

FOR ENERGY EFFICIENT INNOVATIONS

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# 不同功率等级牵引逆变器的 IGBT及碳化硅(SiC)模块方案

VE-Trac™ Power Module Platform:

The most efficient IGBT modules for EV Traction Inverter Solutions

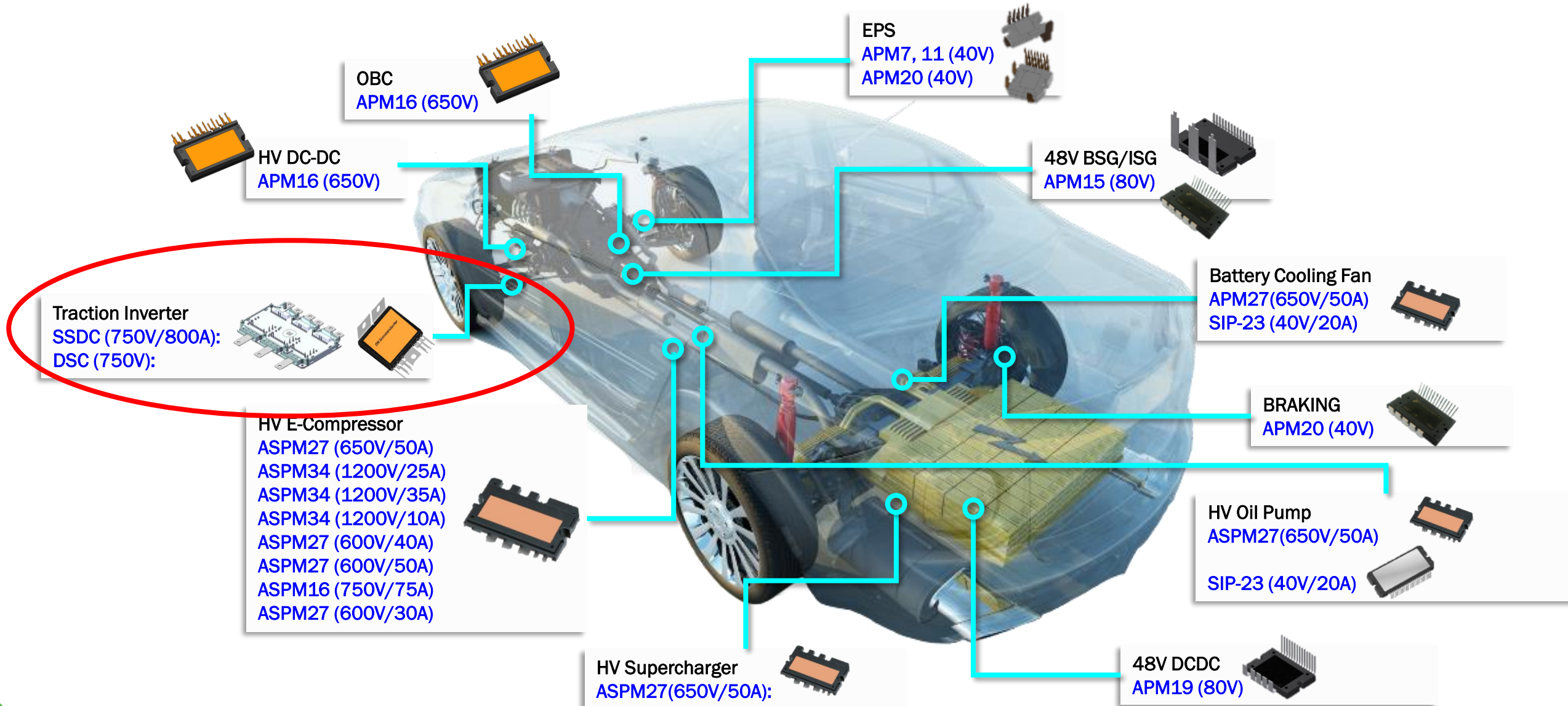
Public Information



# Agenda

- On Semiconductor's HV Automotive Power Modules
- Automotive Traction Inverter description
  - Module functionality
  - Power losses
  - Thermal characteristics
- VE-Trac™ Power Module Platform
  - VE-Trac™ Direct SiC
  - VE-Trac™ B2-SiC
  - VE-Trac™ Dual
  - VE-Trac™ Direct

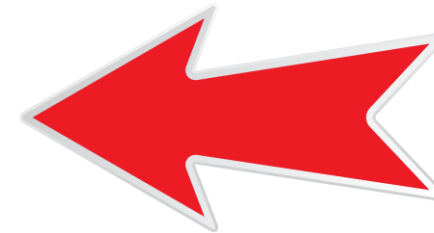
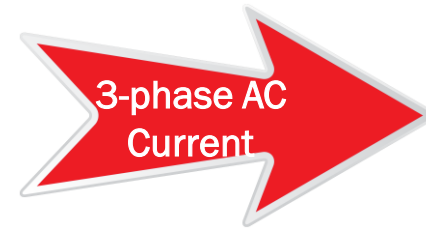
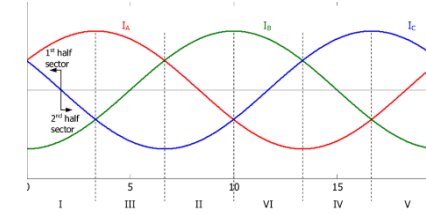
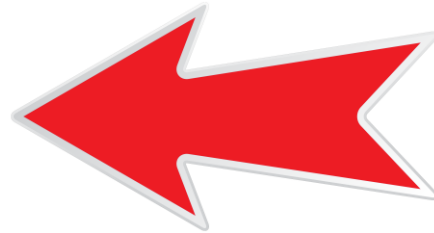
# ON Modules for Automotive



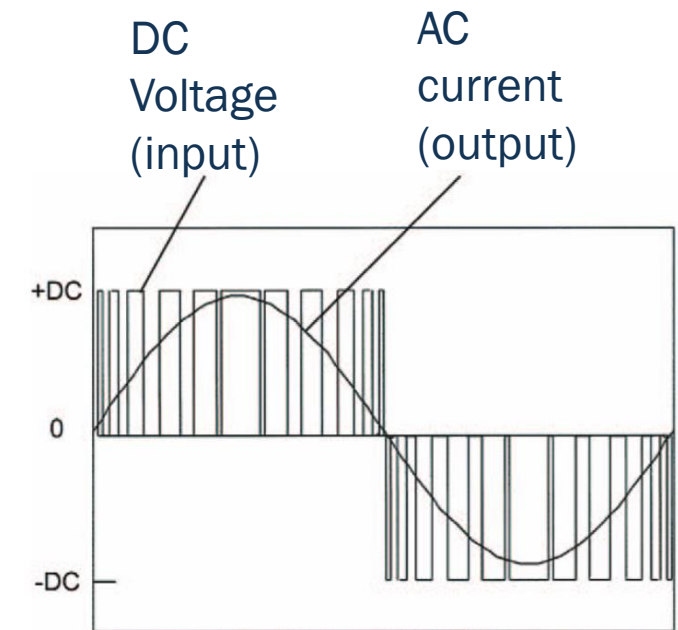
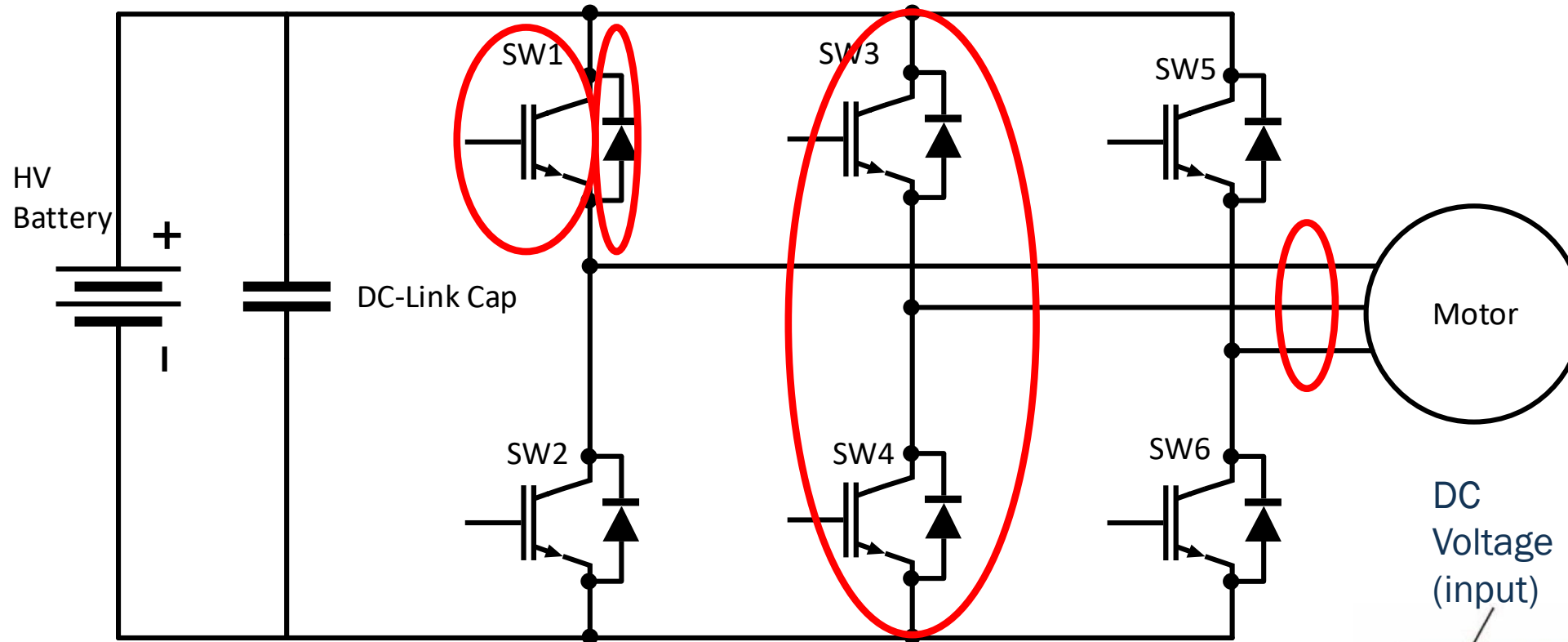
Public Information



