FOR ENERGY EFFICIENT INNOVATIONS

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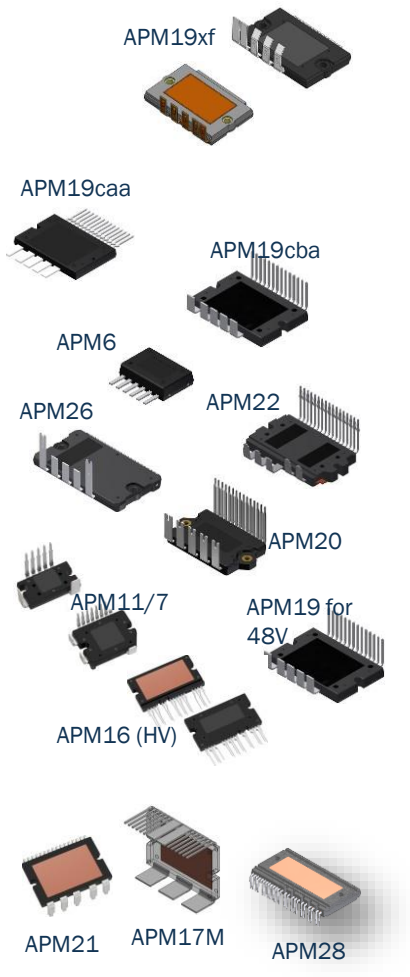
Introduction to HV AUTOMOTIVE POWER MODULE

Public Information

APM – Automotive Power Module Brand since 2008

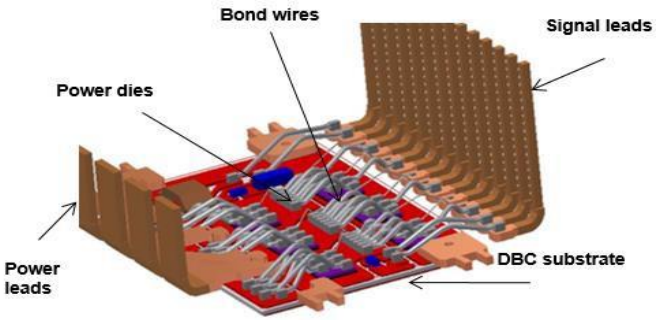


Development start

- 2006
- 2007
- **2008** – 1st APM SOP for EPS (APM19xf series)
- 2009
- 2010
- **2011** – APM22, APM19smh series SOP for EPS
- 2012
- 2013
- **2014** – APM20 SOP for EPS
- 2015
- 2016 – APM20 Brake, APM11/7 SOP
- 2017
- **2018** – 48V APM SOP .HV OBC APM SOP (APM16)
- 2019
- 2020
- 2021
- 2022
- 2023
- **2024** – .Grow and Maintain Leadership in xEV (OBC, 48V) & ICE Market

Core Values of APM to Customer

Solution Seller	High Power Density	Auto Field Proven Reliability
(customized Application)	@ Best Application performance	(Proven over 10 year auto field)

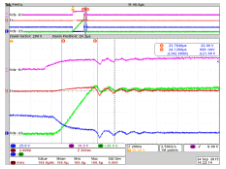


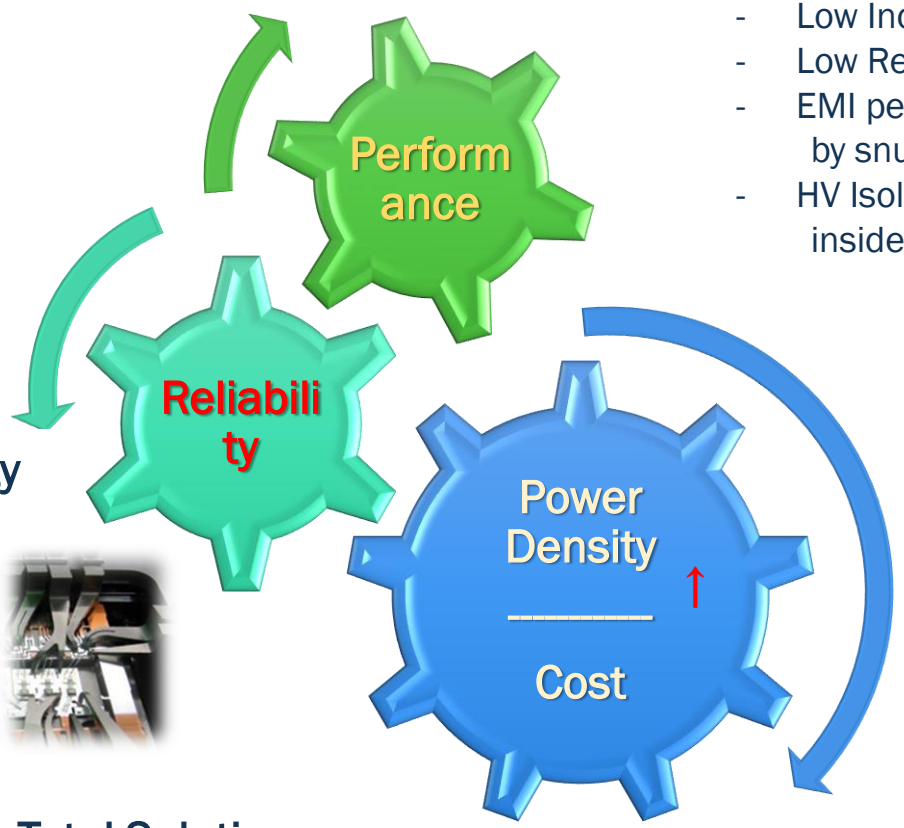
*The Automotive Power modules production has been in mass production **since 2008** after releasing 1st Electrical Power Steering full bridge APM. Since after APM became the #1 leader in MOSFET Automotive Module Market. As of Now, ON semi has the broad portfolio in production from of APMs for various applications for 12V ICE, 48V MHEV and HV EV/BEV, and Expanding its solutions focusing on high power Applications.*

Benefits of ON SEMI APM

Electrical Performance

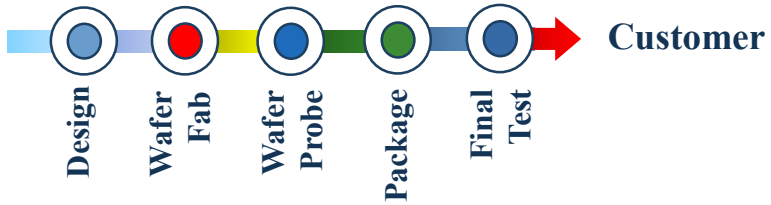
- High Current Capa
- Low Inductance
- Low Resistance
- EMI performance by snubber
- HV Isolation inside



