48 V / 12 V buck-boost converter has been designed utilizing an insulated metal substrate (IMS) with a heatsink for the power stage, with a standard FR4 controller board mounted on top and features six modular power stages capable of 500 W each.

**48 V, 100 A eFuse**

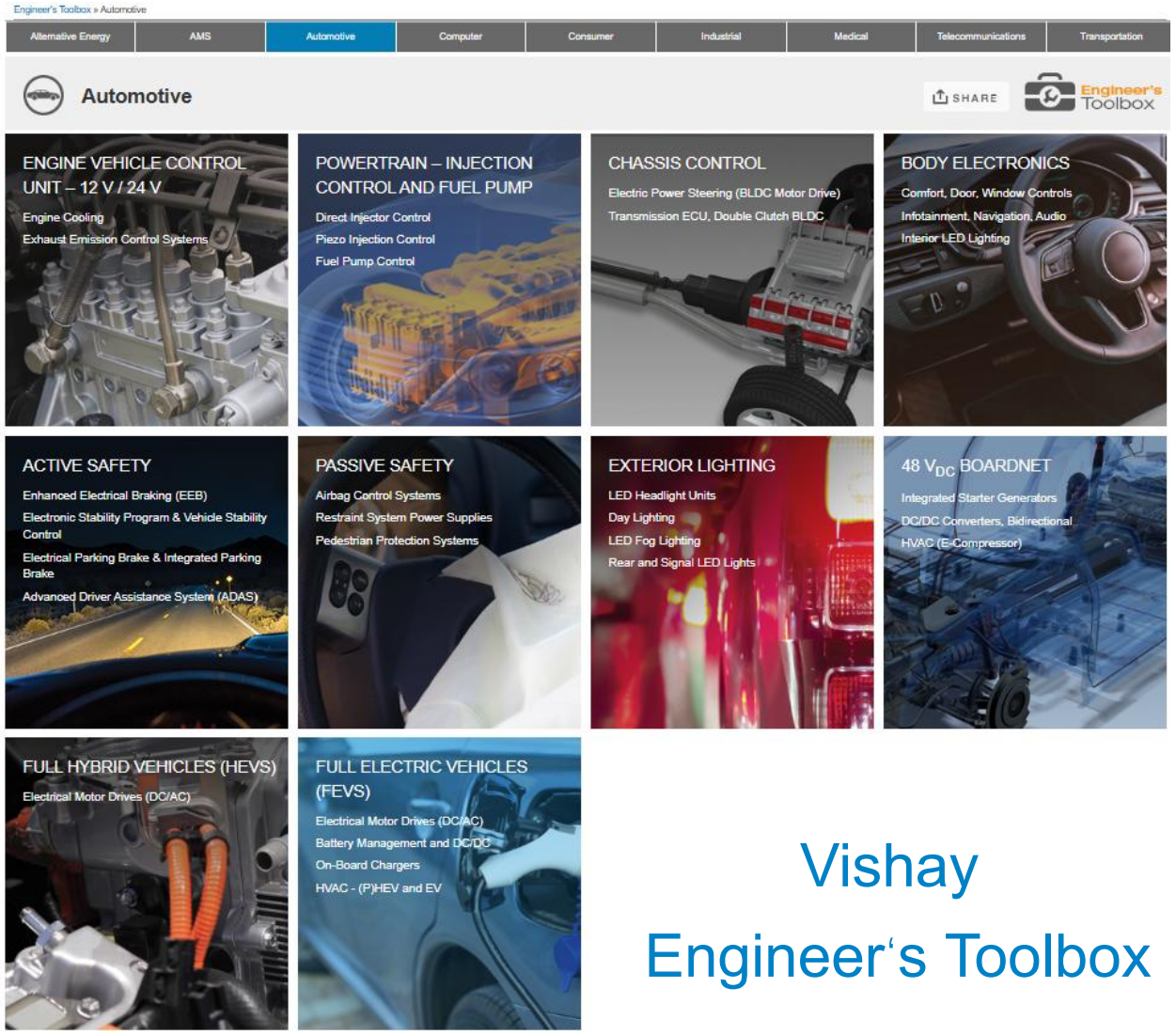
Featuring TrenchFET® MOSFETs, this eFuse has been designed to handle a continuous current up to 100 A and operate continuously at maximum current with less than 14 W of losses, without requiring active cooling.

**48 V Resettable eFuse**

An electronic fuse has been designed to switch loads up to 200A on a compact double-sided FR4 printed circuit board with passive cooling.

