FOR ENERGY EFFICIENT INNOVATIONS

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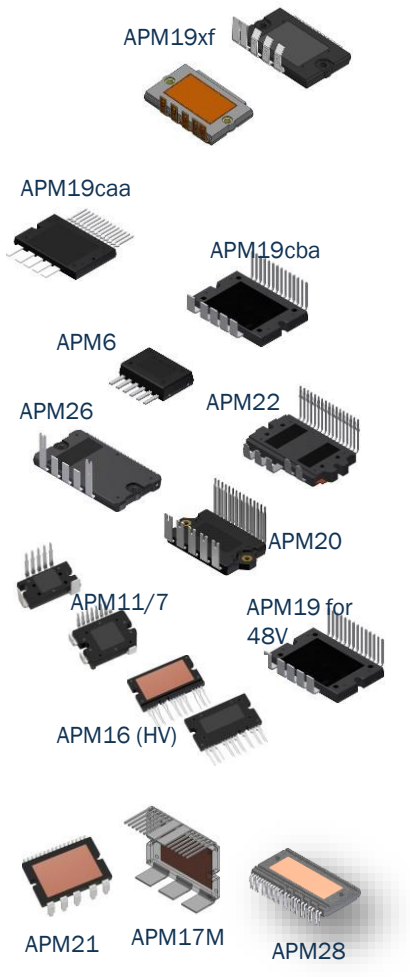
Introduction to LV/MV MOSFET Silicon AUTOMOTIVE POWER MODULE

Public Information

APM – Automotive Power Module Brand since 2008

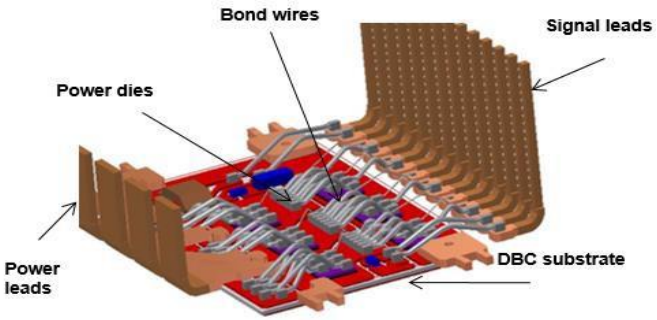


Development start

- 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)

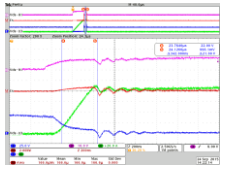


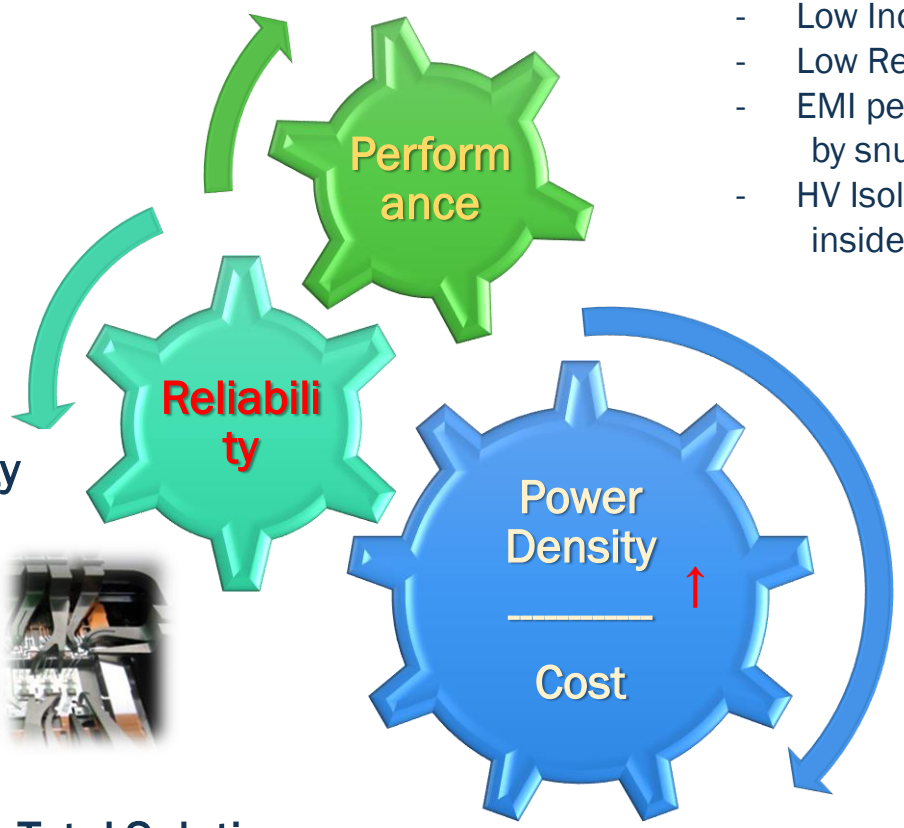
*The Automotive Power modules production has been in mass production **since 2008** after releasing 1st Electrical Power Steering full bridge APM. Since after APM became the #1 leader in MOSFET Automotive Module Market. As of Now, ON semi has the broad portfolio in production from of APMs for various 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

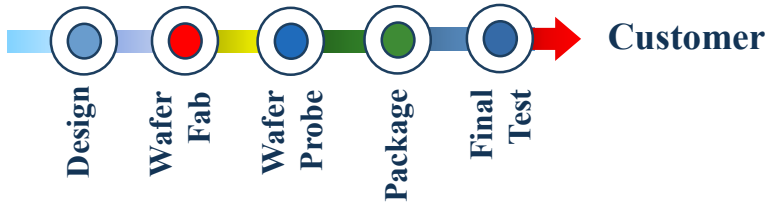
- High Current Capa
- Low Inductance
- Low Resistance
- EMI performance by snubber
- HV Isolation inside



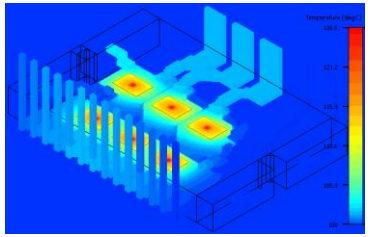


Proven Reliability

Fab + Assembly Total Solution



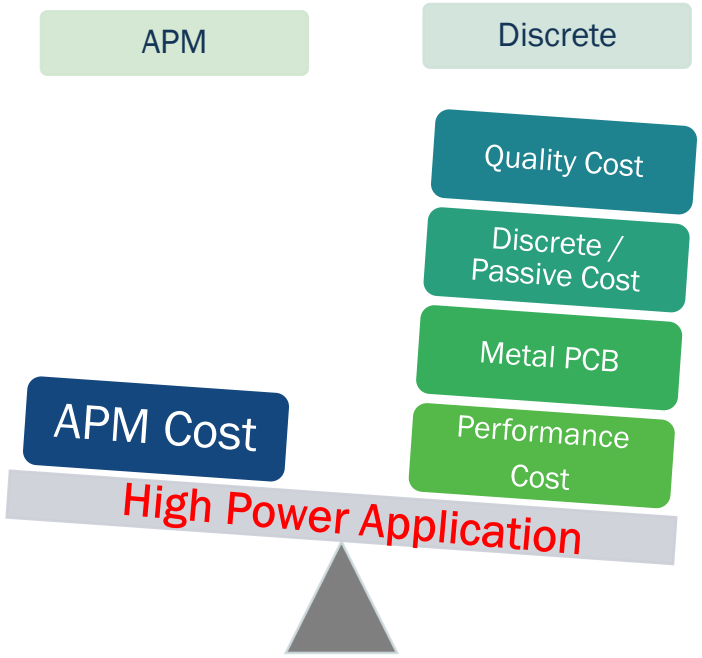
Low Thermal Resistance Junction to Heat sink