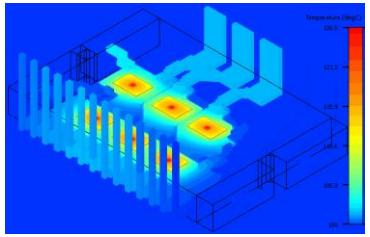


Proven Reliability

Fab + Assembly Total Solution



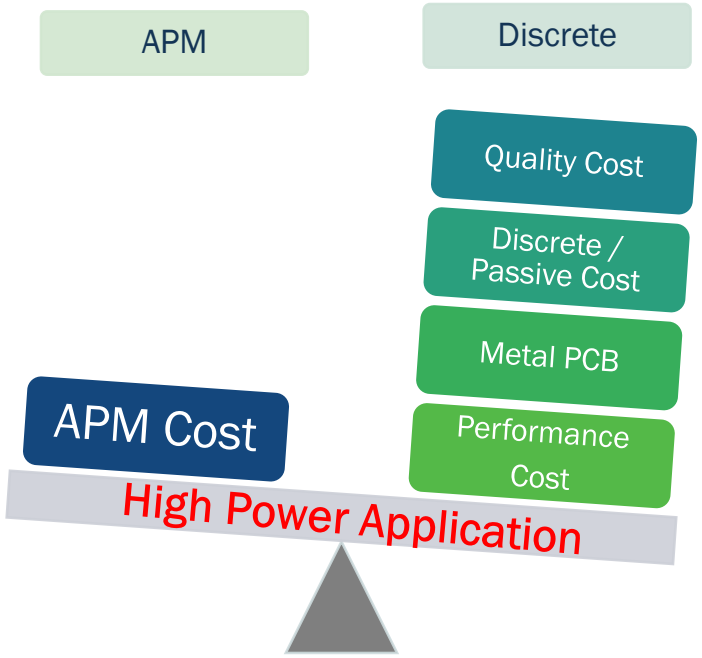
Low Thermal Resistance Junction to Heat sink



Smaller foot print

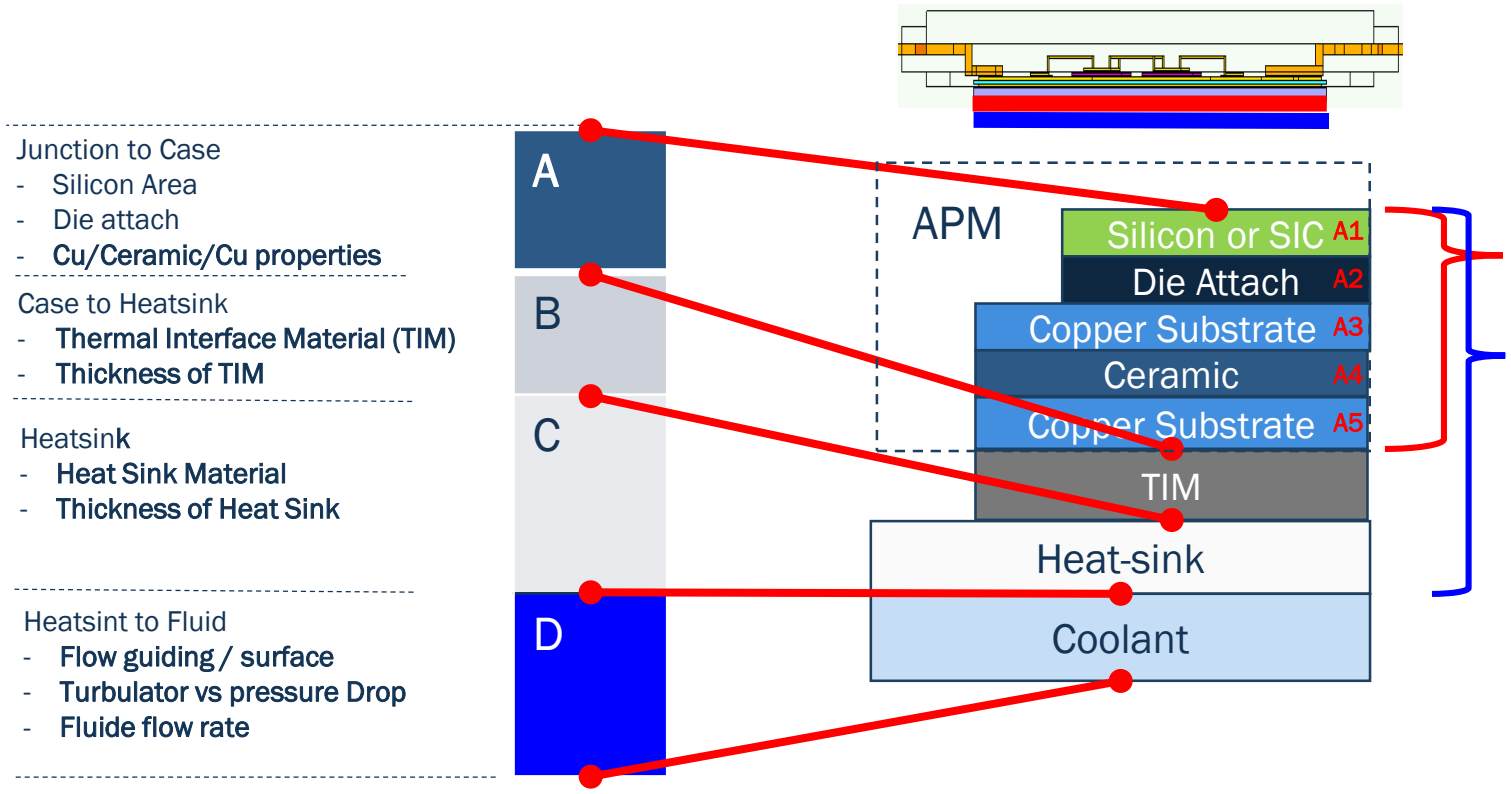
System Cost

(for High Power Application)



Benefit: Thermal

ON APM design enabling better thermal performance of total Rth junction to Heat sink



	APM – ON	Discrete
Rthjc – junction to case = A (A1~A5)	>	
Rthjs – junction to heat sink = A+B+C	<	

Rthjs Simulation result (Per 44mm^2 die)