# Traction Inverter – DC/AC converter

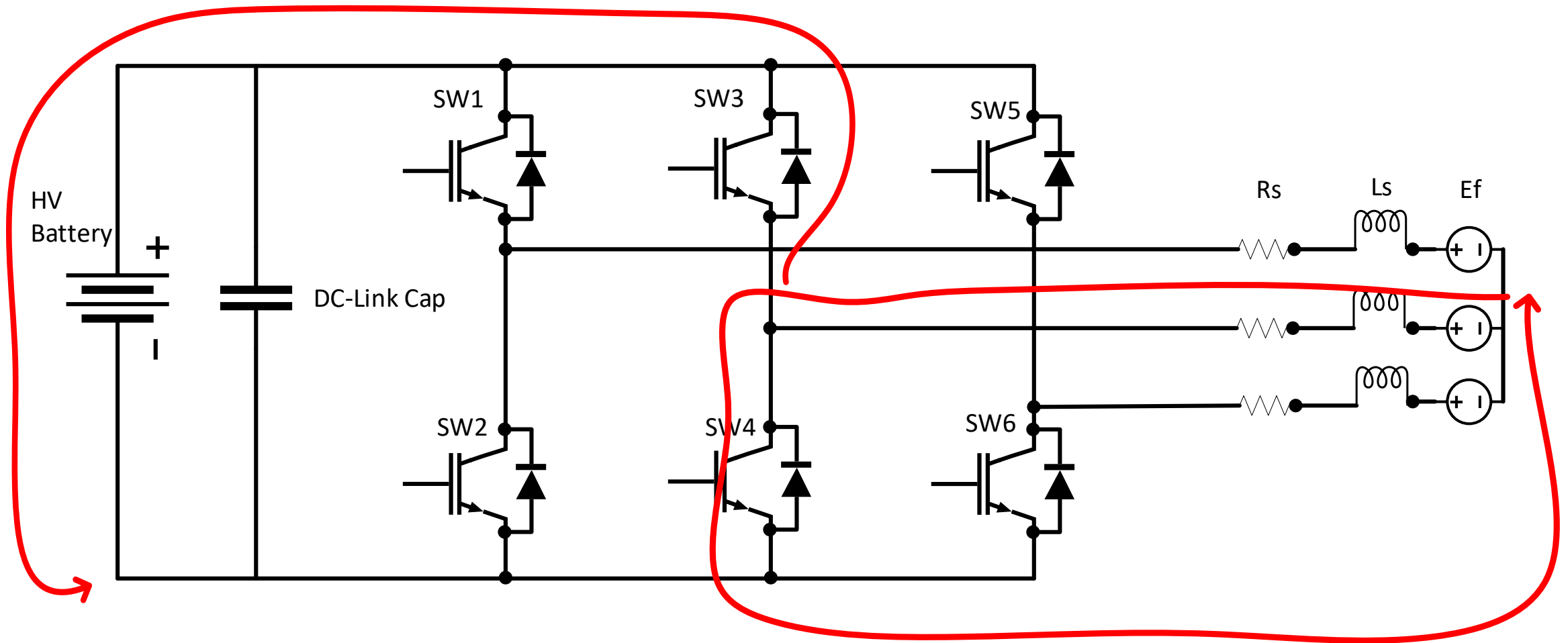


# Traction Inverter – DC to AC Conversion

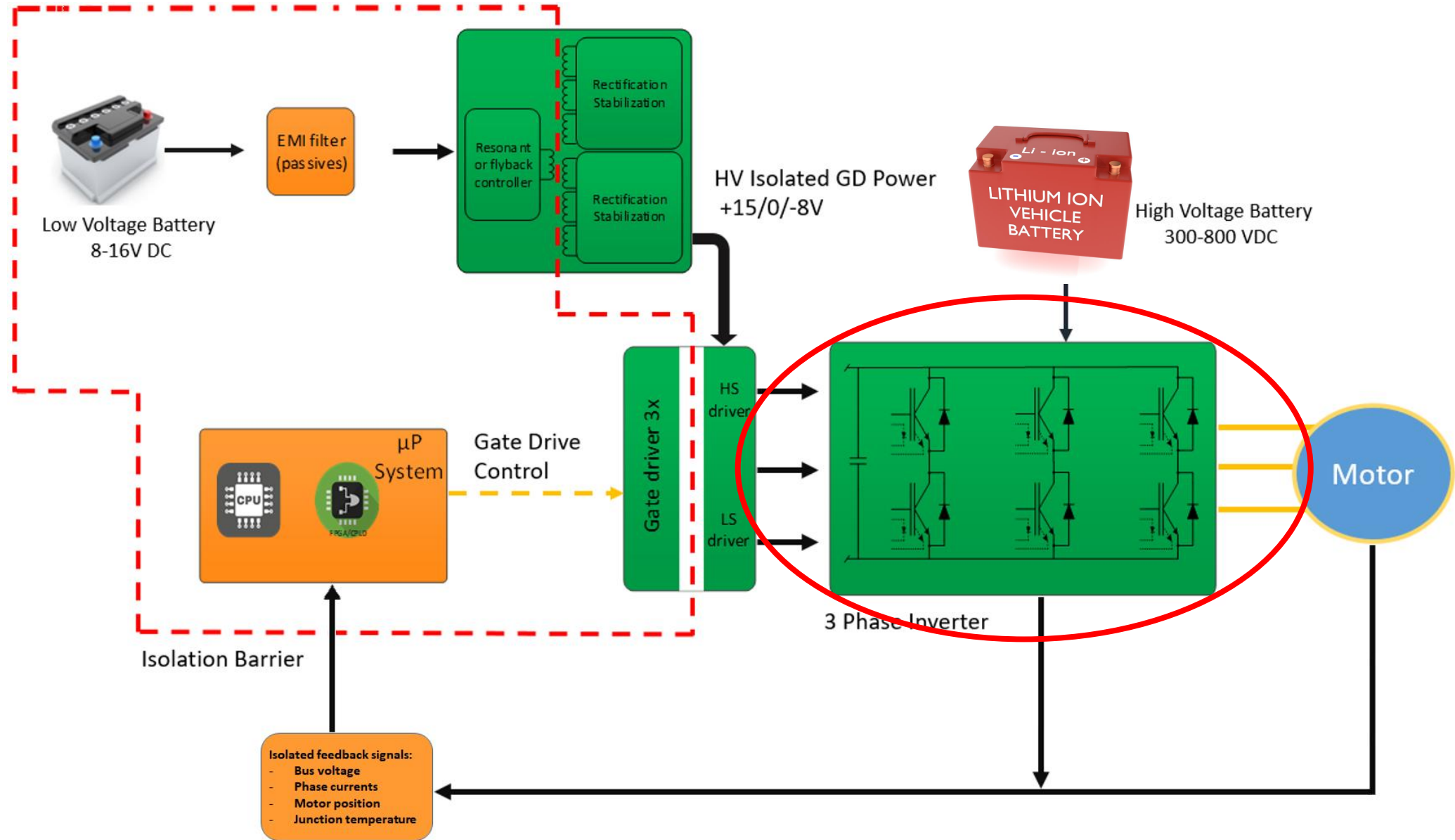




# Traction Inverter – Regenerative Braking



# Traction Inverter – Block Diagram



# Power Module – Junction Temperature

$$T_{\text{junction}} = T_{\text{ambient}} + (P_{\text{dissipation}} * R_{\text{th-junction-to ambient}})$$

- Power dissipation:
  - Switching (dynamic) losses
  - Conduction (static) losses
- Thermal resistance:
  - Semiconductor material
  - Die area and thickness
  - Packaging technology/materials
  - Heatsink design

Keeping  $T_{\text{junction}}$  below the specified maximum limit (i.e. 175°C) is a critical factor to ensure a reliable operation of the power switch throughout its lifetime



# Power Module – Power dissipation

- Traction Inverter will convert Electrical Power (Battery) into Mechanical Power (AC Motor)
- There are power losses through this conversion process
- Efficiency defines how much power was actually transferred from the battery to the motor

A system efficiency of **95%** means that  
**5%** of the input power was lost  
(dissipated as heat)

For a 100kW Traction Inverter with  
95% efficiency, it means that **5kW** are  
dissipated as heat!