Smaller foot print

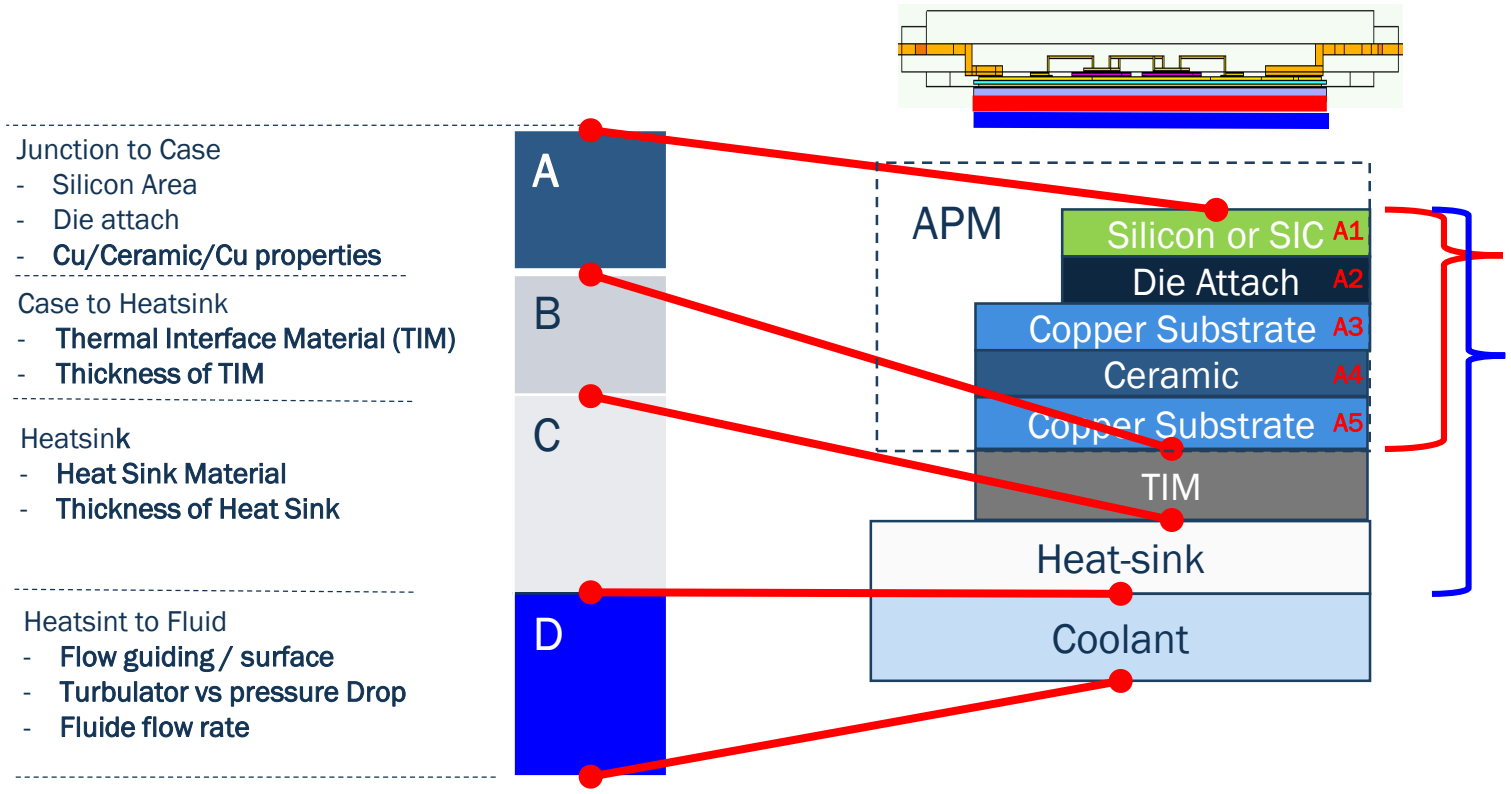
System Cost

(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)

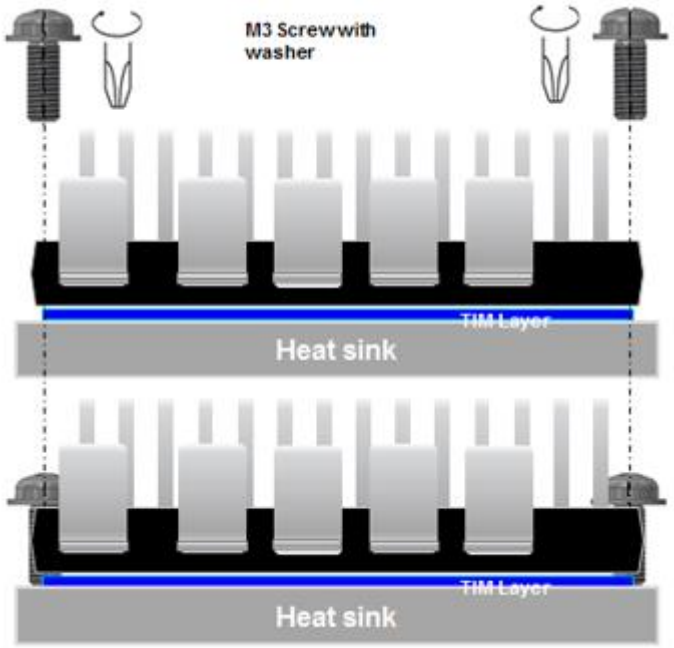
	Low Rth Substrate		AL2O3 Substrate	
	Rth, ˚C/W	%	Rth, ˚C/W	%
A1	0.0202	4.6%	0.0232	3.3%
A2	0.0185	4.2%	0.0185	2.6%
A3	0.0202	4.6%	0.0190	2.7%
A4 – Ceramic	0.0621	14.1%	0.3465	48.7%
A5	0.0113	2.6%	0.0105	1.5%
B TIM	0.0619	14.0%	0.0581	8.2%
C Heat Sink	0.2468	56.0%	0.2363	33.2%
TOTAL	0.4410	---	0.7120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