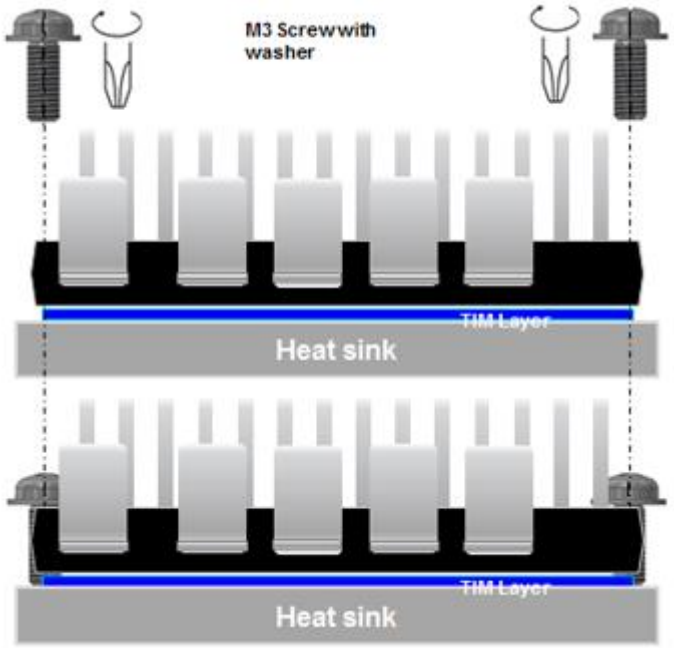
	Low Rth Substrate		AL2O3 Substrate	
	Rth, ˚C/W	%	Rth, ˚C/W	%
A1	0.0202	4.6%	0.0232	3.3%
A2	0.0185	4.2%	0.0185	2.6%
A3	0.0202	4.6%	0.0190	2.7%
A4 – Ceramic	0.0621	14.1%	0.3465	48.7%
A5	0.0113	2.6%	0.0105	1.5%
B TIM	0.0619	14.0%	0.0581	8.2%
C Heat Sink	0.2468	56.0%	0.2363	33.2%
TOTAL	0.4410	---	0.7120	---

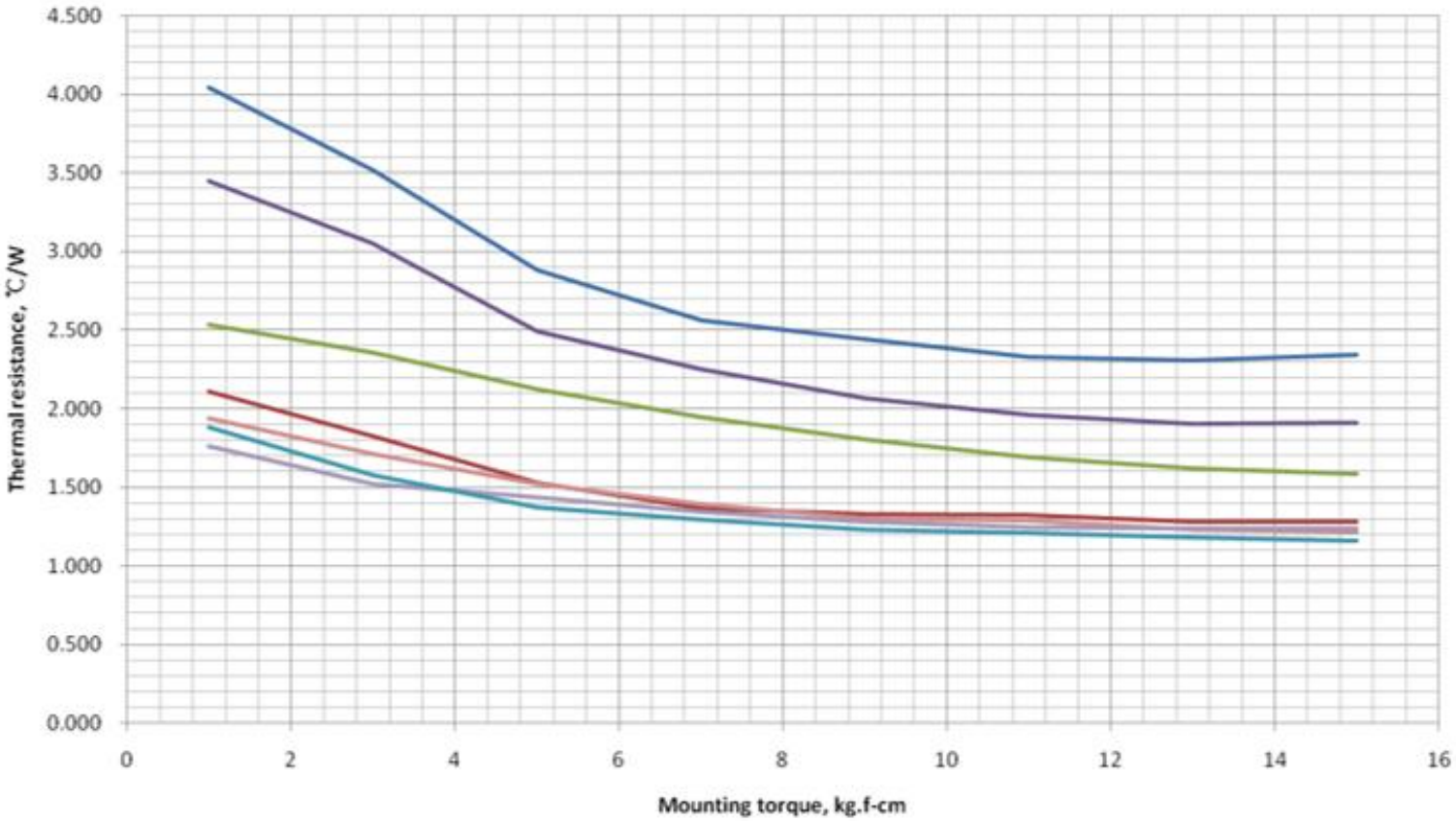
A : Options of vertical structure selection and Internal Design defines Rth Per Power rating of application

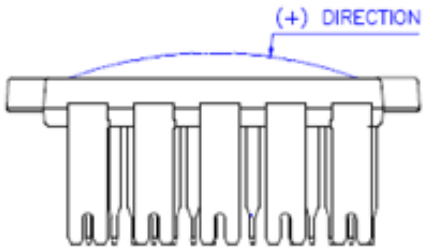
B : By the usage of APM, enable thin layer of B for minimum Rth of of **A+B**