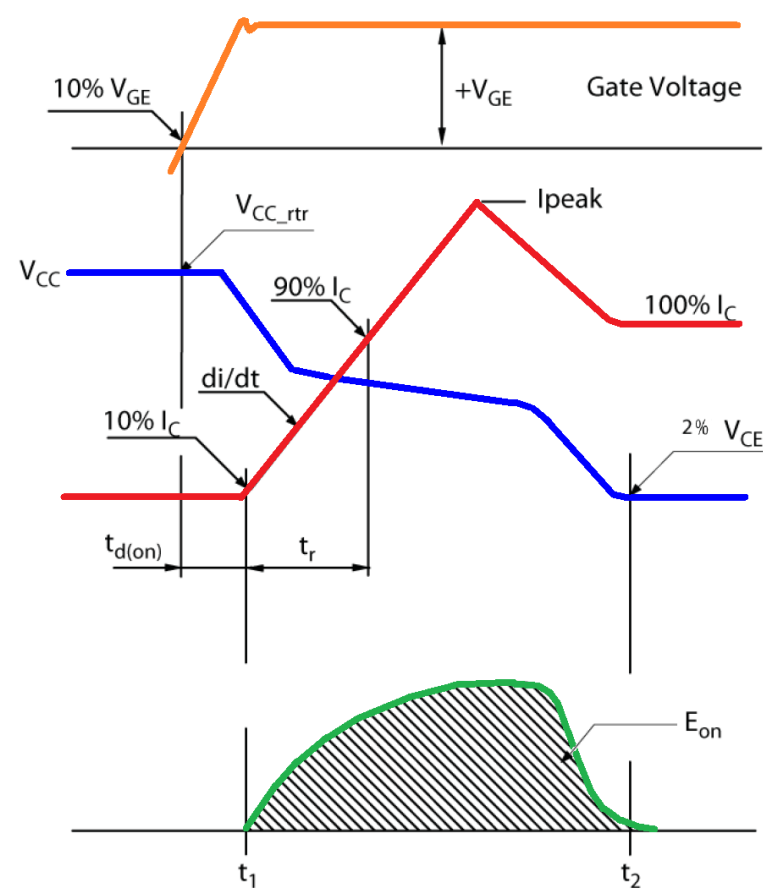
**Power losses (heat) need to be removed:**

- **Power stage losses (static & dynamic)**
- Control and standby losses
- Cable losses
- Motor losses