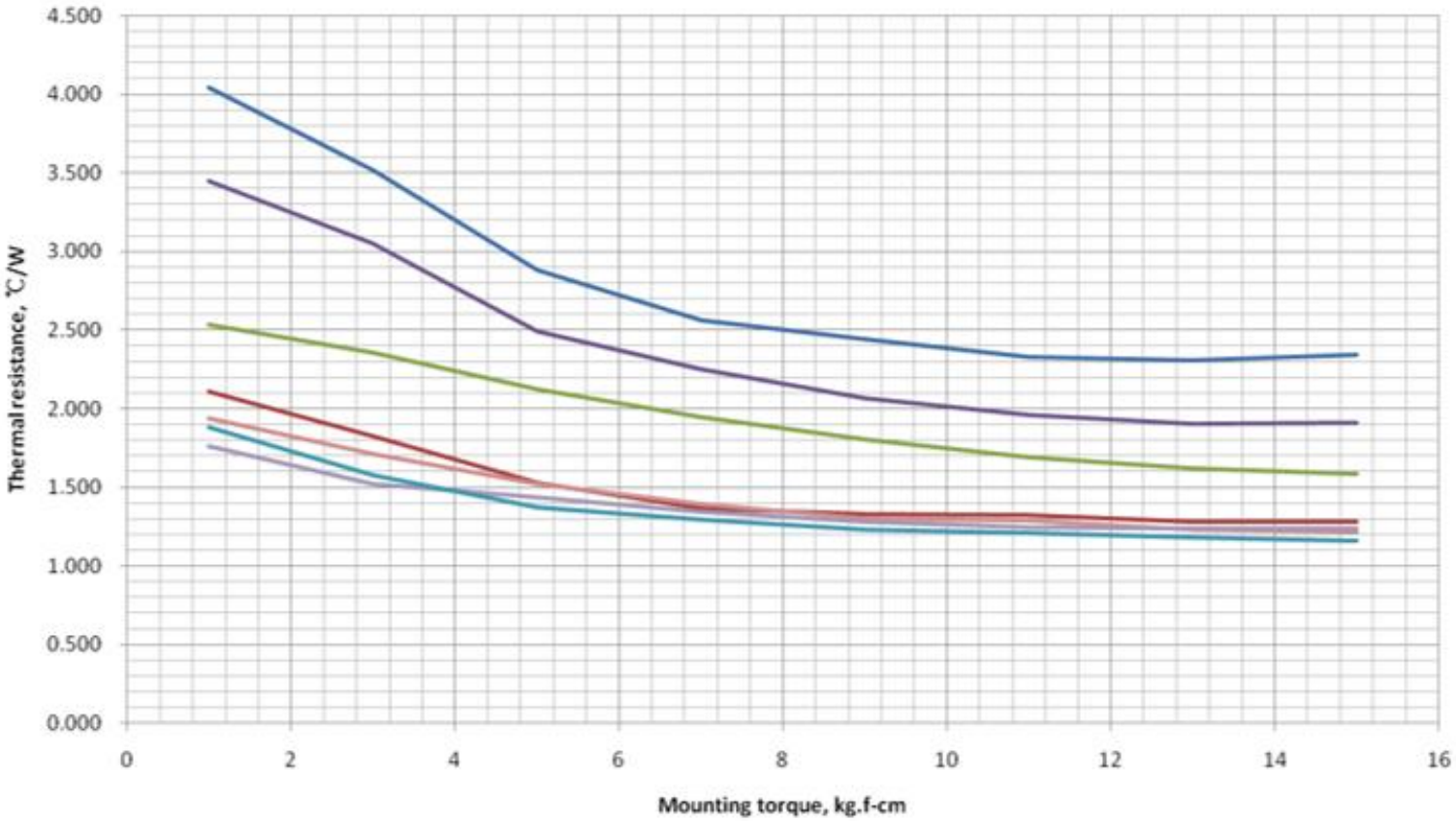
A : Options of vertical structure selection and Internal Design defines Rth Per Power rating of application

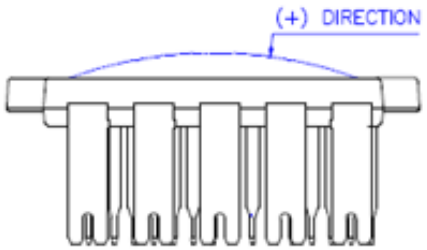
B : By the usage of APM, enable thin layer of B for minimum Rth of of **A+B**

C/D : Customer's design per system requirements

Mounting Guidance for APM





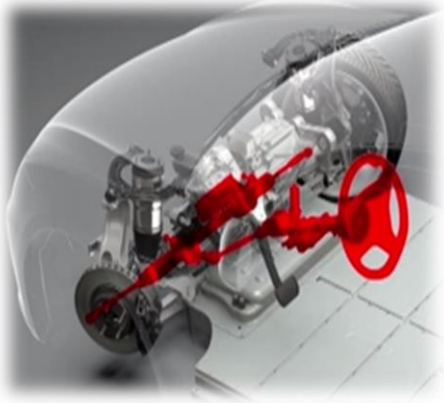


Warpage =>0 enable no void and spread out of TIM during mounting. APM enable thin layer of TIM for lowest thermal resistance