C/D : Customer's design per system requirements

Mounting Guidance for APM

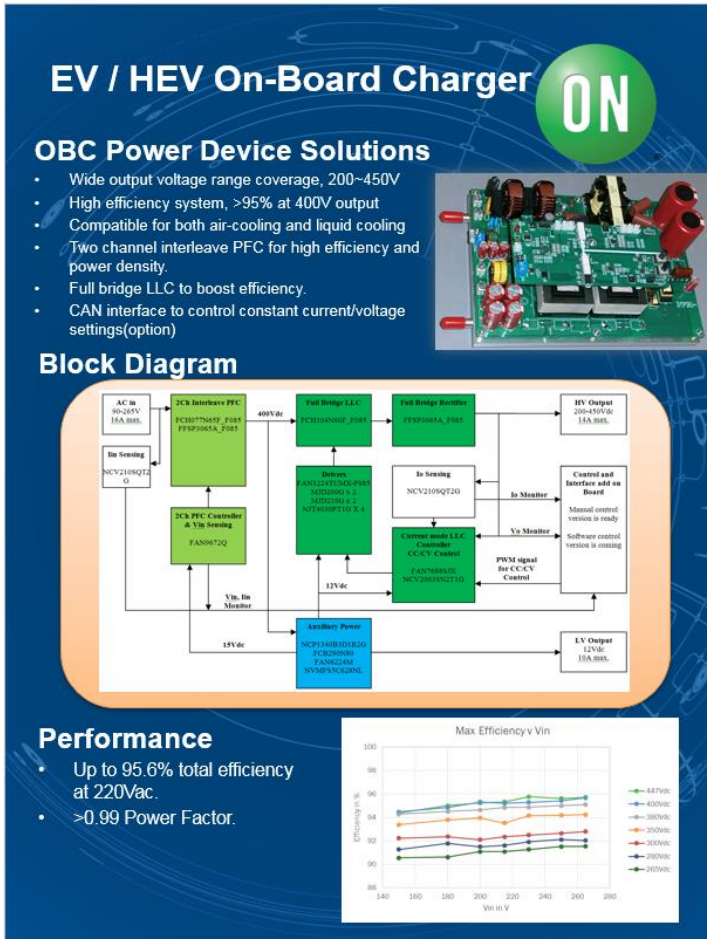






Warpage =>0 enable no void and spread out of TIM during mounting. APM enable thin layer of TIM for lowest thermal resistance

Benefit: Compact System Size



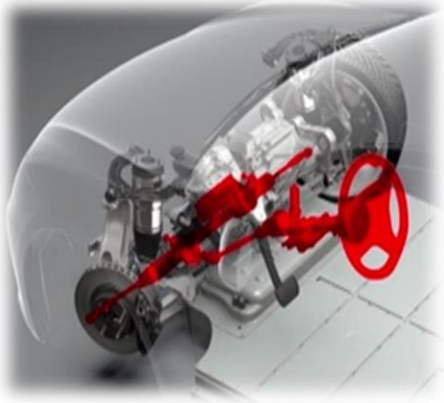
Discrete design
256 X 180 X 60
mm =2.7 l

APM16 design
212X150
X47mm=1.5 l

Benefit: Proven Reliability

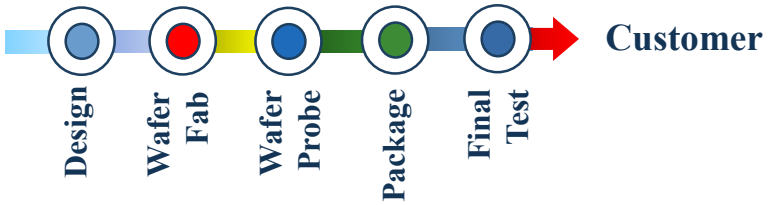
Field proven experience

11 years life in the field



APM released in 2008 for Electrical Power Steering and has been leader in MOSFET Module for LV Auto

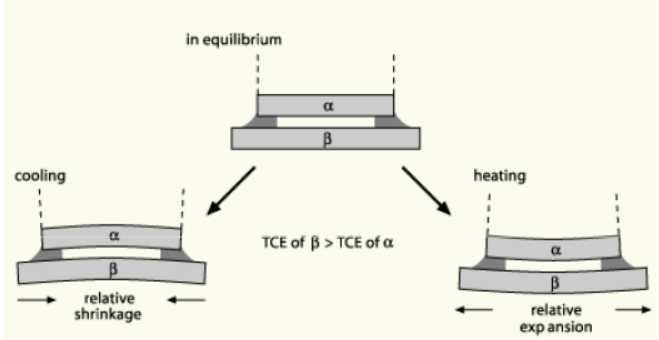
Fab+ Assmebly Total Solution

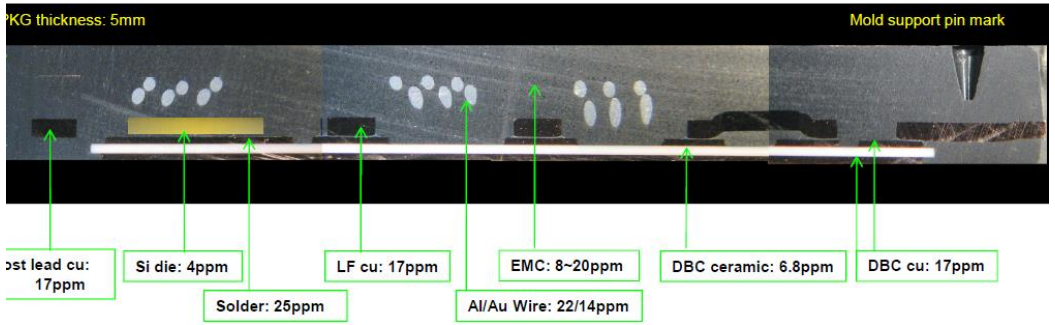


Minimized CTE mismatch in Transfer

Mold DBC technology enables long term thermal cycling

*** CTE(Coefficient of thermal Expansion) mismatch?**



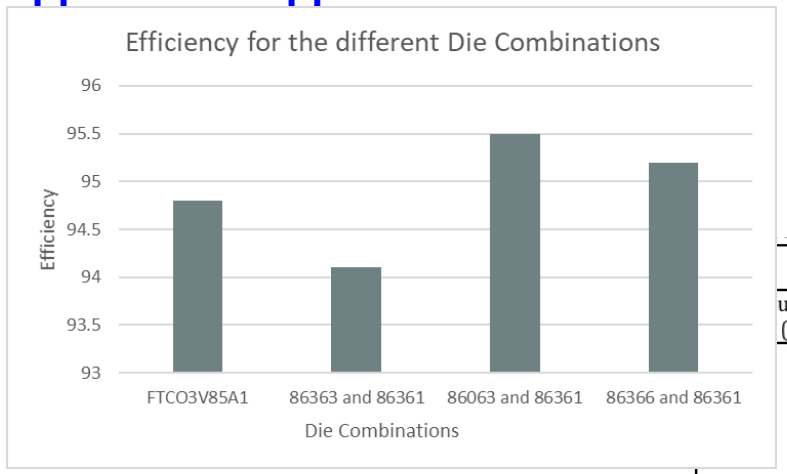


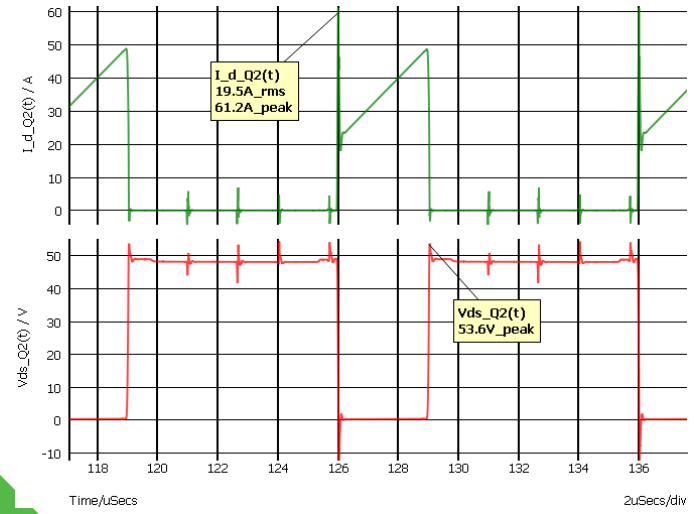
< Structure of power module >

unit: ppm/° C

Benefit: Electrical Performance

Deveopment for best fit for customer requirement in Electrical performance, supported by customized application support.