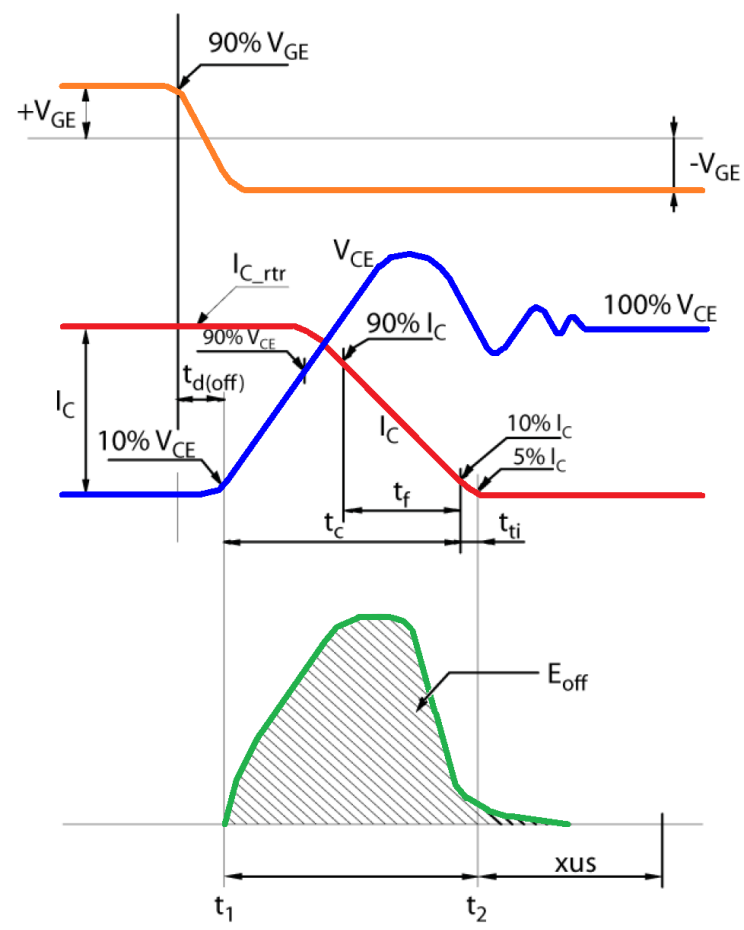
# Power Module – Switching Losses

$$P(t) = V(t) * i(t)$$

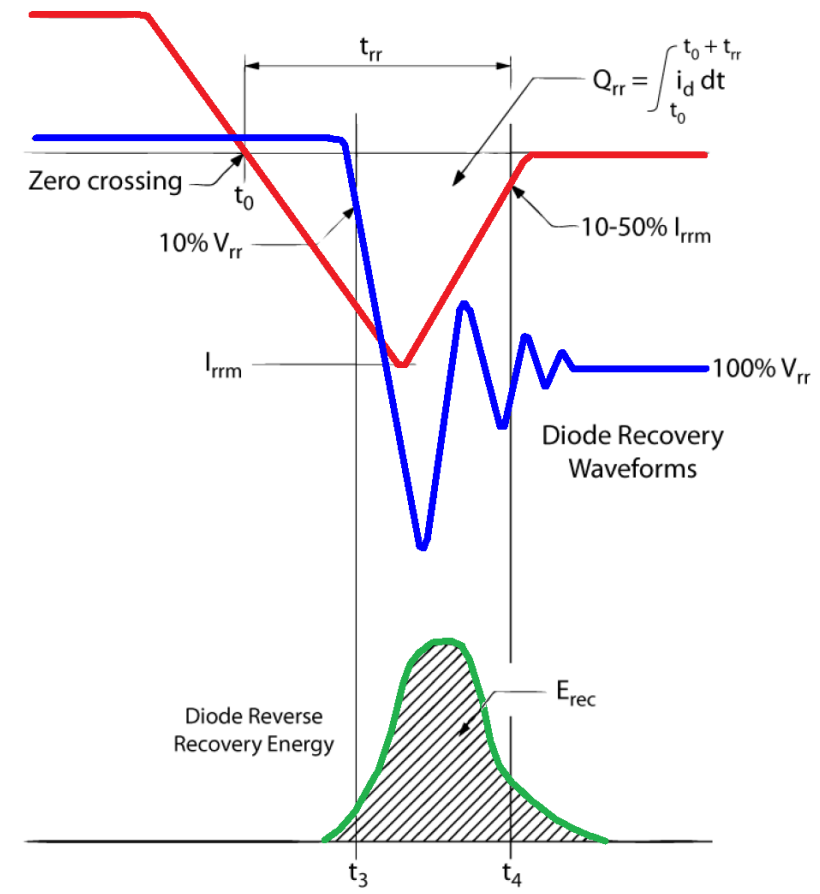
$$E = \int_0^T P(t)dt$$



IGBT Turn-ON losses



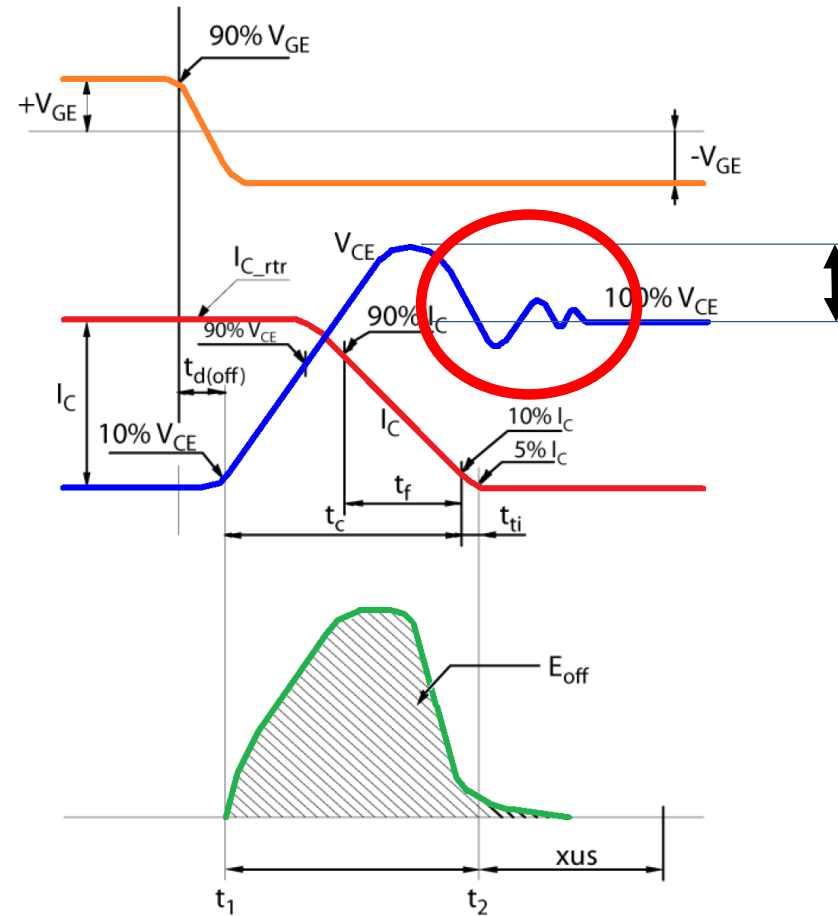
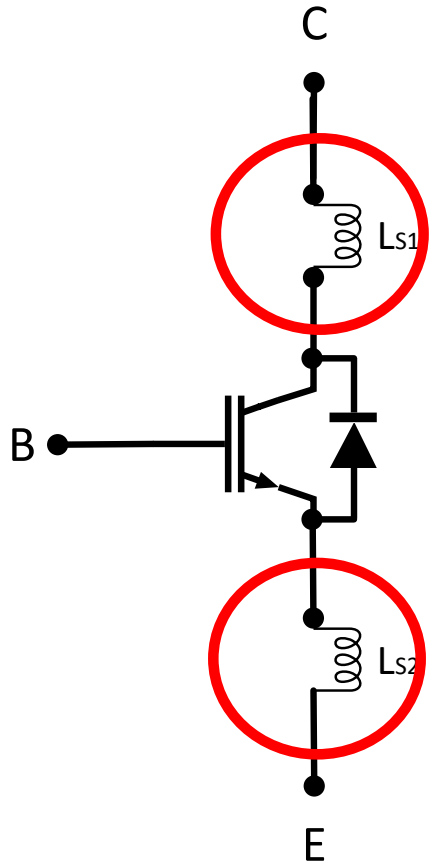
IGBT Turn-OFF losses  
Public Information



FRD Reverse Recovery losses



# Power Module – Stray Inductance



IGBT Turn-OFF

$\Delta V$  voltage overshoot and ringing

$$\Delta V = L_s * \frac{di}{dt}$$

Voltage overshoot can be significant:

$$\Delta V = 15\text{nH} * (8\text{A/ns}) = \mathbf{120V!}$$

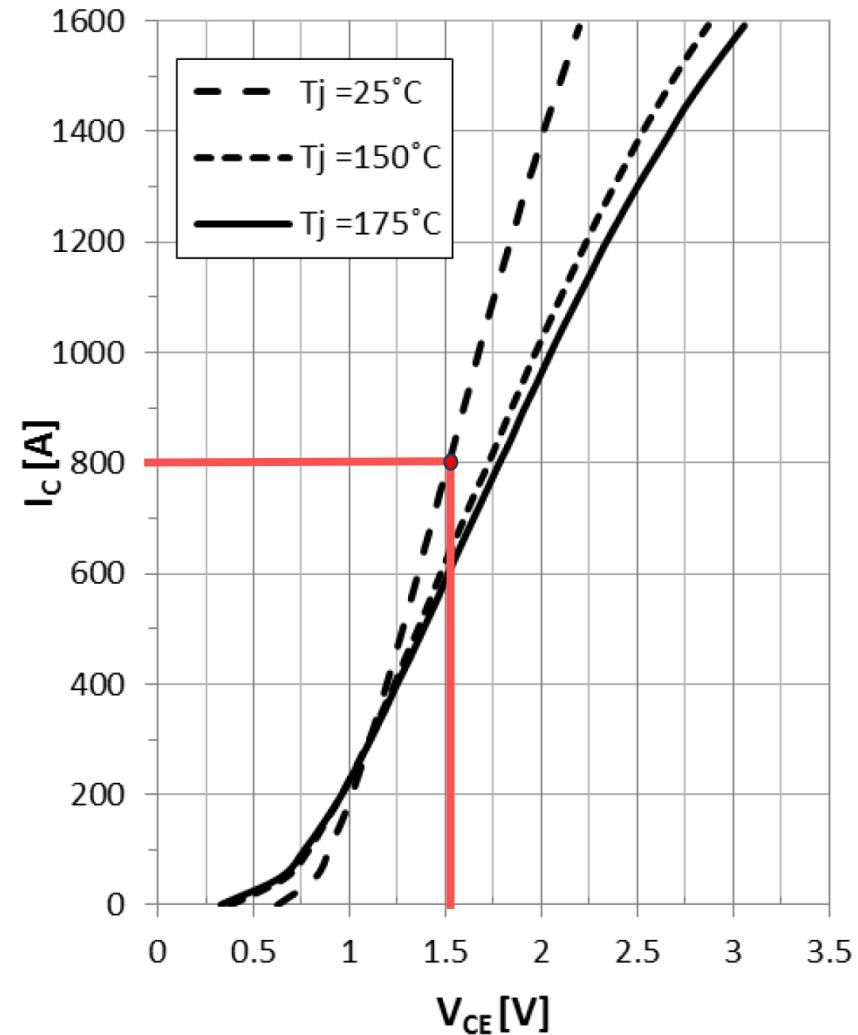
# Power Module – Conduction Losses



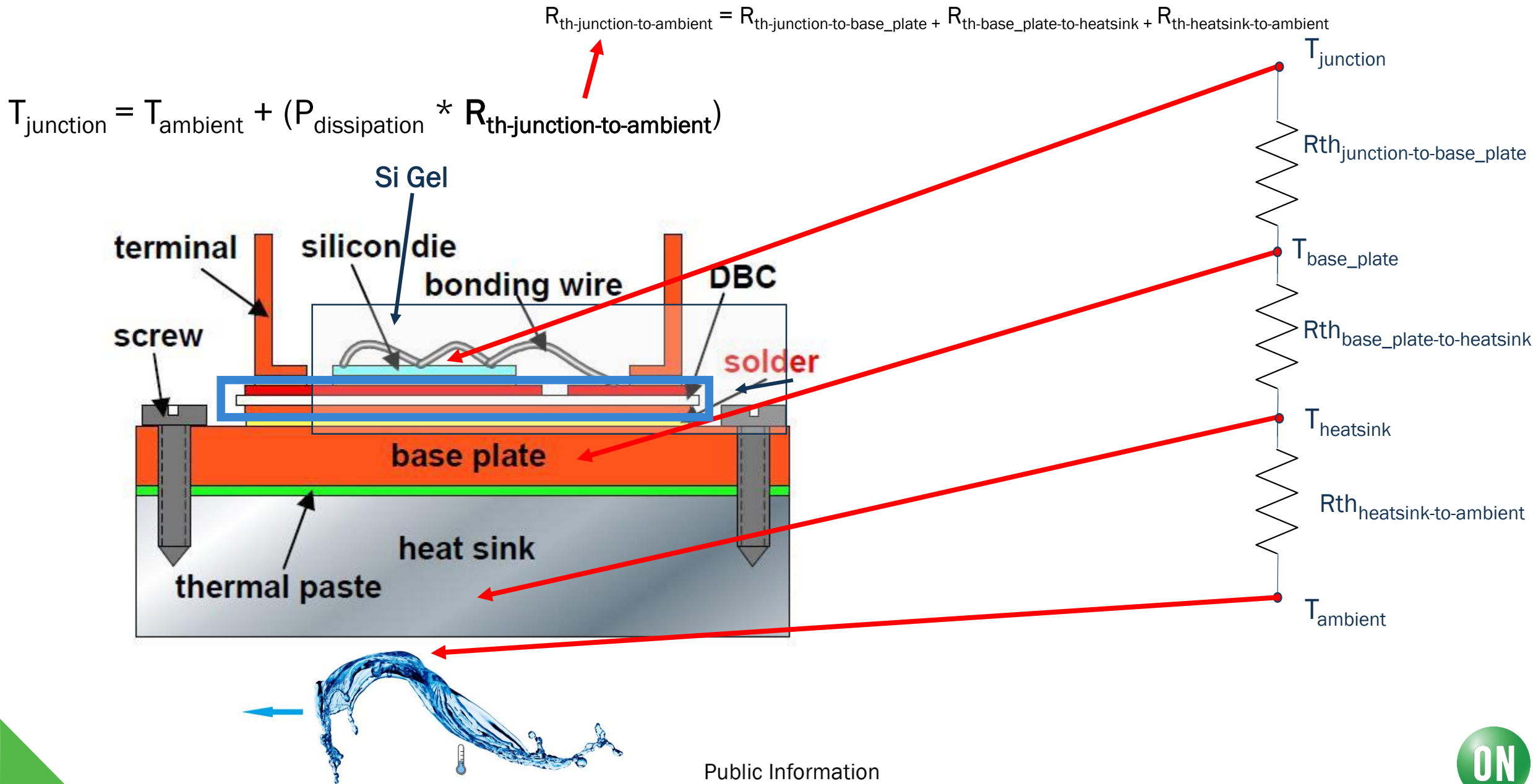
$$P(t) = V_{ce}(t) * i_c(t)$$

Assuming a constant current of 800A the power dissipation is:

$$P = 1.5V * 800A = 1.2kW$$

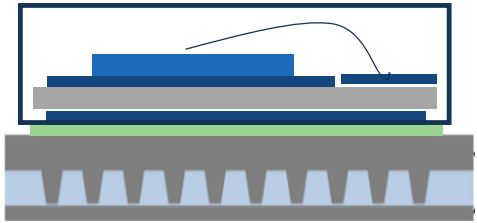


# Power Module – Thermal resistance

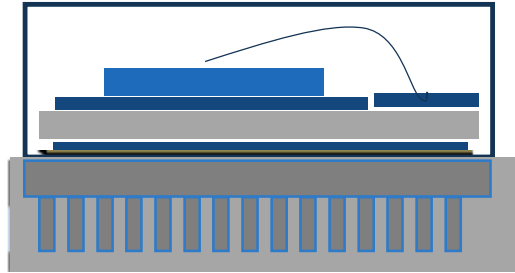


# Cooling / Mechanicals

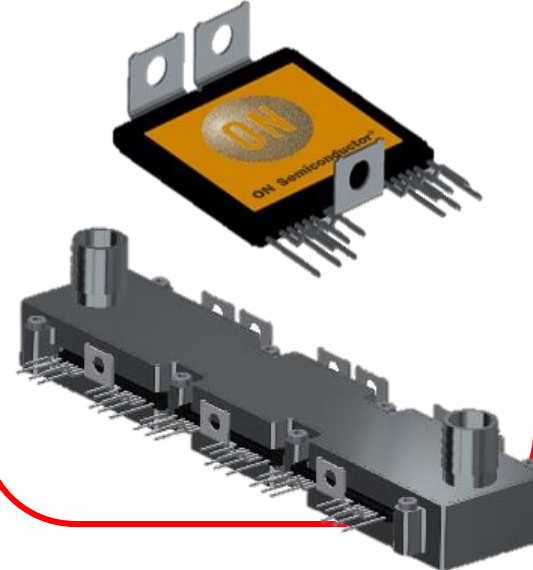
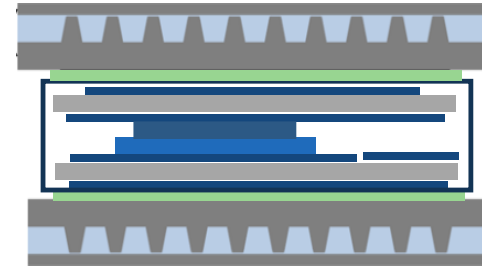
**Single Side, In-Direct Cooling**



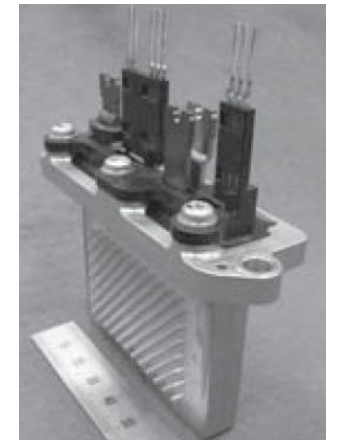
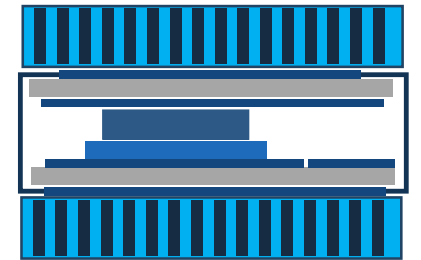
**Single Side, Direct Cooling**



**Dual Side, In-Direct Cooling**



**Dual Side, Direct Cooling**





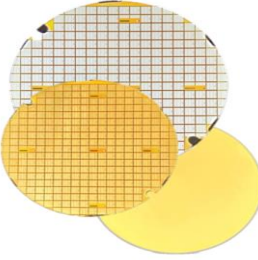
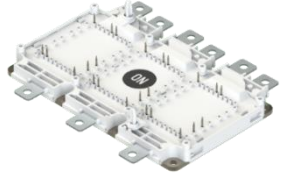
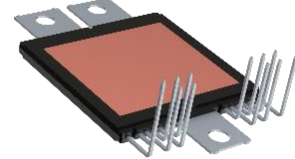
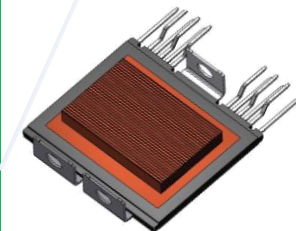
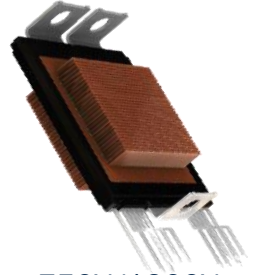
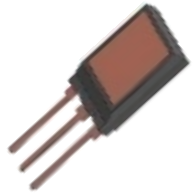
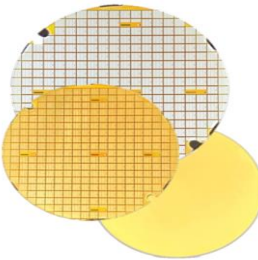
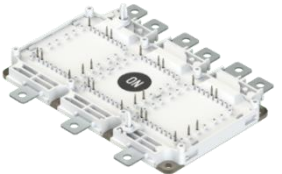
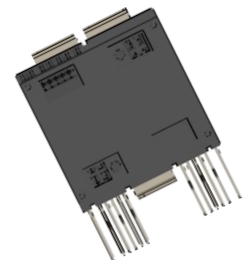
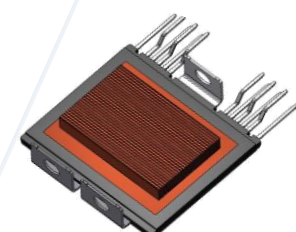
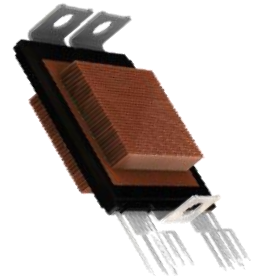
# VE-Trac™

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## EV Power Module Platform

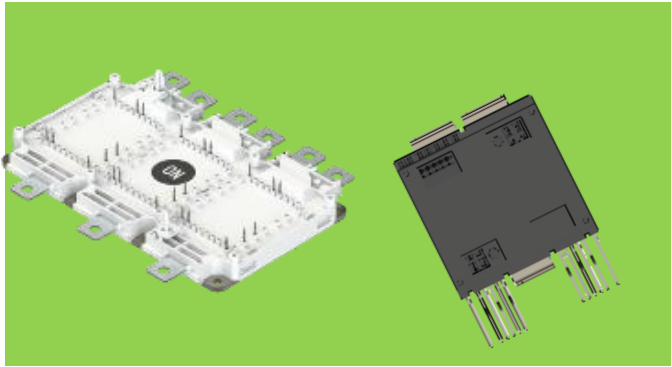
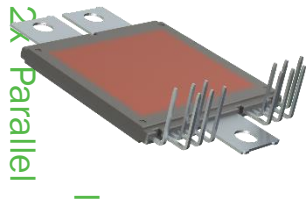
# VE-Trac™ (Vehicle Electrification for Traction) Products

## Comprehensive Traction Solutions

<b>TP/Iso-TP</b>  <ul style="list-style-type: none"><li>• 650V/750V</li><li>• SOP since 2018</li><li>• Tier 1s/OEMs</li></ul>	<b>IGBT</b>  <ul style="list-style-type: none"><li>• 750V/1200V</li><li>• &gt;10 engagements</li></ul>	<b>Direct-IGBTs</b>  <ul style="list-style-type: none"><li>• 750V/1200V</li><li>• SOP from 2019</li></ul>	<b>Dual-IGBTs</b>  <ul style="list-style-type: none"><li>• 750V/1200V</li><li>• SOP from 2019</li></ul>	<b>B2-Direct</b>  <ul style="list-style-type: none"><li>• 750V/1200V</li><li>• Concept</li></ul>	<b>B2-D Direct</b>  <ul style="list-style-type: none"><li>• 750V/1200V</li><li>• Concept</li></ul>
<b>Iso-TO</b>  <ul style="list-style-type: none"><li>• 1200V (concept)</li></ul>	<b>SiC</b>  <ul style="list-style-type: none"><li>• 1200V</li></ul>	<b>Direct-SiC</b>  <ul style="list-style-type: none"><li>• 1200V &amp; 900V</li></ul>	<b>B2-SiC</b>  <ul style="list-style-type: none"><li>• 900V &amp; 1200V</li></ul>	<b>B2-Direct SiC</b>  <ul style="list-style-type: none"><li>• 1200V</li><li>• Concept</li></ul>	<b>B2-D Direct SiC</b>  <ul style="list-style-type: none"><li>• 1200V</li><li>• Concept</li></ul>

