FOR ENERGY EFFICIENT INNOVATIONS

THINK ON.

www.onsemi.com

高压辅助方案：汽车智能功率模块 (ASPM)

Jackie.Zhao@onsemi.com
17317602839
Auto PSG Marketing

Public Information

ON IPM – Global footprint

Phoenix, AZ, US
HQ & Marketing

Gresham, OR, US
HVIC fab

Suzhou, China
Assembly

Assembly site
Fabrication site
Design & marketing

Bucheon, Korea
Design & Power

Niigata, Japan
IGBT, FRD fab

Aizu, Japan
IGBT, Fab site

Gunma, Japan
Design site

S. Portland, ME, US
HVIC fab

Roznov, Czech
IGBT fab

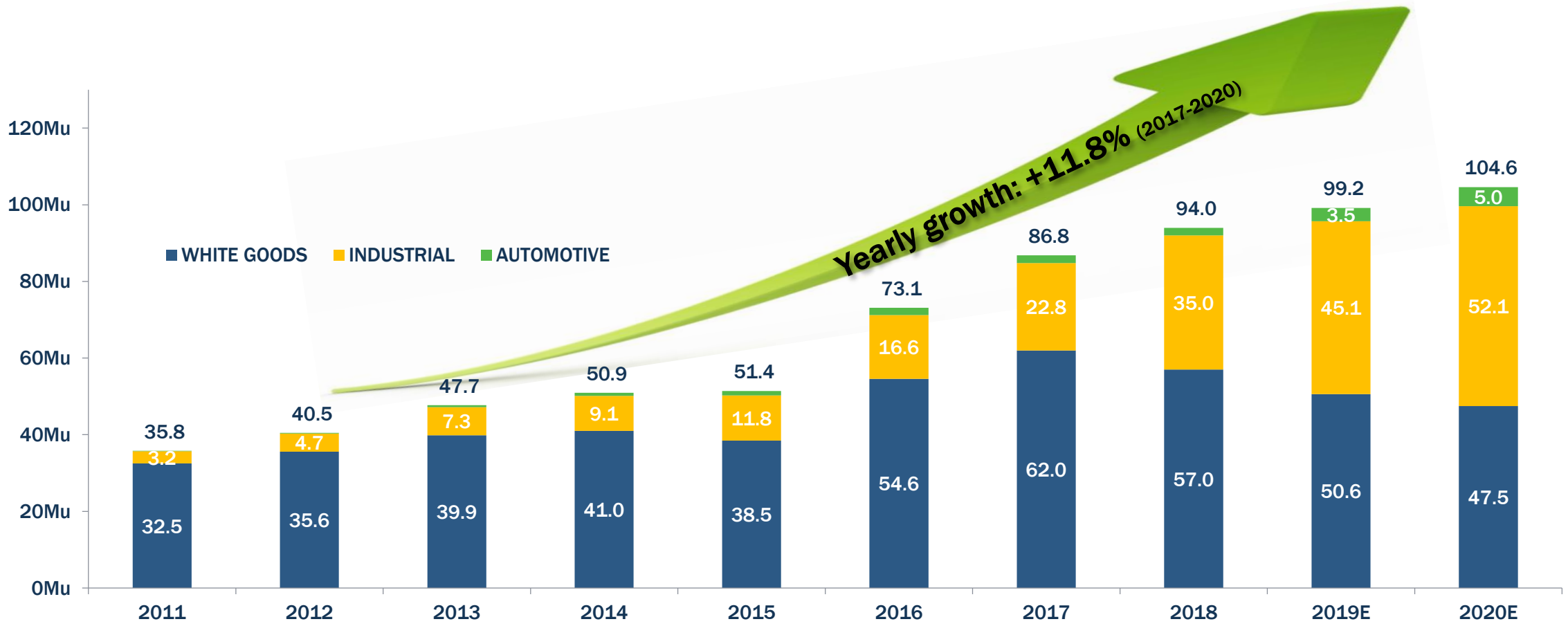
Seremban, Malaysia
Wafer backgrind & test