Benefit: Proven Reliability

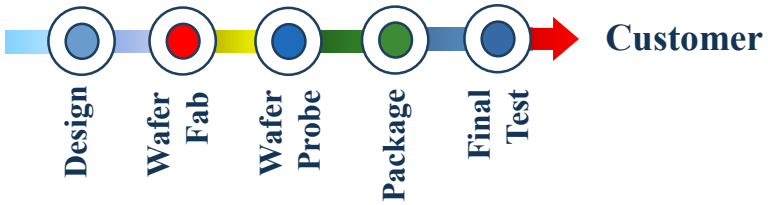
Field proven experience

11 years life in the field



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

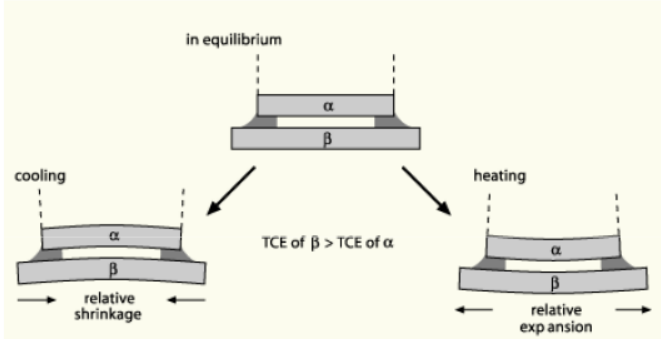
Fab+ Assmebly Total Solution

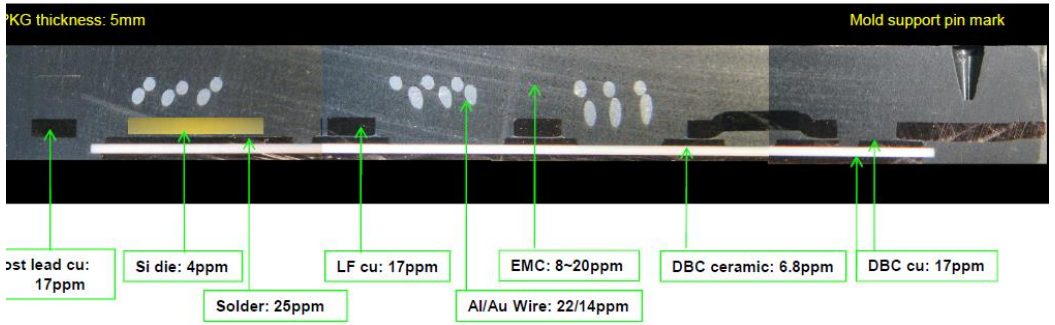


Minimized CTE mismatch in Transfer

Mold DBC technology enables long term thermal cycling

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



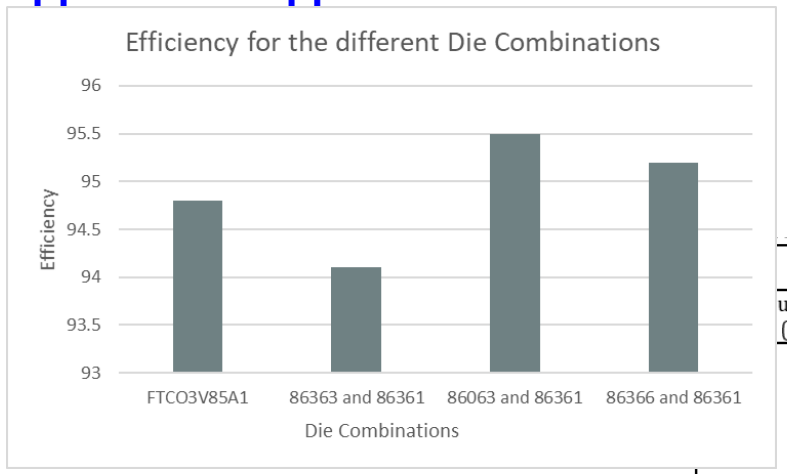


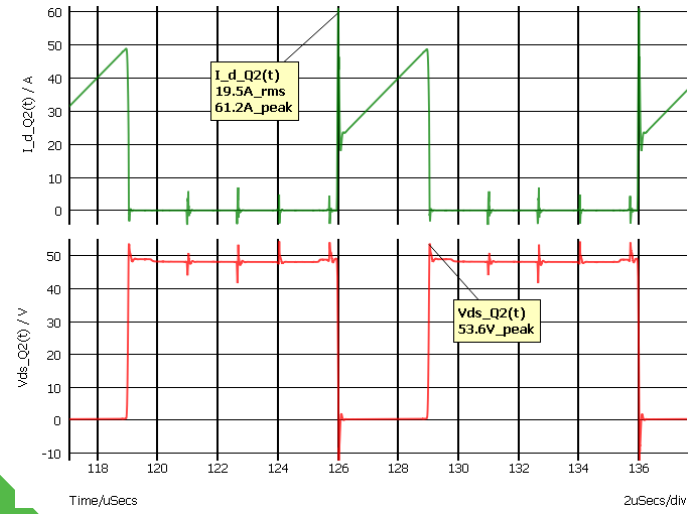
< Structure of power module >

unit: ppm/° C

Benefit: Electrical Performance

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

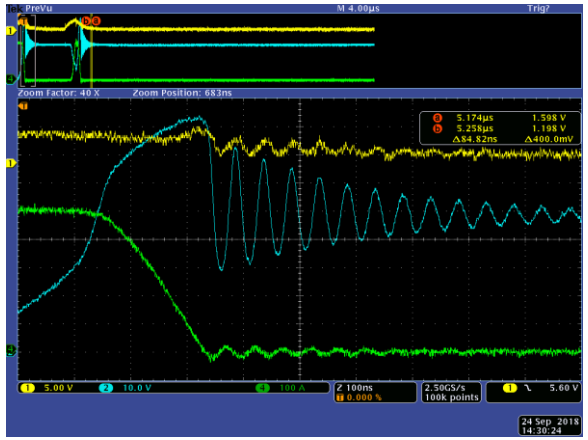




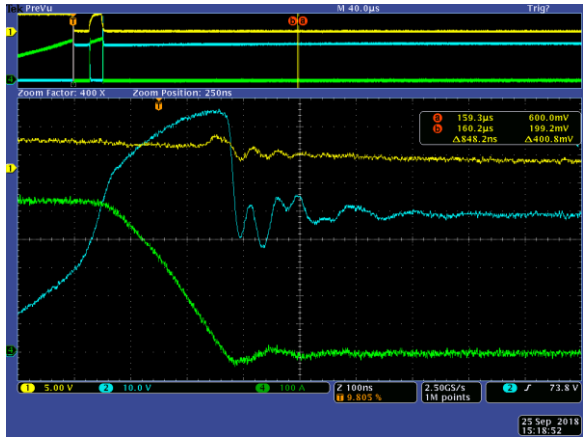
Device			Current [Arms/unit]	P_{sw} [W/unit]	P_{con} [W/unit]	P_{total}/unit [W/unit]	P_{total} [W]
ut Load Inductor (6 x 3.6µH)			36.5Arms	3W			18W
MOSFET	Phase leg 1-High	No	High side 20.5A_rms	11.2	1	12.2	24.4
		RC		11.3	0.9	12.2	24.4
	Phase leg 1-Low	No		5.8	1	6.8	13.6
		RC		5.3	1.4	6.7	13.4
	Phase 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

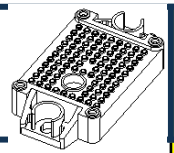


With Snubber Inside Module



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)

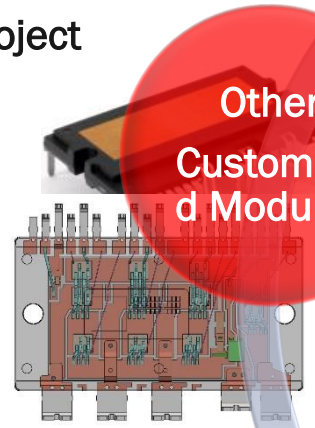
KEY products of Today

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

HV

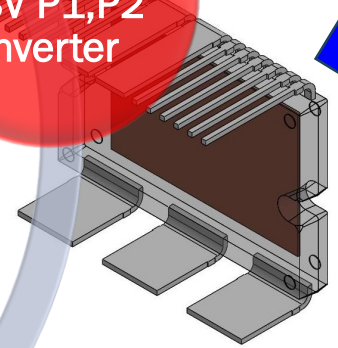
APM16
HV
OBC/DCDC

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



LV, MV, HV

Other
Customize
d Modules



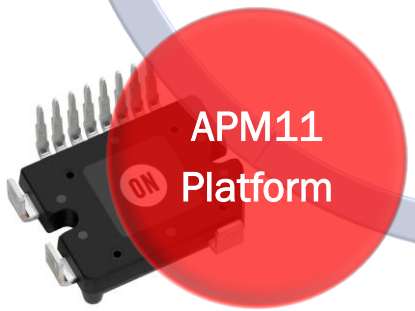
MV

APM17M
48V P1,P2
Inverter

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

LV, MV, HV
Bare Die
Biz

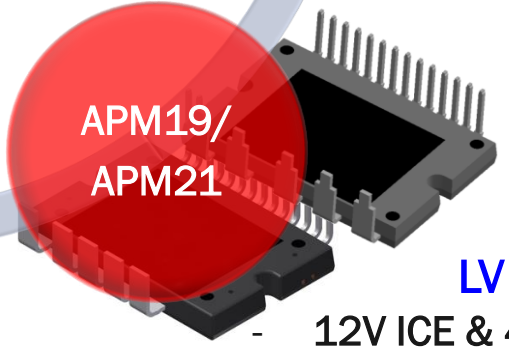
Promote Module and
Bare Die Together



APM11
Platform

- Power Half Bridge
- Battery Switch

LV MV



APM19/
APM21

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

✓Click

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Line Ups

APM Generic Module Platform for 48V

Product Description

APM19, APM21, APM17M (One module tech, Same size APM variants)
Evolved from mass production APM19 EPS

Covers all power applications in 48V systems:

- iSG/BSG (Integrated/Belt-driven Starter Generator)
- 48V to 12V DC-DC Converter
- 12V or 48V Auxiliaries load (motor drive)
- Battery Switch (relay replacement)