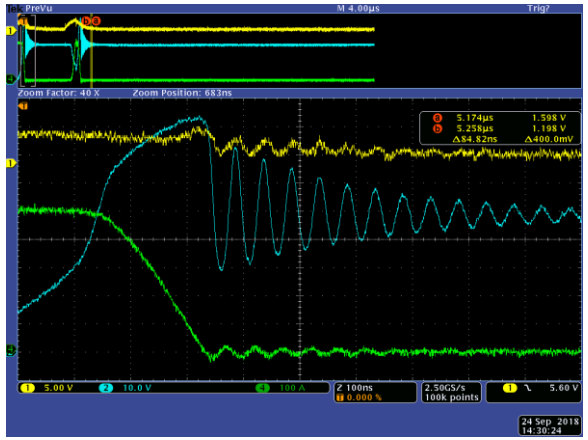




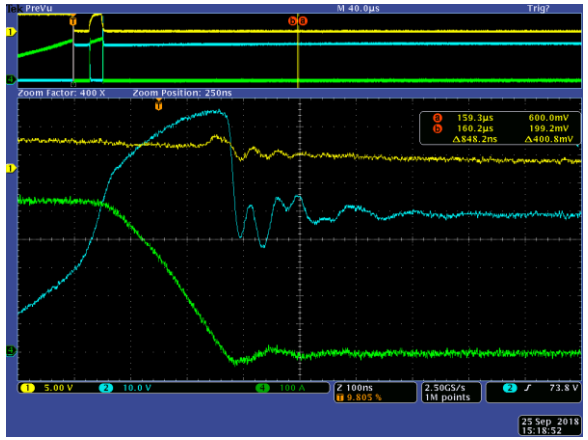
Device			Current [Arms/unit]	P_{sw} [W/unit]	P_{con} [W/unit]	P_{total}/unit [W/unit]	P_{total} [W]
ut Load Inductor (6 x 3.6µH)			36.5Arms	3W			18W
MOSFET	Phase leg 1-High	No	High side 20.5A_rms	11.2	1	12.2	24.4
		RC		11.3	0.9	12.2	24.4
	Phase leg 1-Low	No		5.8	1	6.8	13.6
		RC		5.3	1.4	6.7	13.4
	Phase leg 2-High	No		10	0.8	10.9	21.8
		RC		10.1	0.8	10.9	21.8
	Phase leg 2-Low	No	Low side 30.4A_rms	5.8	0.9	6.7	13.4
		RC		5.1	1.2	6.3	12.6
	Phase leg 3-High	No		10.9	1	11.9	23.8
		RC		10.9	0.9	11.8	23.6
	Phase leg 3-Low	No		5.7	1.1	6.8	13.6
		RC		5.4	1.5	6.9	13.8
RC Snubber			1.1W_on +1.3W_off = 2.4W				14.4
Control and misc.			4				8
Total Converter Loss and Efficiency 86366 +86361	No Snubber		Total Converter Power Dissipation = 136.6W and Converter Efficiency, $E = \frac{2902W}{(2902W+136.6W)} \times 100\% \cong 95.5\%$				
	RC Snubber		Total Converter Power Dissipation = 151W and Converter Efficiency, $E = \frac{2960W}{(2960W+151W)} \times 100\% \cong 95.2\%$				

Integrating the snubber inside provide Enhanced EMI performance

No Snubber

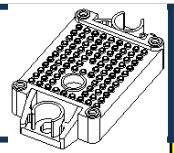


With Snubber Inside Module



APM Competitive landscape

Vs. Gel-filled Case Module



Feature	Case Module Gel-filled	ON's APM
Rth Junction to Heat Sink	Higher	Lower (by better flatness)
Package Warp Control	Worse (using Cu base)	Better
Reliability	Lower	Higher
Weight/Size	Higher	Lower

Vs. Discrete Solution

Feature	Discrete Solution	ON's APM
Rth Junction to Heat Sink	Higher	Lower
Current Carrying Capacity/ Total Resistance	Limited	Better
EMI	Poor	Enhanced
System Weight/Size	Higher	Lower

Vs. Gel-filled Case Module – System

Feature	System level Case Module Gel-filled	ON's APM
Rth Junction to Heat Sink	**Higher**	**Lower**
Reliability	**Lower**	**Higher** Thermal Stress Vibration Mechanical Shock, etc.
Testing	**Limited** for testing Individual Power Components	**Full** Test Coverage
Qualification	**Limited** to full validate or high cost	**Full** Rel. atudy with enough rel. Characterizations

Vs. Competitors in the Market

.Silicon Performance
.Proven Quality in the Field Application
.Rich Portfolio of MOSFET & Module platform (World wide #1 Module suppler (volume))
.Application Support (Solution Provider)

KEY products of Today

- Customization Solution
  - HV : Layout Custom (High integration)
    In APM28/APM27, etc.
  - L,MV : PKG Custom for
    High volume Project

HV

APM16
HV
OBC/DCDC

Why?
- Compact Solution
- Higher Efficiency
- Thermal Performance
- Proven tech for Auto Reliability
- HV Isolation
- Lower Cost than Case module

MV

APM17M
48V P1,P2
Inverter

Why?
- Cost effective High Power Density
- Best Performance (Thermal, Inductance, EMI)
- Proven tech for Auto Reliability

LV MV

APM19/
APM21

- 12V ICE & 48V~ Inverter / DC DC

LV MV

APM11
Platform

- Power Half Bridge
- Battery Switch

LV, MV, HV

Other
Customized Modules

LV, MV, HV
Bare Die
Biz

Promote Module and Bare Die Together

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Line Ups

HV OBC Module - APM16 Platform

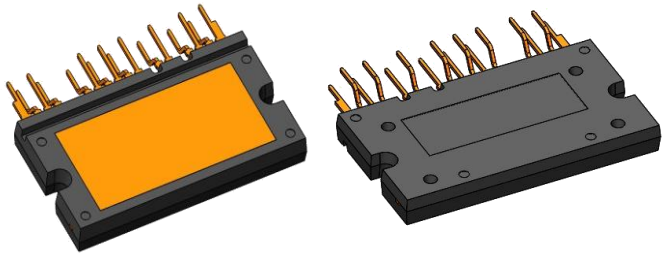
Description

- PFC stage, DCDC converter, Bridge Rectifiers for on-board charger in EV-PHEV
- Creepage and Clearance per IEC60664-1, IEC60950-1
- Low junction-sink thermal resistance
- Highly integrated compact design
- Module flexibility to integrate all technologies Si and SiC and all half Bridge or Full Bridge Circuit topologies
- 5kV/1 sec electrically isolated substrate easy assembly
- Complaint to IEC-60664-1 for functional and reinforced isolation
- Automotive qualified – AQG324