Ho Chi Minh, Vietnam
Assembly

Cebu, Philippine
Assembly

IPM Capability & Shipment

Moving forward to high performance Segment -> Automotive / Industrial



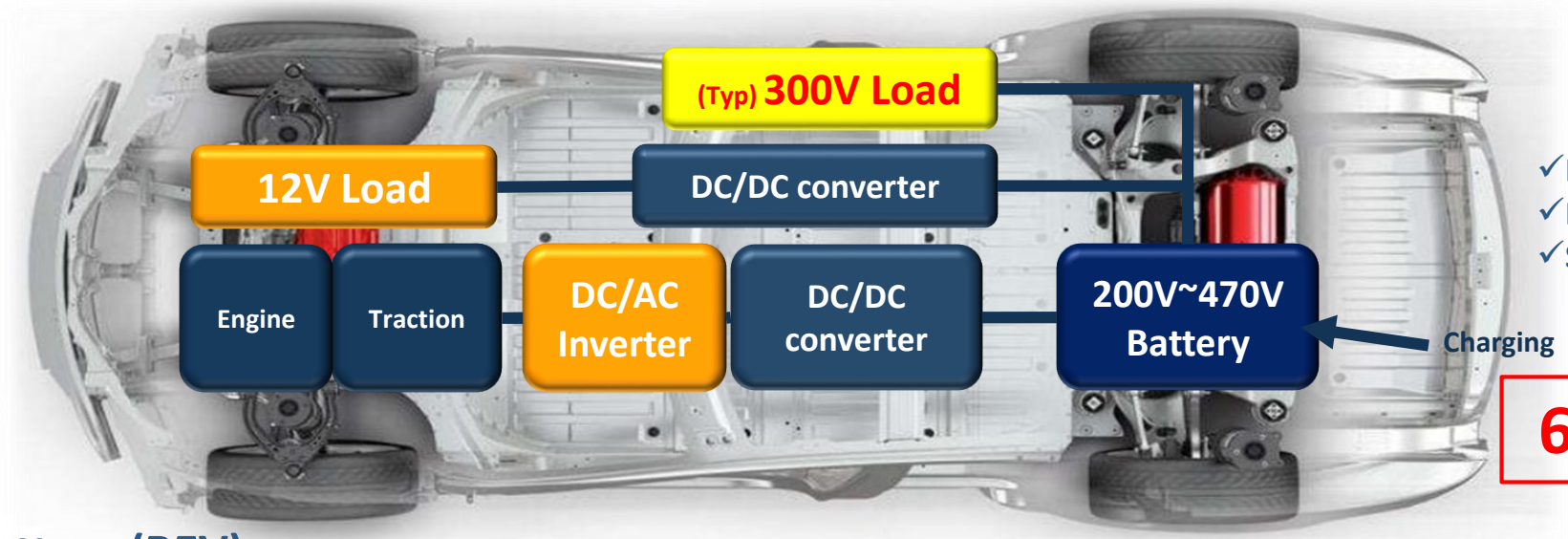
SANYO — 1995~2011 (16yr)

FAIRCHILD SEMICONDUCTOR — 1998~2016 (18yr)