Advantages

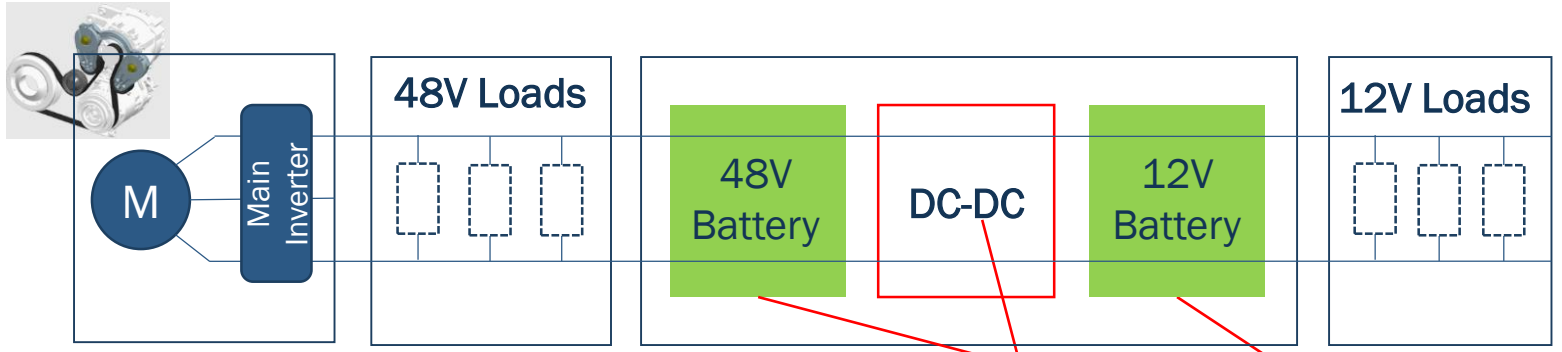
High Power densigh $\frac{\text{Power (kw)}}{\text{COST (\$)}}$

Lower system level cost (vs discretes) for High Power Application

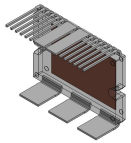
Electrical Performance by Low Stray inductance & Snubber

Compact Space and Reduce Number of components
3 x APM17 replaces up to 36 X TOLL, D2PAK

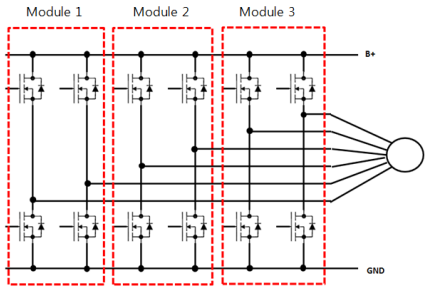
Simplify power stage design allowing fast time to market for customers



15-25 Kw :
3 x APM17 solution
For 3 or 6 Phase

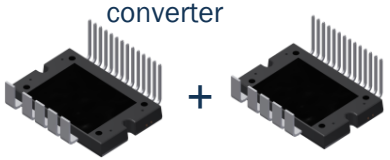


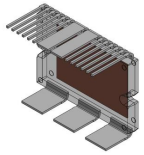
X3



Auxiliary motors:
- E -Compressor
- E-Supercharger

2xAPM for 6 phase 48V DC-DC converter

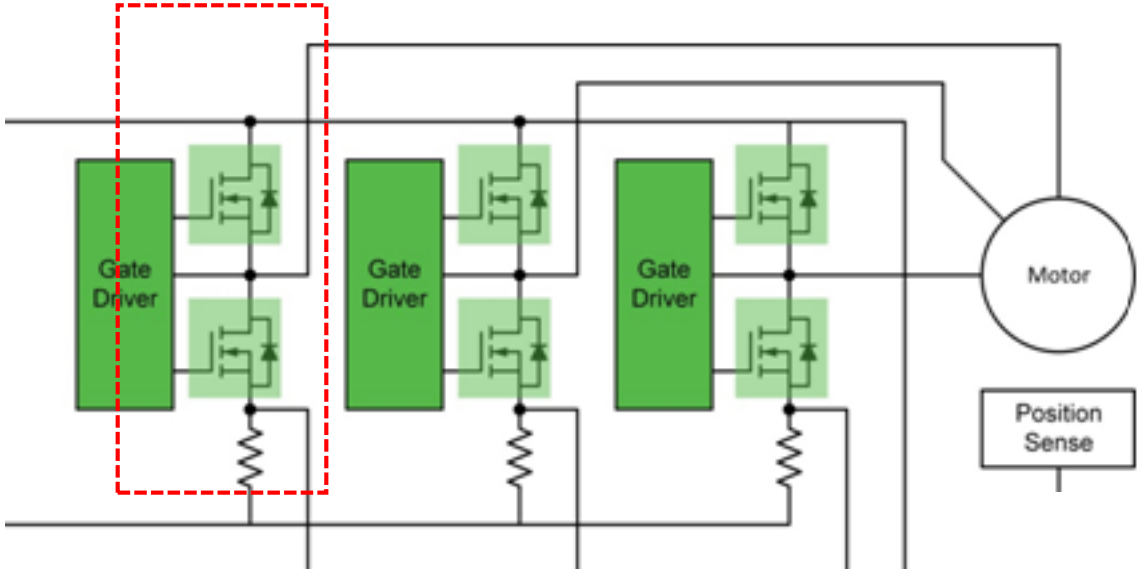


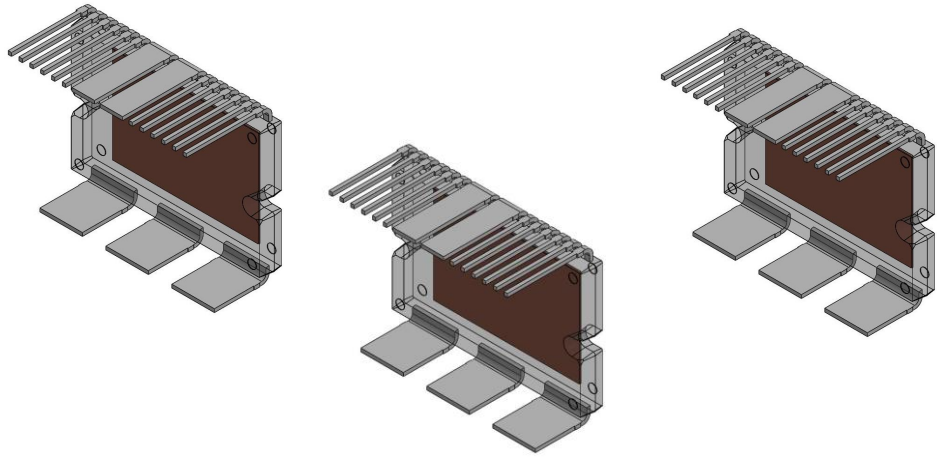


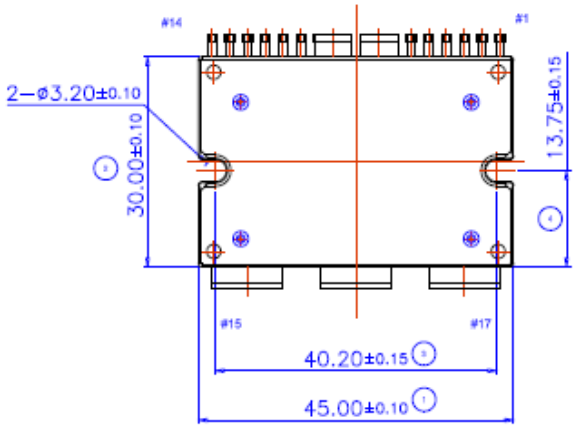
Main Battery switch/ Load Switch replacing mechanical relay :