# Portfolio Positioning for 400V DC Bus Inverters

Power Class	Rthj-f (K/W)	Direct IGBT	Dual-IGBTs	Direct SiC	B2-SiC
80kW	0.23	750V x Flat Base Plate			
100kW	0.16	750V, x Pin Fin Base Plate	750V, X DSB/C		
120kW	0.15 0.13	750V, x Flat Base Plate 750V, x Pin Fin Base Plate	750V, X DSB/C		
150kW	0.12	750V, 820A Pin Fin Base Plate	750V, 800A DSB/C		
180kW	0.10	750V, 950A Pin Fin Base Plate	750V, X DSB/C		
220-250kW	0.07				
280-320kW	0.06				
330kW+	0.05				



# VE – TRAC™ Direct SiC

## Features

- Direct Cooling with Integrated Pin-Fin Heatsink
- Low RDS(ON) and Low Switching losses
- Si3N4 Substrate for Higher Thermal Performance and Ruggedness
- Ag Sintering for Die Attach
- Ultra low thermal resistance up to  $R_{thJ-F} < 0.09$  k/W
- $T_{jmax} = 175^{\circ}\text{C}$  continuous operation

## Benefits

- Low System Cost
- Lower Energy Losses
- Higher Inverter Peak Output Power
- Improved Inverter Efficiency
- Optimized for Automotive Traction Applications
- Easy Design and Integration

## 900 V Line-up

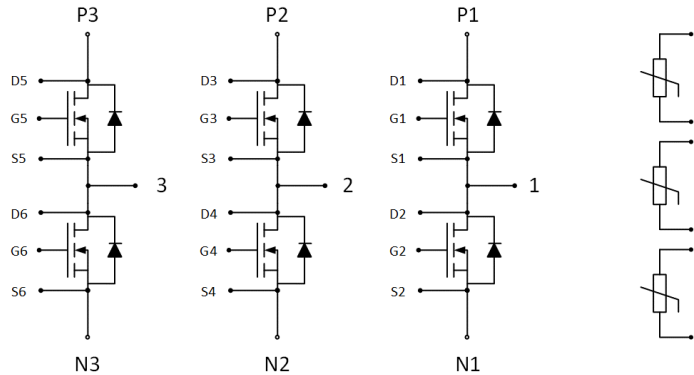
Product	Voltage	Current	Configuration	$R_{thJ-F}$ [k/w]	RTM
NXV90VR02WSTB	900 V	TBD	Pin-fin, Si <sub>3</sub> N <sub>4</sub>	TBD	TBD
NXV90VR03WSTB	900 V	TBD	Pin-fin, Si <sub>3</sub> N <sub>4</sub>	TBD	TBD

## 1200 V Line-up

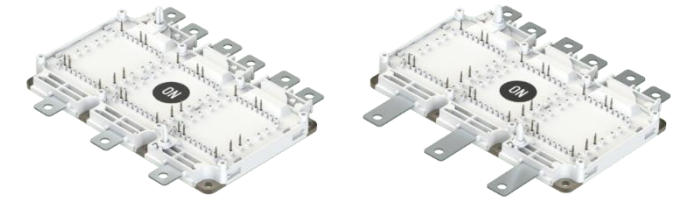
Product	Voltage	Current	Configuration	$R_{thJ-F}$ [k/w]	RTM
NXVk2VR03WSTB	1200V	TBD	Pin-fin, Si <sub>3</sub> N <sub>4</sub>	TBD	TBD
NXVk2VR04WSTB	1200V	TBD	Pin-fin, Si <sub>3</sub> N <sub>4</sub>	TBD	TBD

\* @ 450 V bus , 10 kHz switching frequency  
\*\* @ 650 V bus . 10 kHz switching frequency

## Block Diagram



## Package : 155 mm X 100 mm X 32 mm



# VE-Trac™ B2-SiC

## Features

- Low RDS(ON) and Low Switching losses
- AlN Substrate for Higher Thermal Performance and Ruggedness
- Ag Sintering for Die Attach and Clip to enhance thermal performance and current capability
- Ultra low thermal resistance up to  $R_{thJ-F} < 0.115$  k/W
- $T_{jmax} = 175^{\circ}\text{C}$  continuous operation and 200  $^{\circ}\text{C}$  for 200 hrs operation over life time

## 900 V Line-up

Product	Voltage	Current	Package	$R_{thJ-F}$ [k/w]	RTM
NXV90AR02WXT	900 V	TBD	A1HPM	TBD	TBD
NXV90AR03WXT	900 V	TBD	A1HPM	TBD	TBD

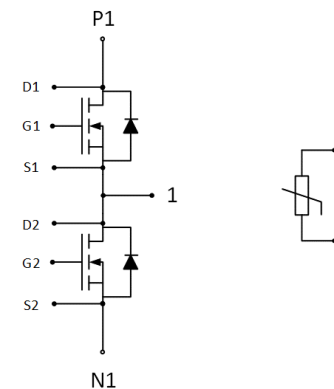
## 1200 V Line-up

Product	Voltage	Current	Package	$R_{thJ-F}$ [k/w]	RTM
NXVk2AR03WXT	1200V	TBD	A1HPM	TBD	TBD
NXVk2AR04WXT	1200V	TBD	A1HPM	TBD	TBD

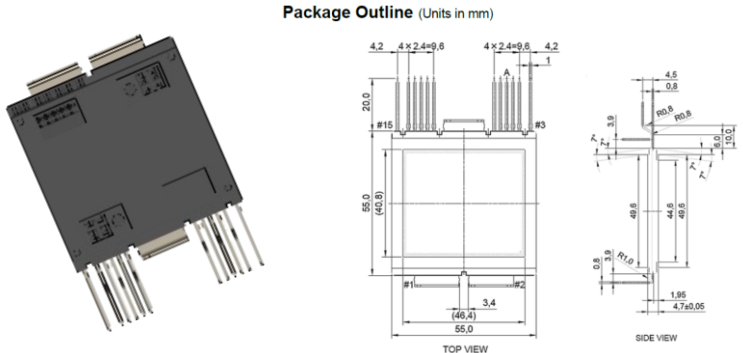
## Benefits

- Low System Cost
- Lower Energy Losses
- Higher Inverter Peak Output Power
- Improved Inverter Efficiency
- Optimized for Automotive Traction Applications

## Block Diagram



Package : 55 mm X 55 mm X 4.7 mm



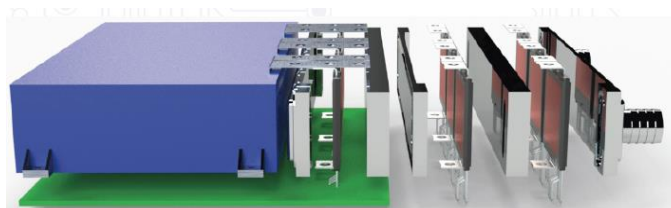
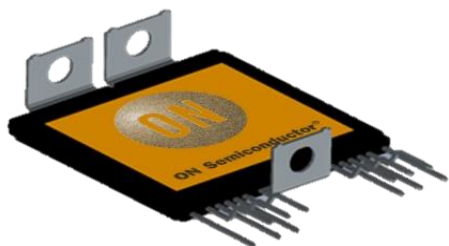
\* @ 450 V bus , 10 kHz switching frequency  
\*\* @ 650 V bus . 10 kHz switching frequency



# VE-Trac™ Power Module Strategy

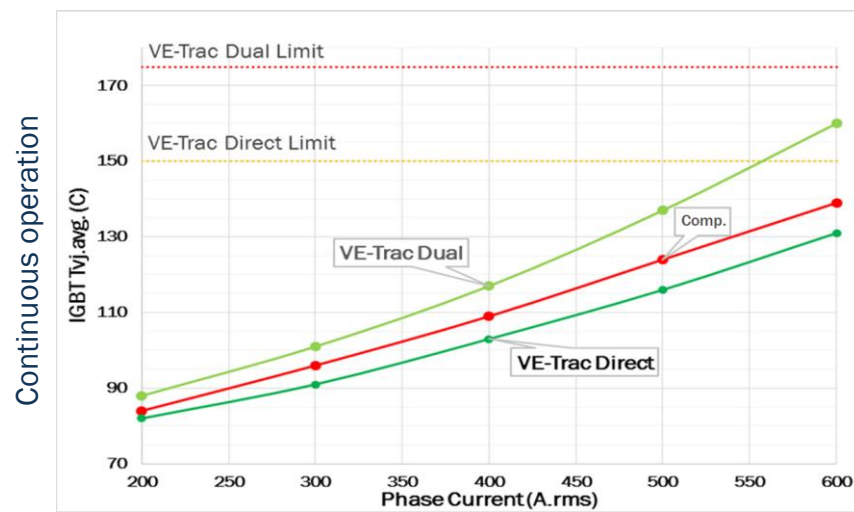
## VE-Trac™ Dual (Dual Side Cooling)