ON Semiconductor — TODAY

HV Vehicle Architecture

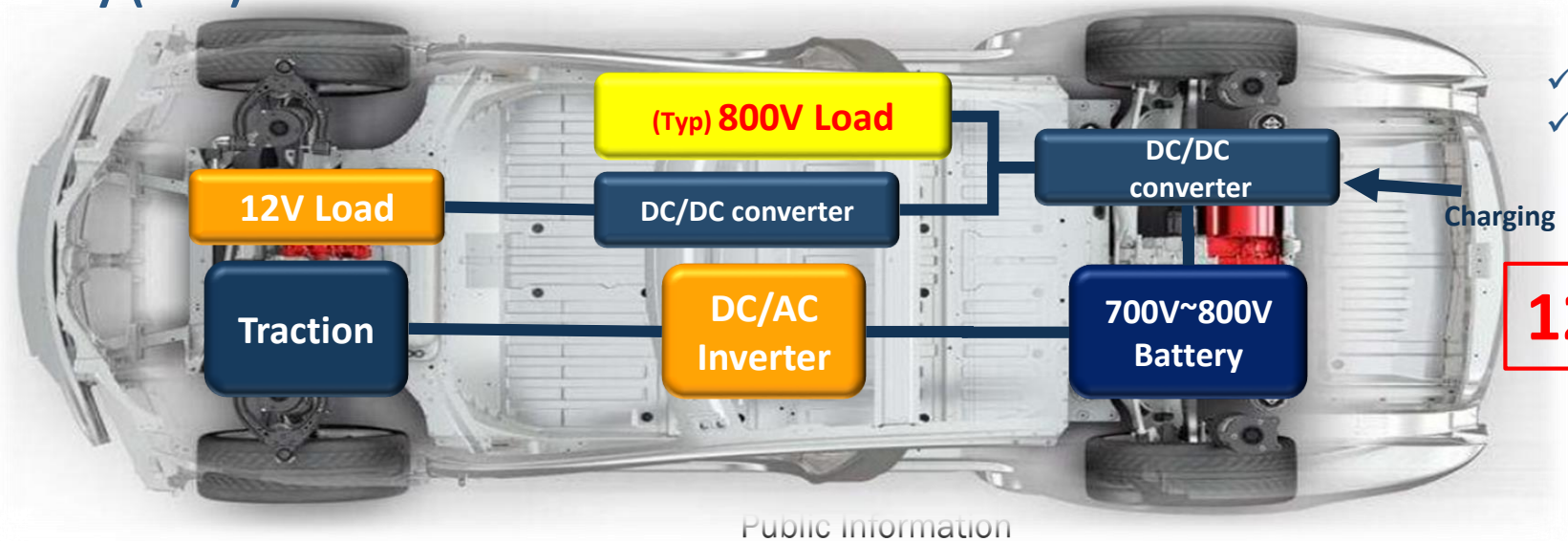
200V~470V battery +Boost ((P)HEV)



- ✓Lower current
- ✓More electrification
- ✓Simple system structure & wiring

650V IGBT

700V~800V battery (BEV)



- ✓Faster charging time
- ✓Longer distance

1200V IGBT

Public Information

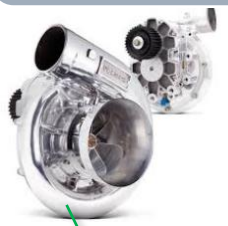
Auxiliary ASPM Target Application

Targeting for all of HV auxiliary motor w/ ASPM in xEV market

Exciter
For Traction motor
(Exclusive)