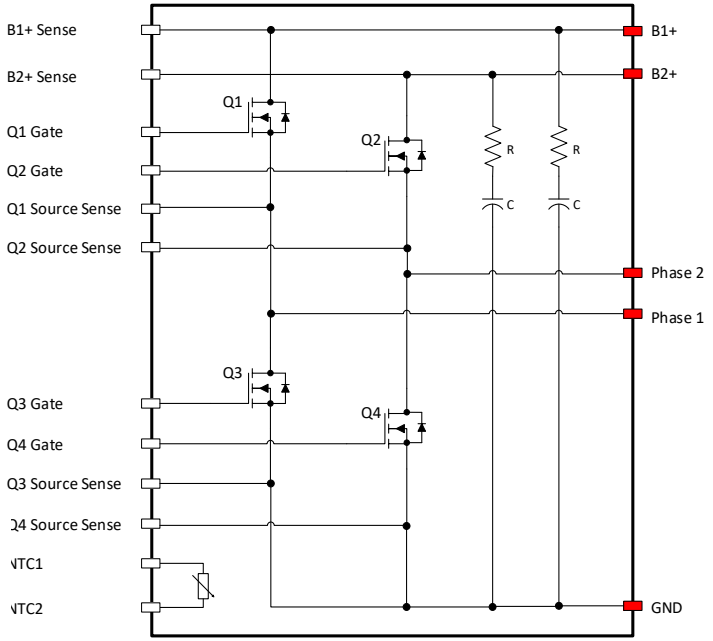
APM17M for 3 phase and 6 phase Inverter

- APM17M Platform







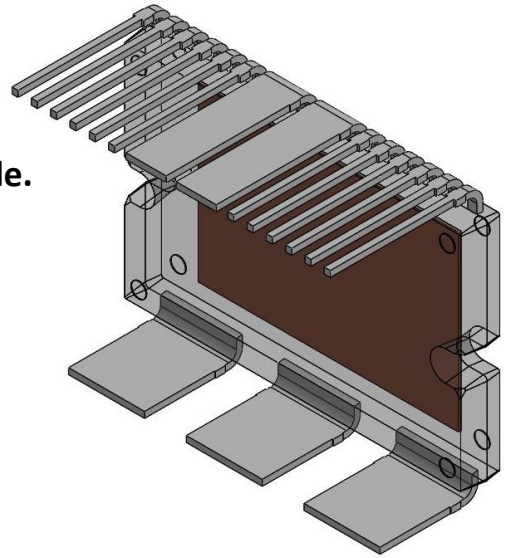


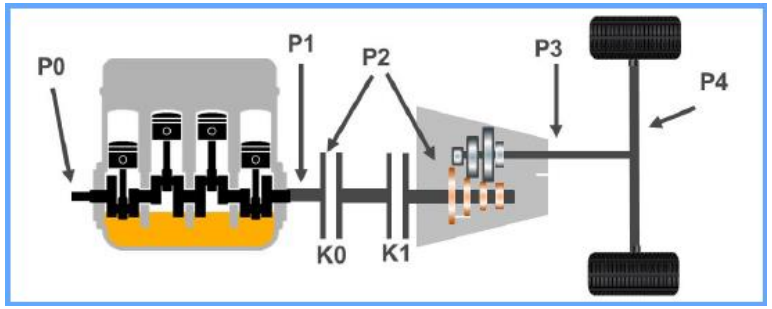
Lead forming option can be customized

APM17M for 48V Mild Hybrid Main inverter – In Development

Description

- High Power 48V Main Inverter solutions
- Flexible application both 3 phase and 6 phase motor system by 3 APMs
- Low junction-sink thermal resistance
- Highly integrated compact design
- Low electrical resistance
- Low stray Inductance
- Better EMI with snubber inside module.
- Electrical isolation over 3KV
- Easy and reliable installation
- High current handling
- Improved overall system reliability
- Temperature sensing
- Pb Free
- Automotive qualified – AQG324

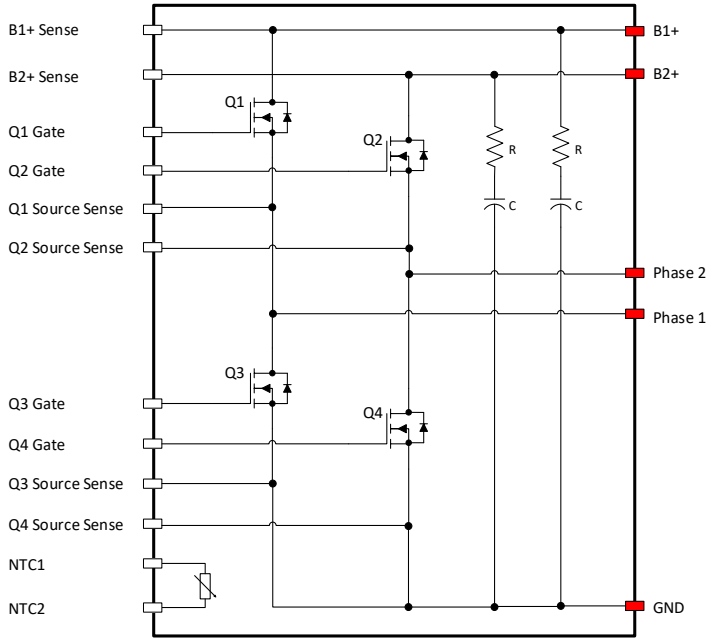




- P0 / P1 - 6kw, 12kw
- P2, P3, P4 - ~ 24kw

Dual ½ Bridge

½ Bridge



ICE,48V MHEV – Standard APM19 Platform

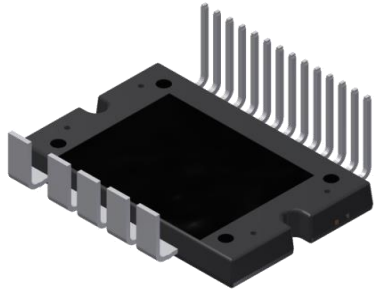
Description

- Low junction-sink thermal resistance
- Highly integrated compact design
- Low electrical resistance
- Better EMI and electrical isolation
- Easy and reliable installation
- High current handling
- Improved overall system reliability
- Precise shunt current sensing
- Temperature sensing
- Automotive qualified

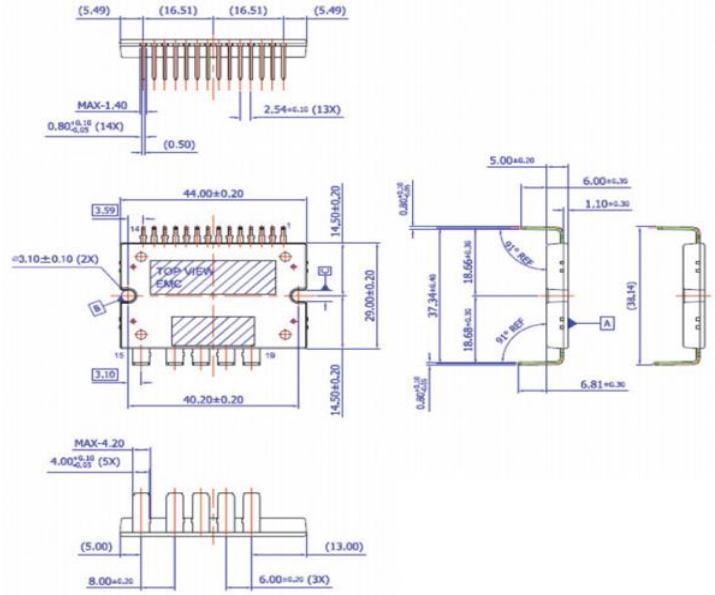
Application

	Transmission Oil Pump	Electrical Power Steering	Intelligent Brake	DC DC converter
12V ICE	40V	40V	40V	
24V Bus/Truck	80V	80V		
48V MHEV	80V	80V	80V	80V