**400 $V_{DC}$, 100 A Bidirectional eFuse**

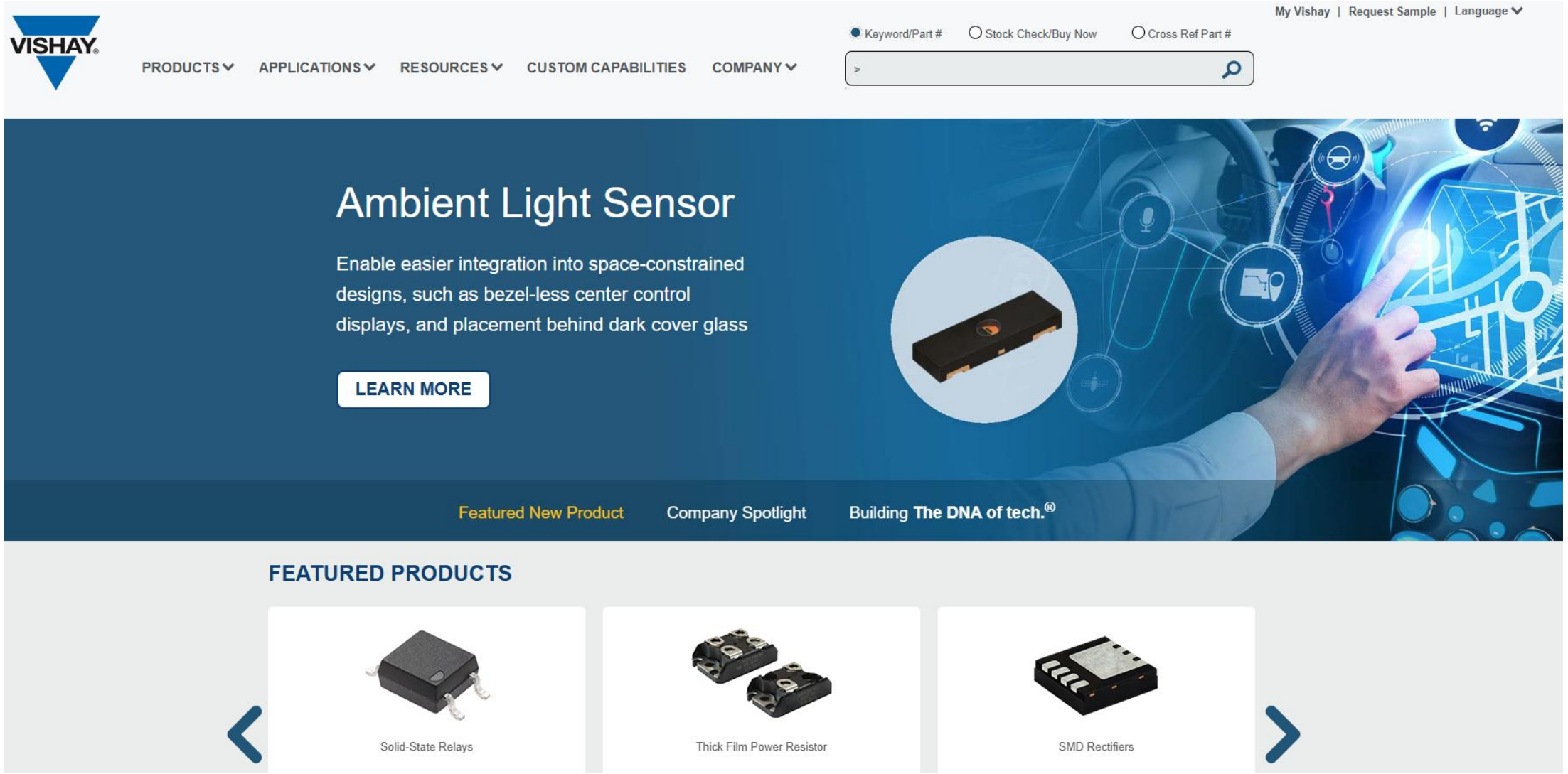
Featuring SiC MOSFETs and a VOA300 optocoupler, this design handles continuous power up to 40 kW and operates continuously at full power with less than 30 W of losses and no active cooling, and also features a preload function, continuous current monitoring and overcurrent protection (with shutdown in less than 2.5 µs).




Vishay

Engineer‘s Toolbox

# Learn more at www.vishay.com



# Thank you!

**Meet you at**

## N5, C48