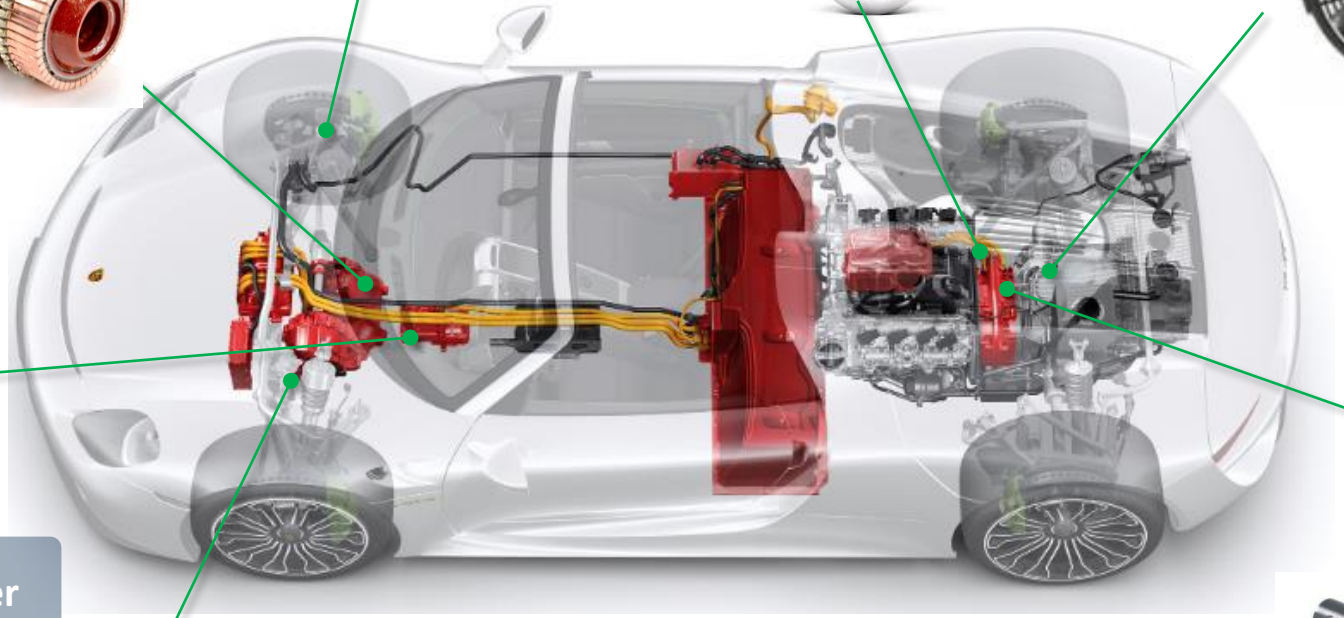
Active Suspension
w/ e-comp

HV Supercharger
w/ e-comp.



HV Cooling Fans
for Radiators, Battery, Engine

HV AC-Comp.
(E compressor)



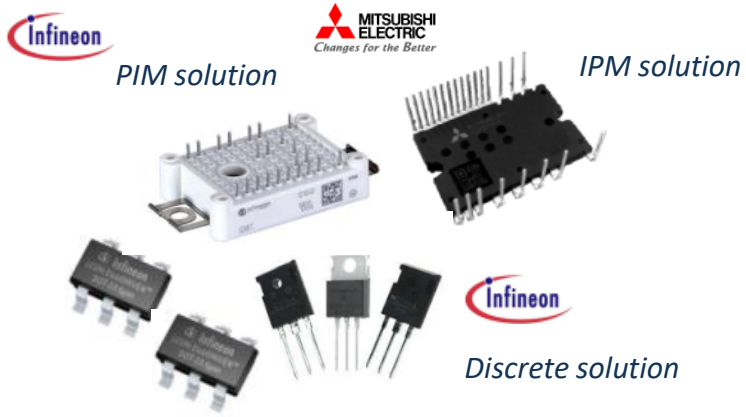
HV EOP (Electric Oil Pumps)
HV EFP (Electric Fuel Pumps)
HV EWP (Electric Water Pumps)

HV PTC Heater

EPS Oil pump for e Bus

Public Information

Market Pain - Auxiliary motor



e Compressor

HV oil pump controller

Reliability

✓**No right solution for automotive**

- OEM ask AEC-Qual
- EU OEM built up AQG324 for module
- Higher BV (650V~)

→ **Automotive qualification**

Quality

✓**Not sufficient reliability**

- Car driving profile is very complicate & dynamic
- Field environment is not clear

→ **Better TMCL & Power Cycle**

Performance

✓**Severe ambient temp. & performance**

- Ambient temp. is normally around 100°C
- Worst case reach 130~140°C
- Better EMI & Long short circuit withstand time
- Also asking -40°C guarantee

→ **Better power device & package structure**

Product concept

✓**Getting smaller size & cost pressure**

- Mechanical limitation for light car weight
- Already customer is asking tough price based on discrete cost

→**Competitive product portfolio**

Why ASPM ??