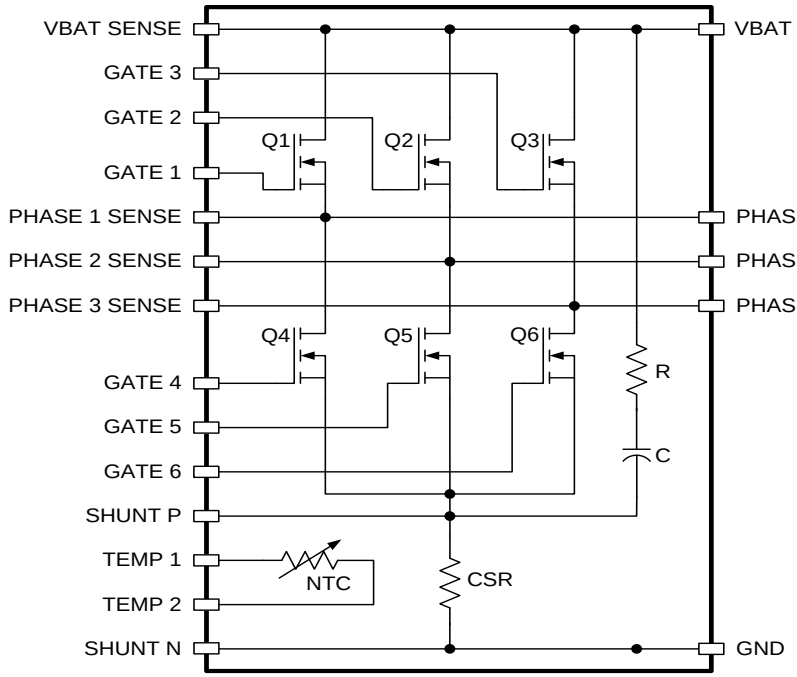
Package : 44 mm × 29 mm × 5.0 mm



Package Details

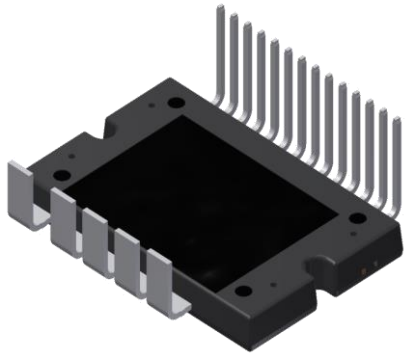


Schematic



ICE,48V MHEV - APM19 Platform Proliferation Plan

Option1	AL203 Substrate	
Option2	40V	80V
Option3	Die Options	



DBC Options	Standard Substrate				
BV Options	40V		80V		80V Die Combination
Die Options	1.45mΩ 0.8(K/W)	1.2mΩ 1(K/W)	3.1mΩ 1(K/W)	2.1mΩ 0.8(K/W)	3.1 / 2.1mΩ 1.0 / 0.8(K/W)
OPN	FTCO3V455A1	NXV04V120DB1	NXV08V080DB1	NXV08V110DB1	FTCO3V85A1
Release Plan	**Released**	**Released**	**Released**	**Released**	**Released**
Samples Availability	Available	Available	Available	Available	Available

* Common : All APM19 have 1 NTC, 1 Shunt & R-C Snubber btw B+ & GND

ICE,48V MHEV – Standard APM21 Platform – In development

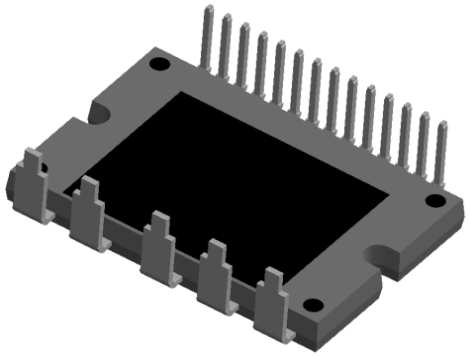
Description

- 2 shunts for current sensing for EPS application
- High Power 48V Motor Inverter solutions
- Low junction-sink thermal resistance
- Highly integrated compact design
- Low electrical resistance
- Better EMI and electrical isolation
- Easy and reliable installation
- High current handling
- Improved overall system reliability
- Temperature sensing
- Automotive qualified

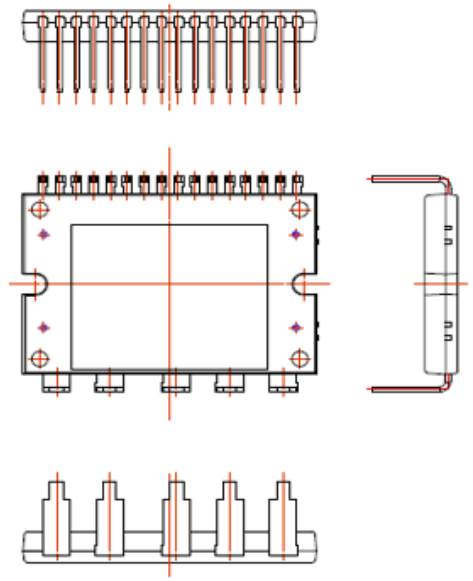
Application

	~ 1kw EPS (2 Shunts EPS)	5~7kw 48V E-Comp/E-Boost	5~7kw 48V E-Super Charger	12kw 48V BSG 6 Phase (APM * 2)
12V ICE	40V	40V	40V	
48V MHEV	80V	80V / 100V	80V / 100V	80V / 100V

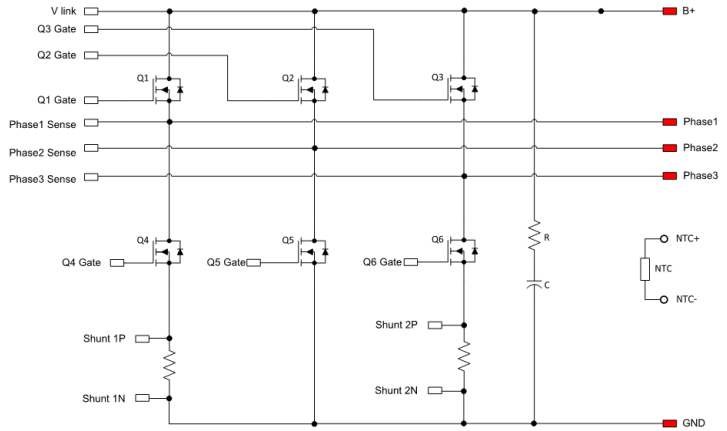
Package : 44 mm × 29 mm × 5.0 mm



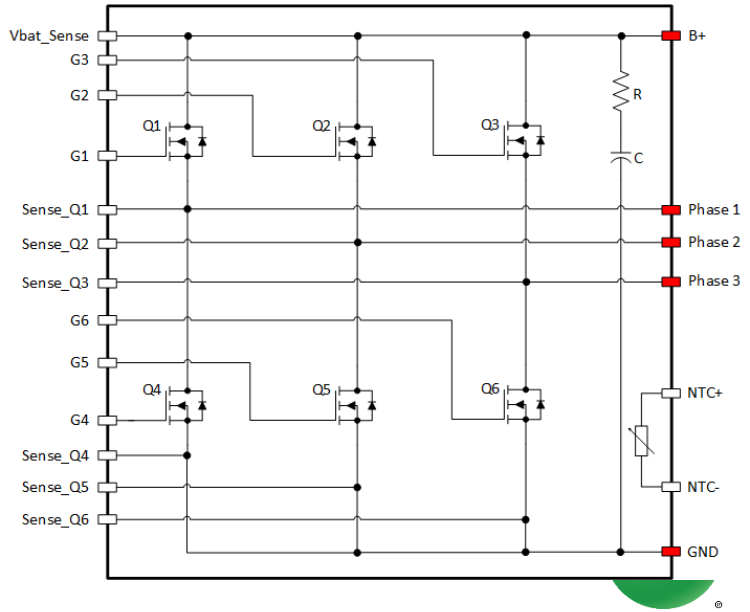
Package Details



Schematic – 2 Shunts EPS

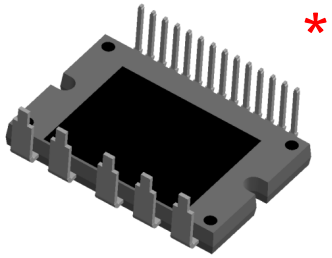


Schematic 2 – 48V High Power



ICE,48V MHEV - APM21 Platform Proliferation Plan

Option1	AL2O3 Substrate	Low Rth Substrate
Option2	80V	100V
Option3	Die Options	
Option4	Shunt or No shunt	
Option5	Lead Options (Std or Customized)	