NVG800A75L4DSC  
750V, 800A Half bridge, DSC  
NVG400A120L2DSC  
1200V, 400A Half-bridge, DSC



**S C A L A B I L I T Y**

- Scalable (80-300kW)
- Best-in-class \$/KW
- 2x lifetime

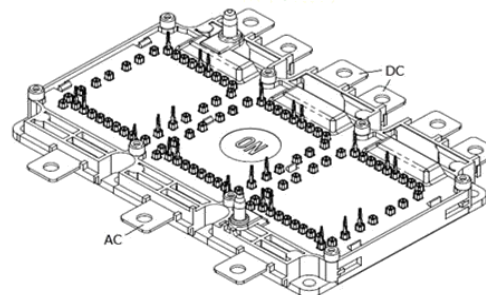


## VE-Trac™ Direct (Single Side Direct Cooling)

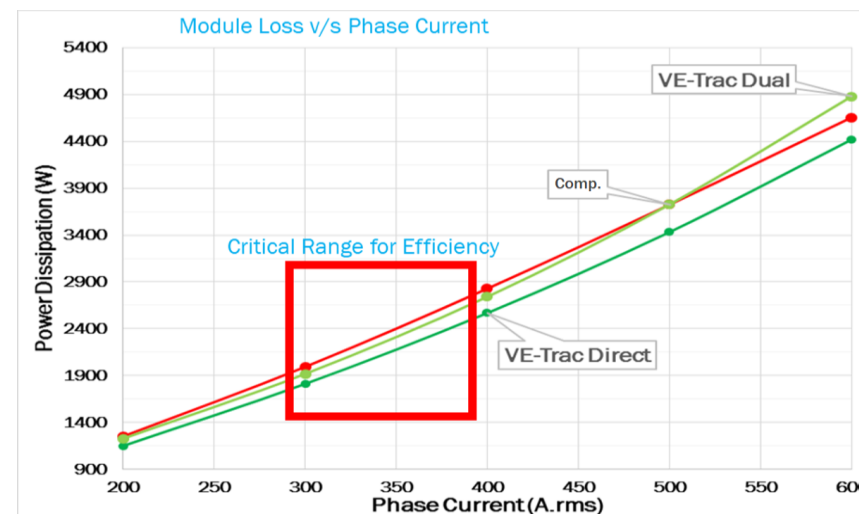
NVH820S75L4SPB  
750V, 820A 6-pack  
NVH950S75L4SPB  
750V, 950A 6-pack

NVH820S75L4SPC  
750V, 820A 6-pack

NVH820S75L4SPA  
750V, 820A 6-pack

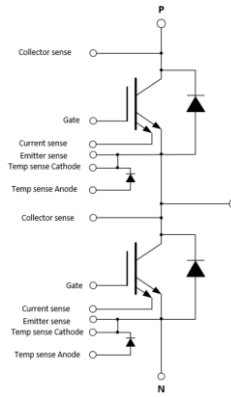
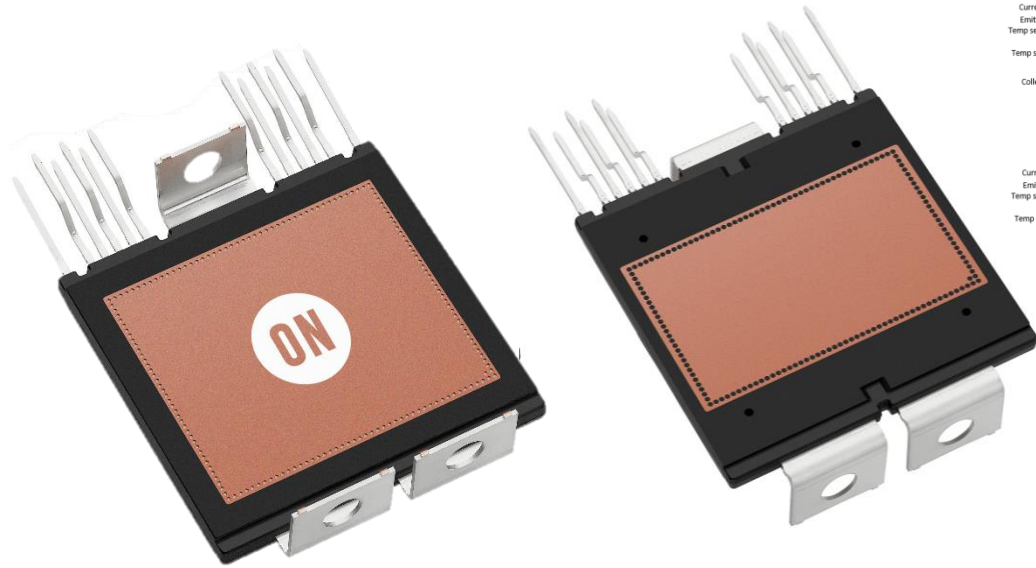


- Industry standard pin-out
- Best-in-class performance
- Supply assurance

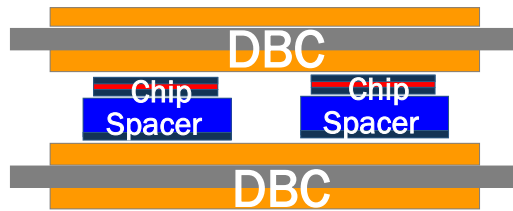




# VE-Trac™ Dual



- Lowest cost \$ per kW
- $T_{jmax} = 175^{\circ}\text{C}$  continuous operation
- Scalable, modular, and compact
- 750V & 1200V voltage classes
- Wirebond-free module for high reliability
- On-chip current and temperature sense
- Ultra low stray inductance of  $<7\text{nH}$