Benefits of Automotive HV ASPM Modules

Automotive qualification

•AEC qualification Support - US ; AEC-Q100, AEC-Q101

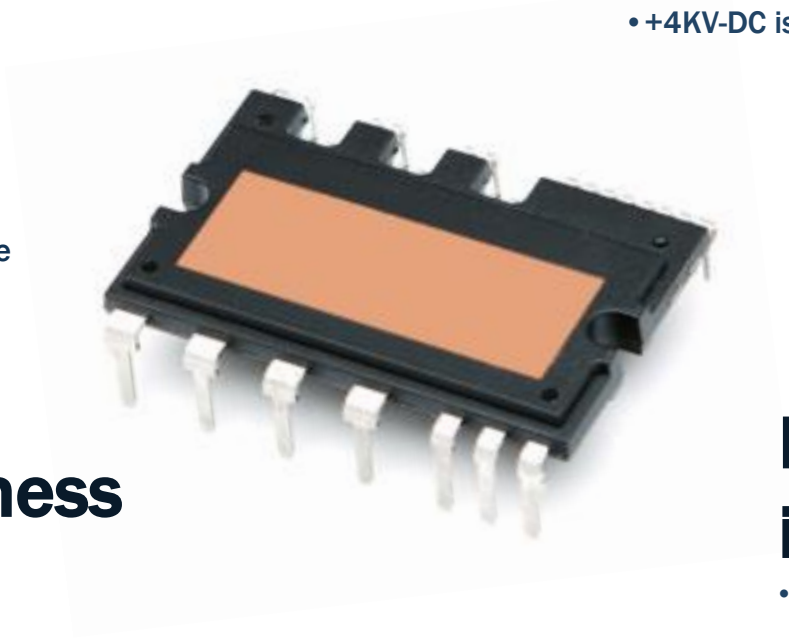
•AQG324 qualification Support - EU

** Ultra low Rth (<0.35K/W) & Isolation via DBC

• ASPM27 50A Rth(j-c) IGBT is 0.35°C/W
• +4KV-DC isolation voltage

Extra long lifetime

•The best-in-class reliability for TMCL & Power Cycle w/ DBC & Epoxy mold against PIM & discrete



** Guaranteed Tj=175°C

• Mitsubishi Guarantee only 150°C even automotive
Power Device, GDU is 150°C

Outstanding ruggedness

*SCWT is over 5us @ worst case

High integration in compact form factor

•6 power device / HVIC / DBC / full protection fn. etc.

Short design cycle & assembly process

•ASPM is already fully optimized for stable EMI & thermal performance
•Only 1 parts need instead of 25~30pcs part

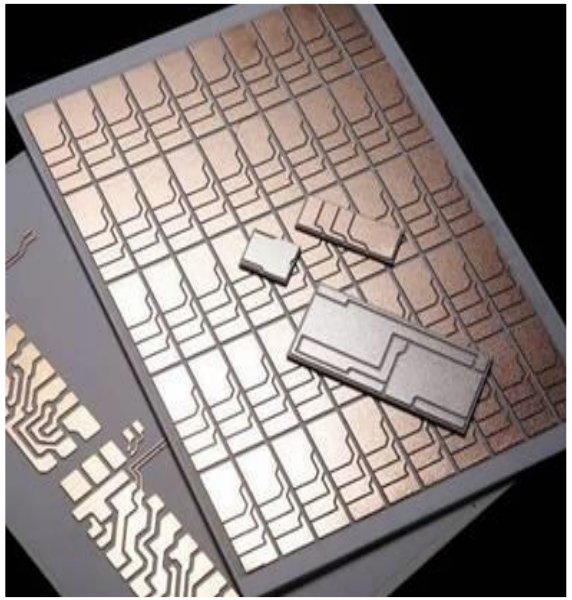
Package Technology – DBC (Direct Bonding Copper)