* Release Plan can be adjusted per customer's request

DBC Options	Standard Substrate					Low Thermal resistance Substrate		
BV Options	40V	80V		100V	100V / 80V	80V	100V	150V
Eq. Discrete / Rdson max. / Rthjc typ.	FDBL9406 1.2mΩ 1(K/W)	FDBL86366 3.0mΩ 1(K/W)	FDBL86360 1.3mΩ 0.6(K/W)	FDBL86062 2.0mΩ 0.7(K/W)	FDBL86063/86361 2.6 / 1.4mΩ 0.8 / 0.7(K/W)	FDBL86360 1.3mΩ 0.22(K/W)	FDBL86062 2.0mΩ 0.32(K/W)	4.0mΩ 0.22(K/W)
Shunt Options	2 Shunts (BVN-0.5mohm)	2 Shunts (BVN-0.5mohm)	1 Shunt (BVN-0.5mohm)	1 Shunt (BVN-0.5mohm)	No Shunt	No Shunt	No Shunt	1 Shunt (BVN-0.5mohm)
OPN	NXV04V130DB1	NXV08V081DB1	NXV08V170DB1	NXV10V125DB1	NXV09D100DT1	NXV08V230S(X)T1	NXV10V160S(X)T1	NXV15V100S(X)B1
Release Plan	TBD **Per customer's demand**	TBD **Per customer's demand**	2021 2H	2021 2H	2021 2H	2021 2H	2021 2H	2022 1H
Samples Availability	TBD **Per customer's demand**	TBD **Per customer's demand**	Available	Available	Available	Available	Available	Available

* Customer sample available in 1~3 Months after order

ICE,48V MHEV – APM11 Platform

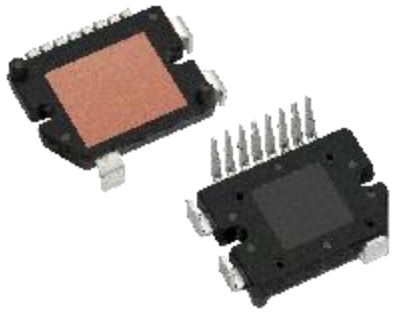
Description

- High flexibility for system design
- Low junction to sink thermal resistance
- Better EMI and electrical isolation
- Easy and reliable installation
- Improved overall system reliability
- Temperature sensing – Optional
- Current sensing – Optional
- Automotive qualified – AQG324

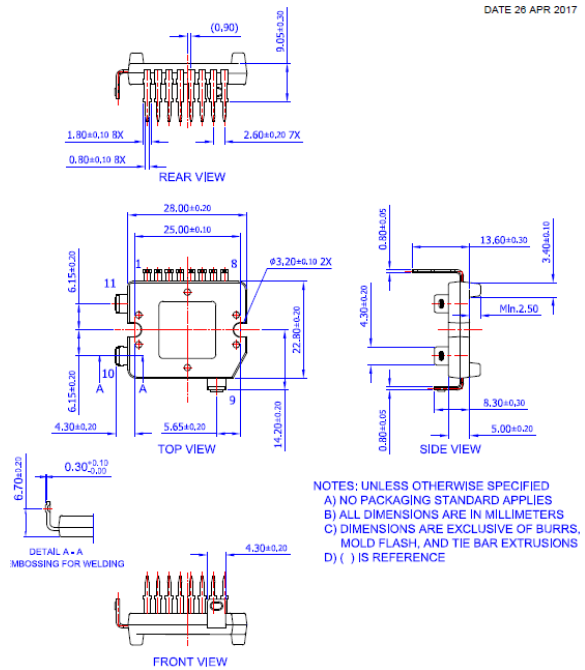
Application

- 12V Back-to-back Battery Switch
- 48V Back-to-back Battery Switch
- 48V DC/DC Secondary Rectifier
- 48V n-Phase motor inverter by using x N APM11s

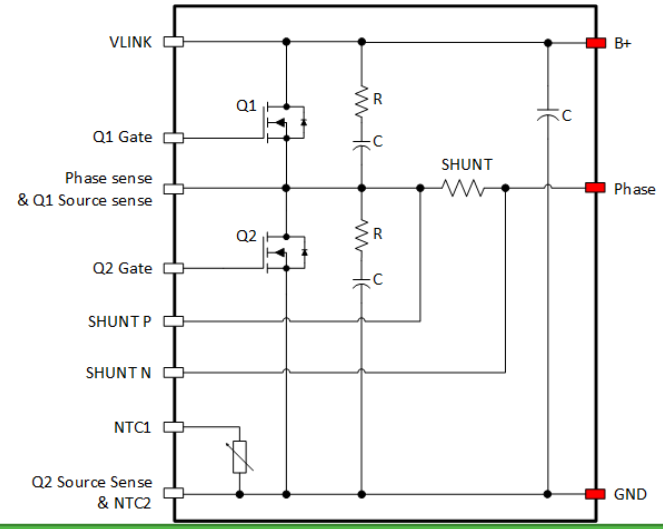
Package : 28 × 22.8 × 5.0 mm



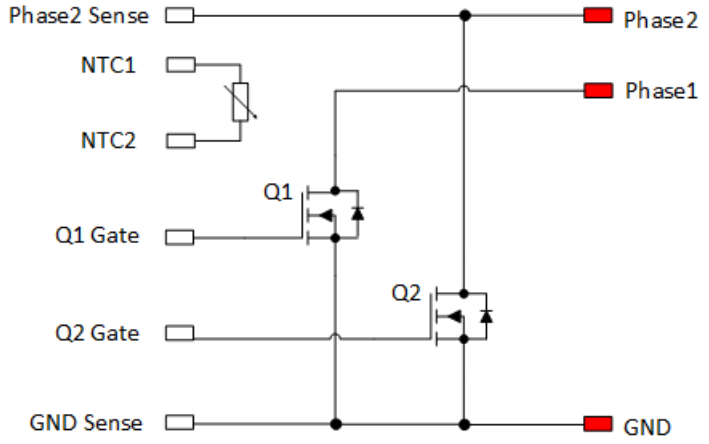
Package Details



Schematic 1 – Single Phase Motor Inverter



Schematic 2 – SR / Battery Switch



APM11 Platform Proliferation in Development

Topology	Single Phase Half Bridge		Back-to-Back Switch	
BV Options	40V	80V	40V	80V
Die Options	0.9mΩ 0.8(K/W)	1.4mΩ 0.7(K/W)	0.3mΩ 0.38(K/W)	0.8mΩ 0.38(K/W)
Current Sensor Options	Hall IC	1 Shunt (BVT-0.3mohm)	No Shunt	No Shunt
OPN	SXV04A080DC3	NXV08A170DB1	NXV04B300DZ1	NXV08B260DZ1
Release Plan	**Released**	2021 2H	Per customer's demand	Per customer's demand
Samples Availability	Available	Available	Available	Available

* Customer sample available in 1~3 Months after order