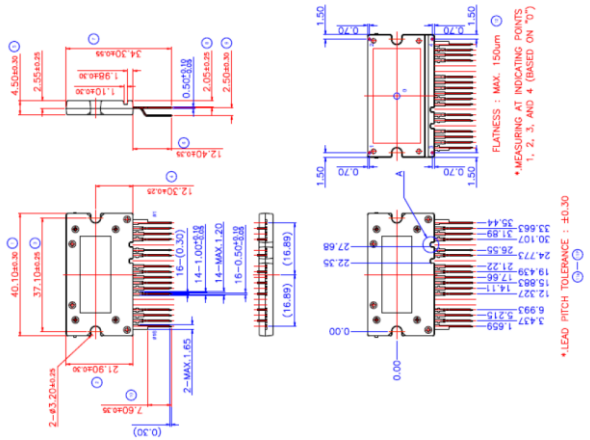
Application

3,3KW	6,6KW	3,3KW	6,6KW
DCDC APM16 Al2O3 Substrate	**DCDC APM16** AlN Substrate	**PFC APM16** Al2O3 Substrate	**PFC APM16** AlN Substrate

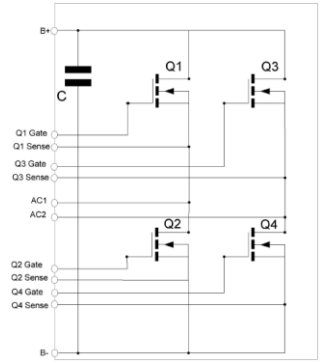
Package : 40.1 mm × 21.9 mm × 4.5 mm



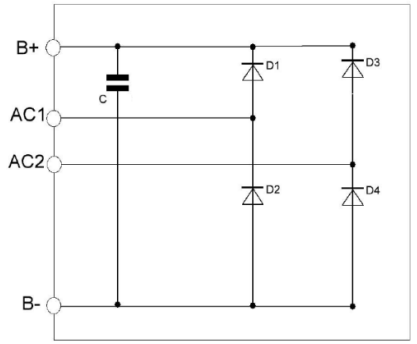
Package Details



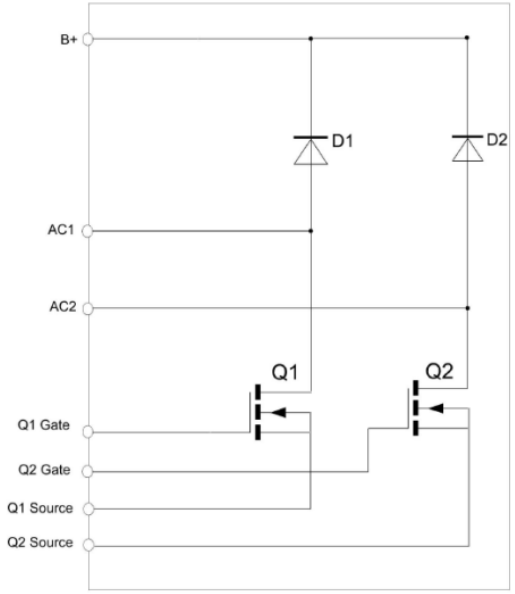
DC DC



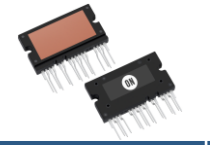
Bridge Rectifier



PFC

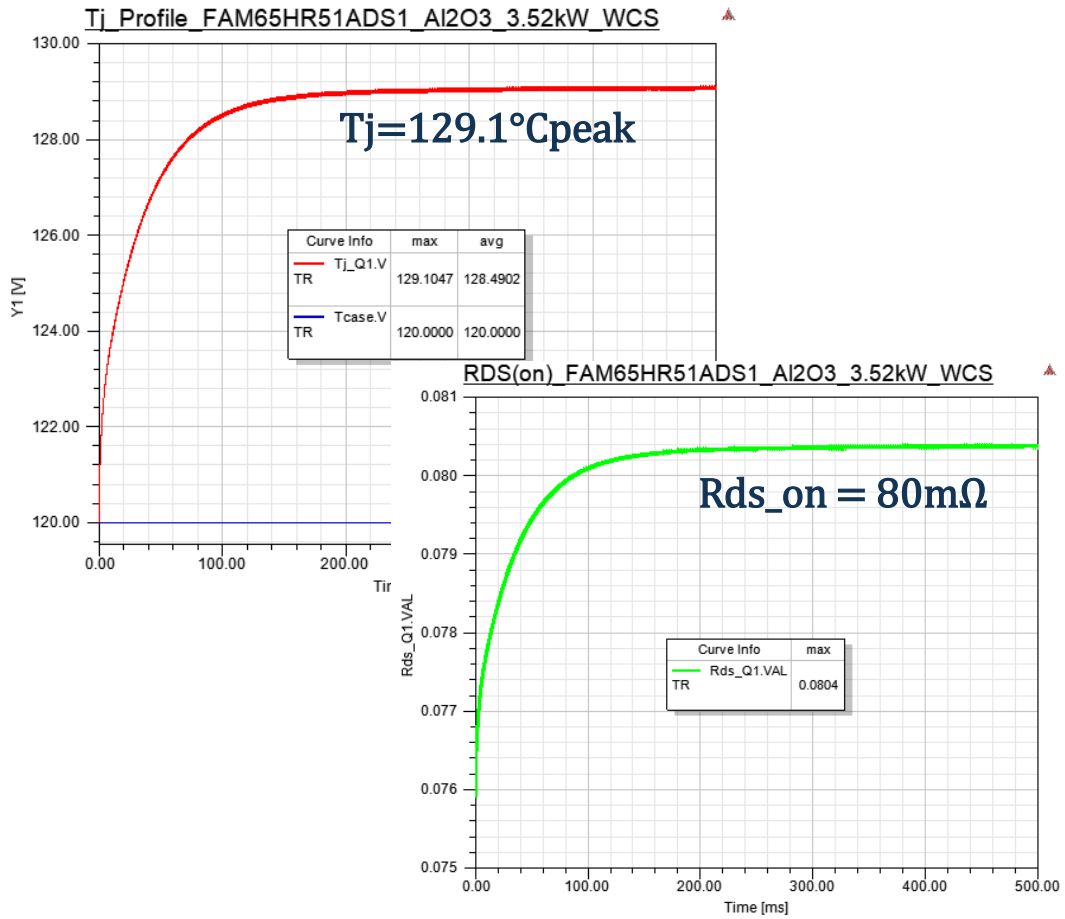


HV OBC Module - APM16 Platform Proliferation Plan

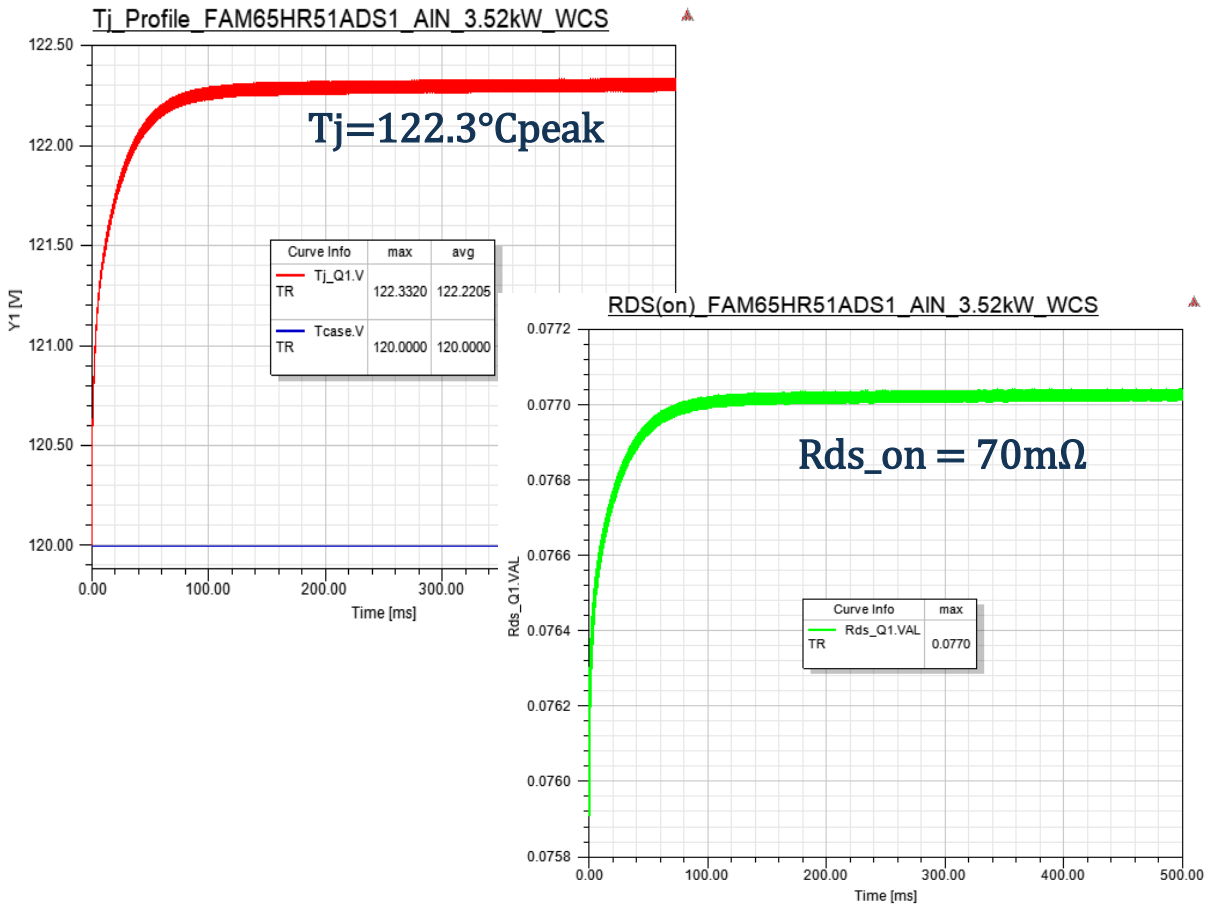


Application	DCDC								PFC								Bridge Rect.	
Power (recommend)	51mohm APM X 1 :~3.3kw~ APM X 3 :~ 11kw			51mohm APM X 1 :~6.6kw APM X 2 :~ 11kw		82mohm APM X 1 :1.5~3.3kw			51mohm APM X 1 :~3.3kw APM X 3 :~ 11kw		51mohm APM X 1 :~6.6kw APM X 2 :~11kw		51mohm APM X 1 :~3.3kw APM X 3 :~ 11kw		51mohm APM X 1 :~6.6kw APM X 2 :~11kw		Ultrafast Diode (Input Rec)	Hyperfast Diode (output Rec)