AlN

Aluminium Nitride

for huge power

*Thermal conductivity : 170W/mk@20C

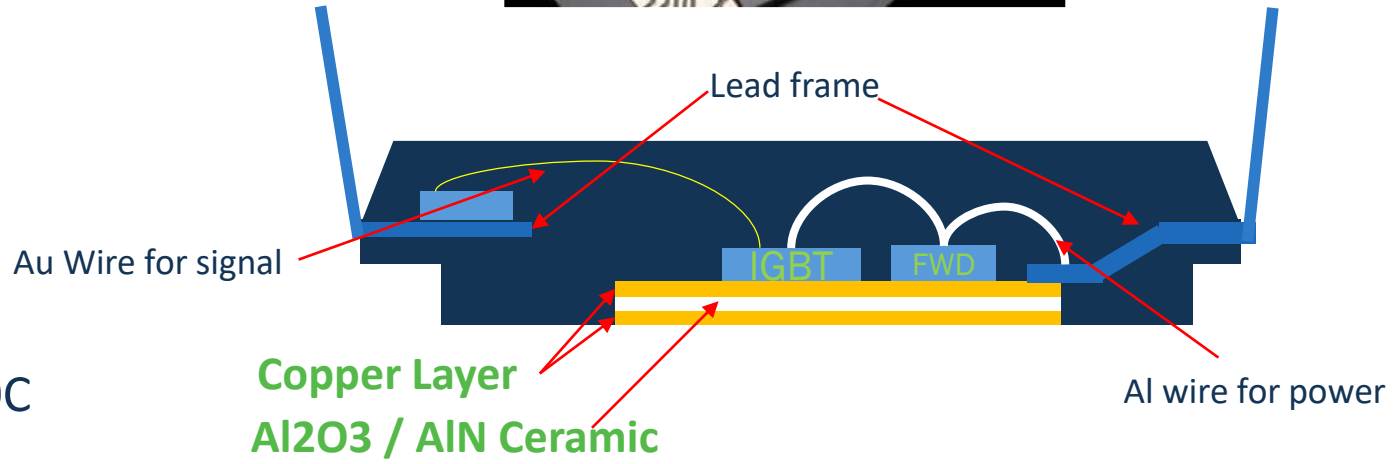


Al_2O_3

Alumina

for medium power

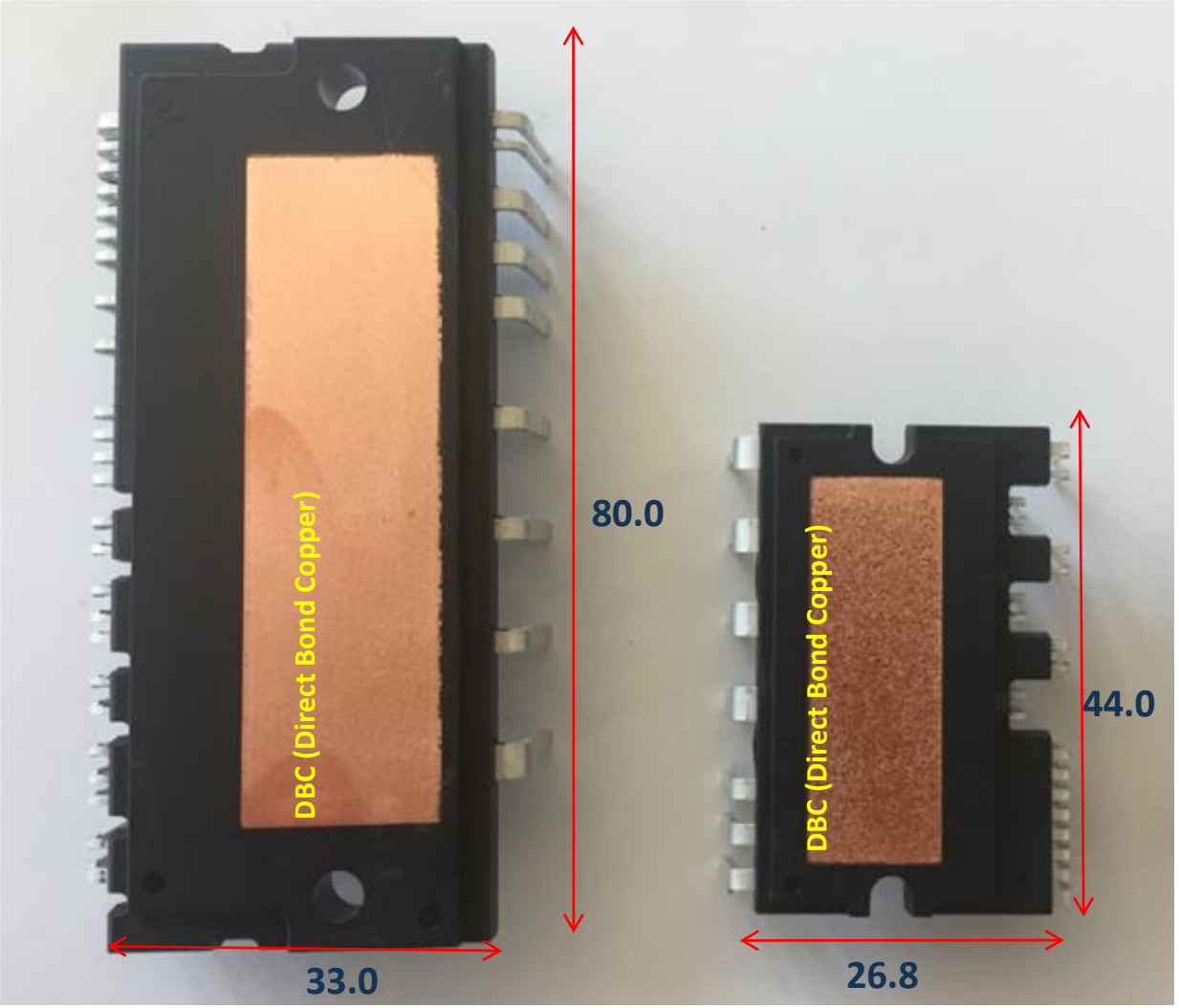
*Thermal conductivity : 24W/mK@20C



Product Outlook

ASPM34 1200V

for ~800V battery



ASPM27 650V

for ~450V battery

Product Roadmap

650V ASPM® 27 V2

Features

- All-in-one solution ; 6-IGBT & FWD, HVIC in pkg
- Below 500V battery system
- Supports AEC-Q100/101, AQG324
- Transfer-molded module with DBC substrate for better TMCL & PRCL than Gel-filled

Benefits

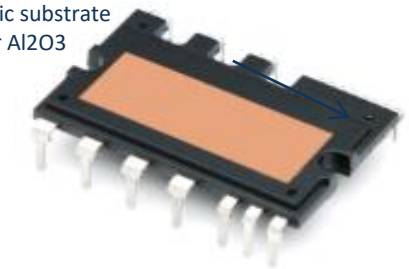
- Smaller footprint than discrete solution
- Electrically isolated substrate for easy assembly
- Superior thermal performance