Device	Current Rating	Voltage Class
NVG800A75L4DSC	800A	750V

# VE-Trac™ Dual - Inverter Kit

440VDC, 560Arms, up to 160kW 3-ph Inverter

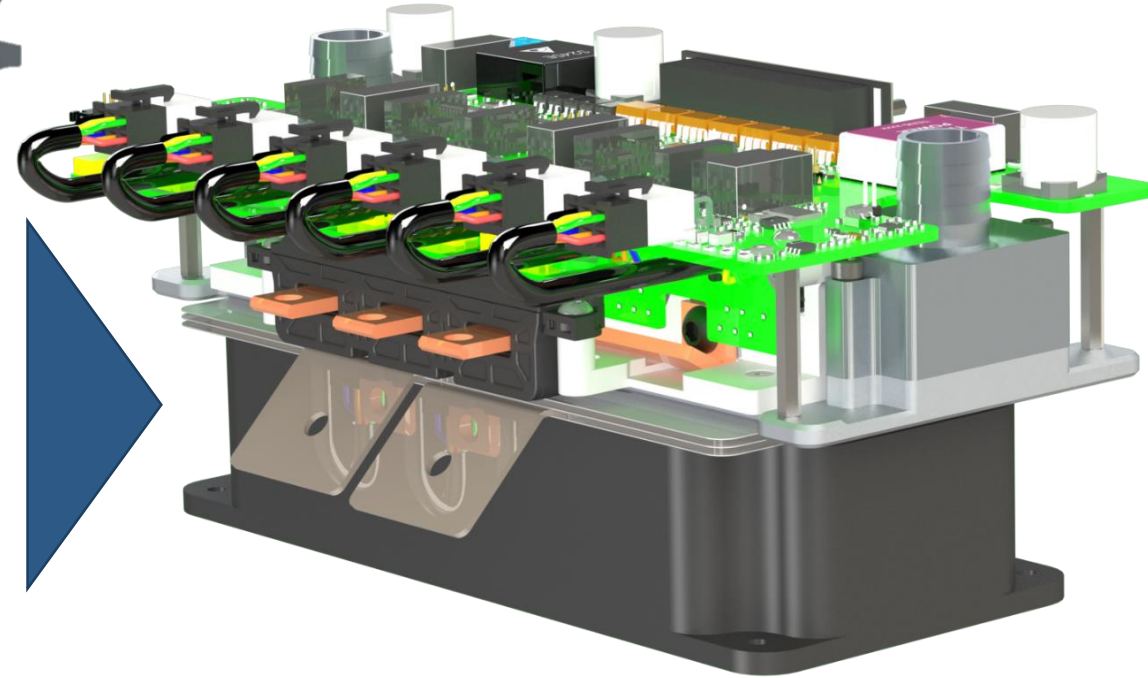
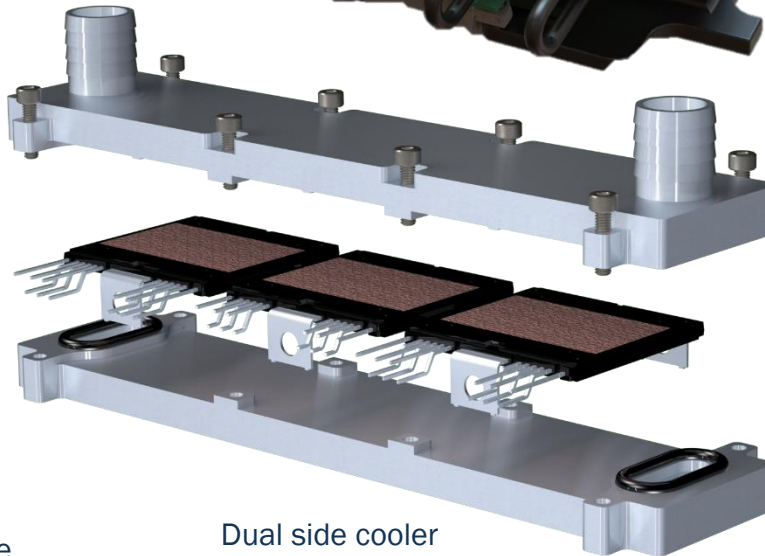
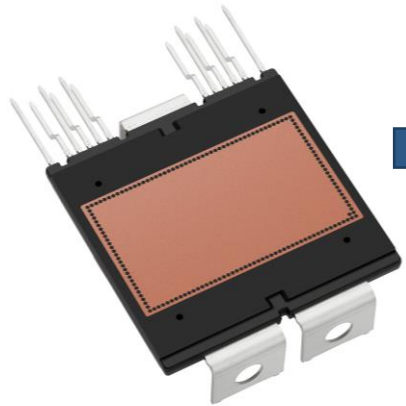
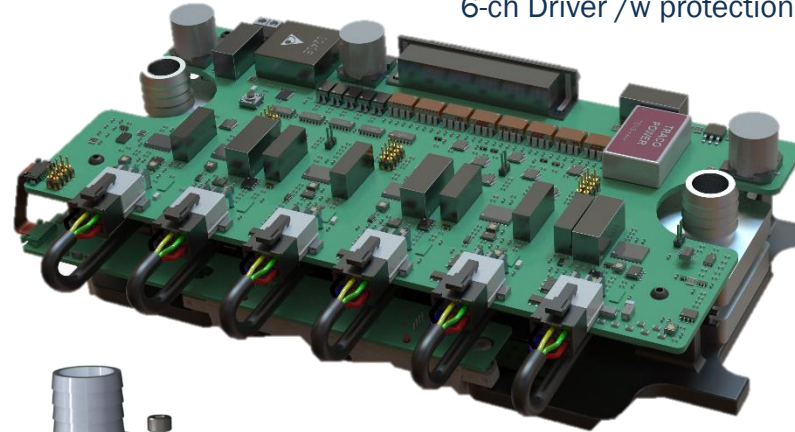
Compact size: 110 x 240 x 120 mm

Design kit makes it easy  
to test performance  
→ time to market

2-ch Isolated Driver



6-ch Driver /w protection



VE-Trac™ Dual Half-Bridge Module

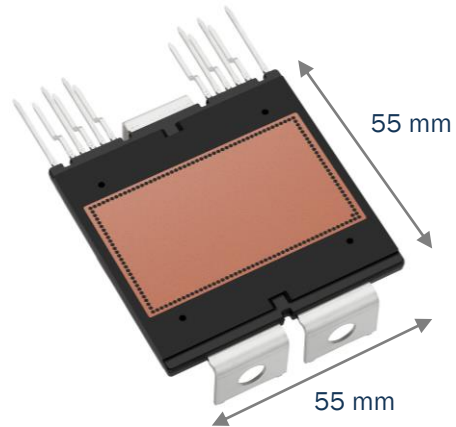
Dual side cooler

▲ Complete Inverter Kit

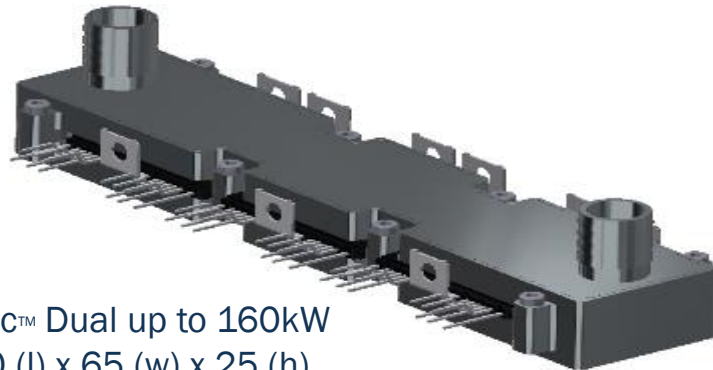
Public Information



# One Power Module: Many power levels



3x VE-Trac™ Dual up to 300kW  
Size: 230 (l) x 65 (w) x 39 (h)



3x VE-Trac™ Dual up to 160kW  
Size: 230 (l) x 65 (w) x 25 (h)

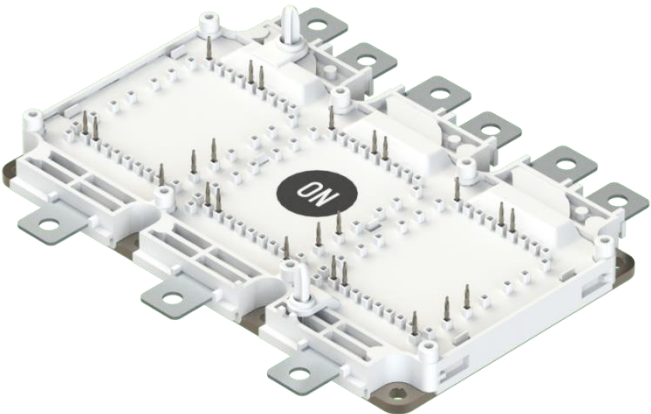
200% Increase in Output Power  
(only a 50% increase in volume)

## SCALABILITY

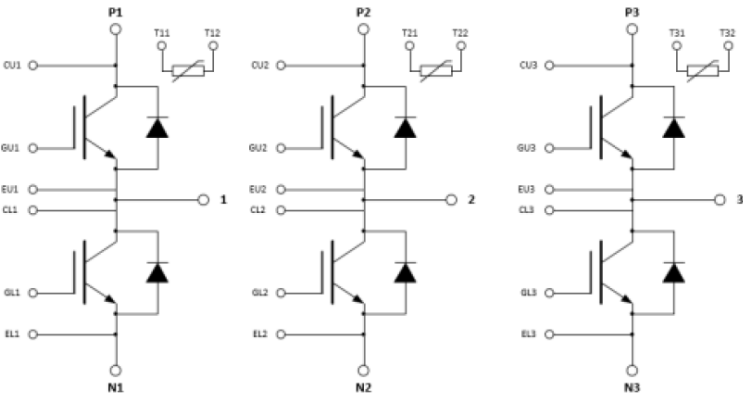
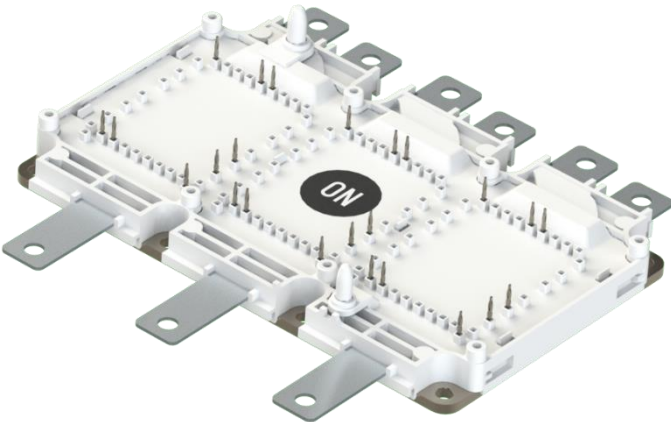


# VE-Trac™ Direct

## VE-Trac™ Direct SPB



## VE-Trac™ Direct SPC



- High reliability press-fit pin design
- Optimized Pin FIN with lower Rth-jf
- Short term operation up to 175 °C

Device	Current Rating	Voltage Class
NVH820S75L4SPB/SPC	820A	750V
NVH950S75L4SPB	950A	750V





# Key Takeaways

- ON Semiconductor now offers a very competitive product family to address EV Traction Inverter applications
- VE-Trac™ Dual is a dual side cooling module that offers the lowest cost per kW and allows a scalable inverter design with an ultra-low stray inductance
- VE-Trac™ Direct is a drop-in replacement to existing legacy products with an innovative and reliable press-fit pin technology
- VE-Trac Inverter Kit is a reference design using VE-Trac Dual modules which is available to speed up customer's designs

# Thanks