Option 1	Al2O3			AlN		Al2O3			Al2O3		AlN		Al2O3		AlN		Al2O3	
Option 2	Si					Si			Si FETs + SI Diodes				Si FETs + SiC (Diodes)				Si	
Option 3 Forming	L	Y	L	L	Y	L		Y	L	Y	L	Y	L	Y	L	Y	L	L
Release Plan	Released	Released	Released	Q4 2020	Q4 2020	Dec. 2020		Dec. 2020	Released	Released	July 2020	July 2020	Oct 2020	Oct 2020	Q4 2020	Q4 2020	TBD per customer's demand	
Snubber "C" (DC DC only)	O		X	O	O	X	O	X	O									
OPNs	FAM65HR51DS2	FAM65HR51DS1	NXV65HR51DZ2	FAM65HR51XS2	FAM65HR51XS1	NXV65HR82DZ2	NXV65HR82DS2	NXV65HR82DZ1	NXV65HR82DS1	FAM65CR51DZ2	FAM65CR51DZ1	FAM65CR51XZ2	FAM65CR51XZ1	FAM65CR51ADZ2	FAM65CR51ADZ1	FAM65CR51AXZ2	FAM65CR51AXZ1	FAM65R030DS2	FAM65R031DS2
Spec	FET : 650V 51mΩ, TJ max 150C					FET : 650V 82mΩ, TJ max 150C			FET : 650V 51mΩ, TJ max 150C Diode : 600V,15A, Tj max 175C (1.24V@15A)				FET : 650V 51mΩ, TJ max 150C Diode : 650V,30A, Tj max 175C (1.5V@30A/Tj=25C)				600V 30A, Tj max 175C (1.2V,60ns and 30A @Tj=25C)	

SIM - APM16 Tj Profile in 3.52kW LLC Converter in WCS

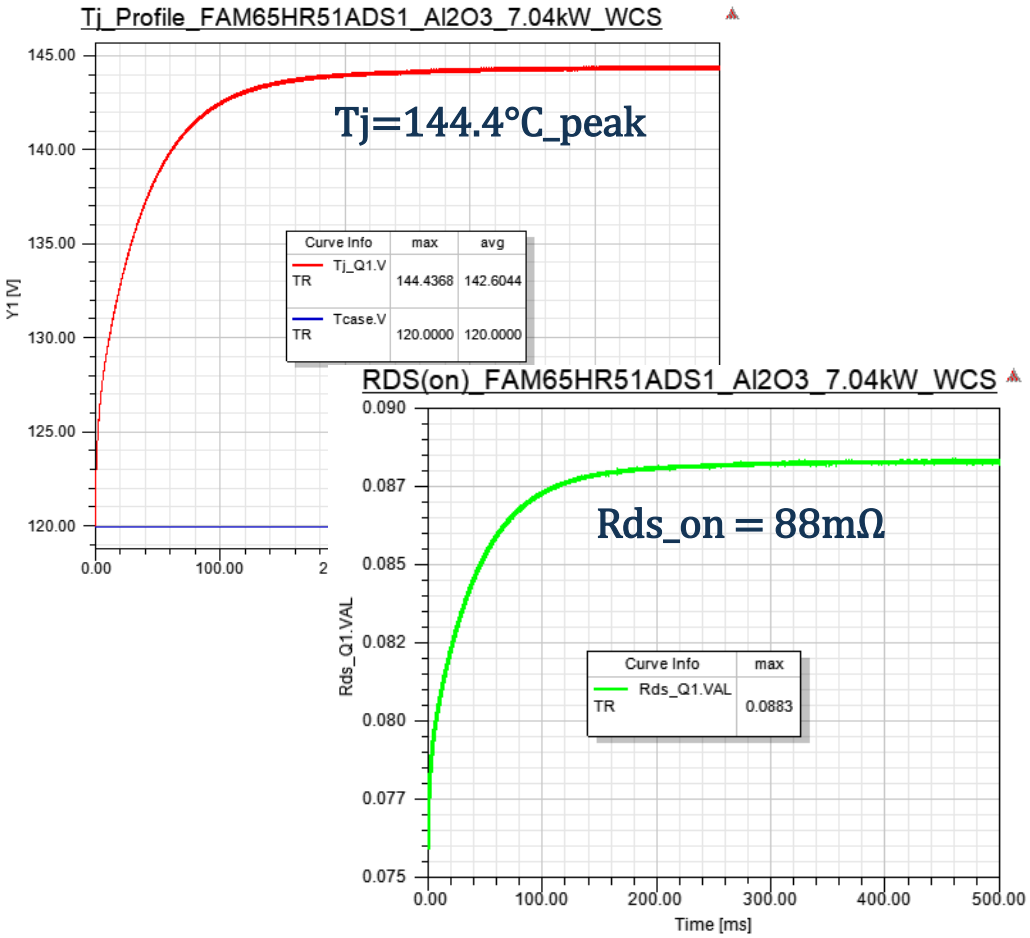


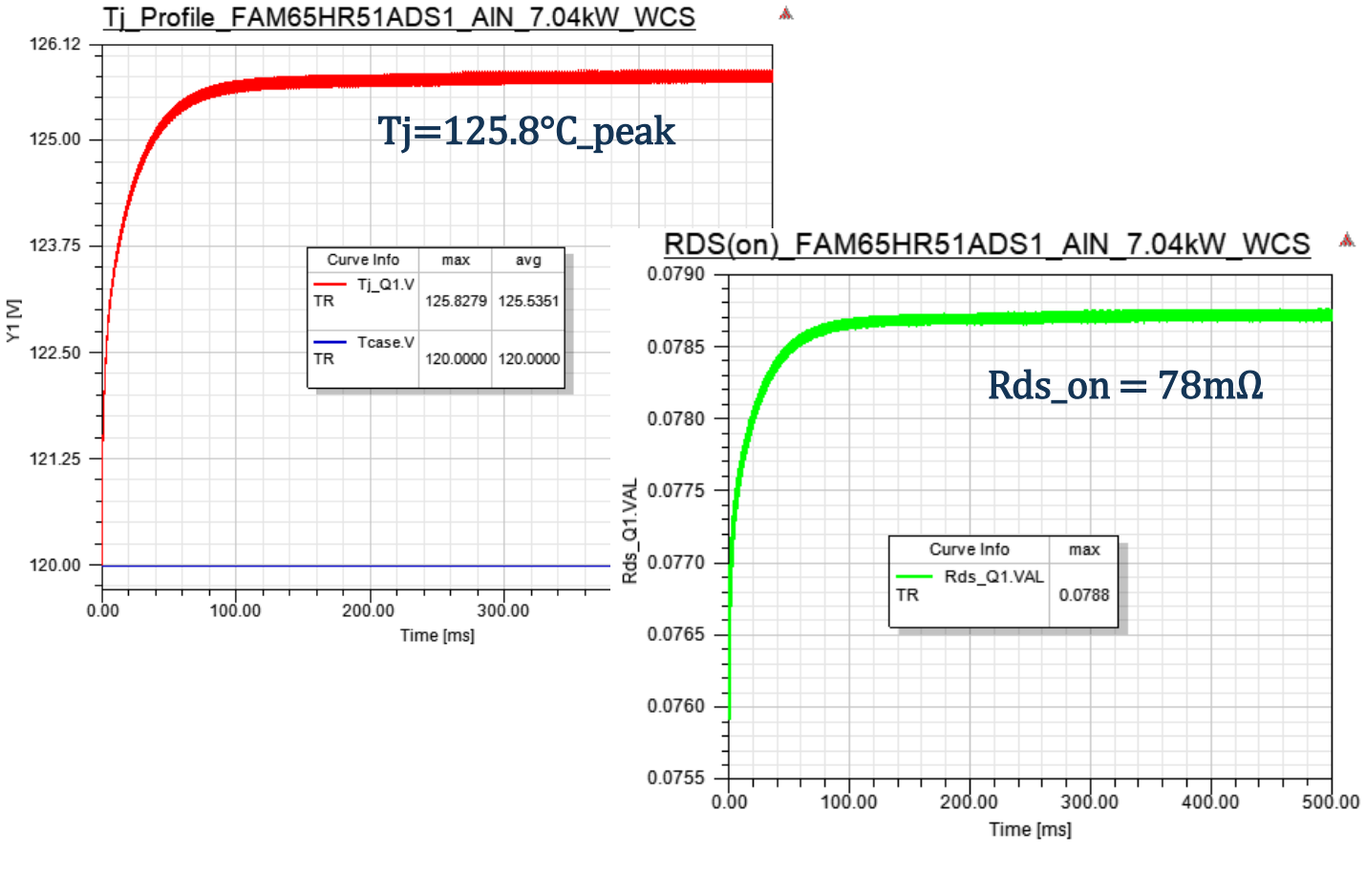
APM16: 635um Al2O3 DBC applied (Tcase = 120°C)



APM16: 635um AlN DBC applied (Tcase = 120°C)

SIM - APM16 Tj Profile in 7kW DC/DC Converter in WCS





APM16: 635um Al2O3 DBC applied

APM16: 635um AlN DBC applied