- Excellent EMI performance

Specifications

Product	Silicon	Io/A	BV [V]	Gate driver	Rth(j-c)	Substrate	Sample /MP
NFVA35065L32	FS3 IGBT	50A	650V	Integrated	0.35°C/W	DBC(AIN)	Available / MP
NFVA34065L32		40A	650V	Integrated	1.19°C/W	DBC(Al2O3)	Available / MP
NFVA33065L32		30A	650V	Integrated	1.4°C/W	DBC(Al2O3)	Available / MP

Package : 44 mm × 26.8 mm× 5.5 mm

Ceramic substrate
AIN or Al2O3



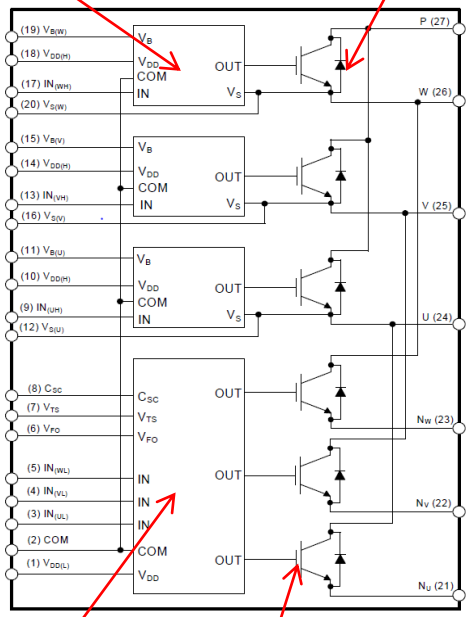
End products

- Automotive Applications
  - -Electric Air-conditioner Compressor
  - -HV Automotive Fan
  - -HV super/turbocharger w/ e Comp
  - -HV Oil/Water Pump

Block Diagram

HVIC
- 2A source / 4A sink
- Fpwm up to 20KHz
- Protection ;UVLO

Diode
- Soft recovery for easy drive and low EMI



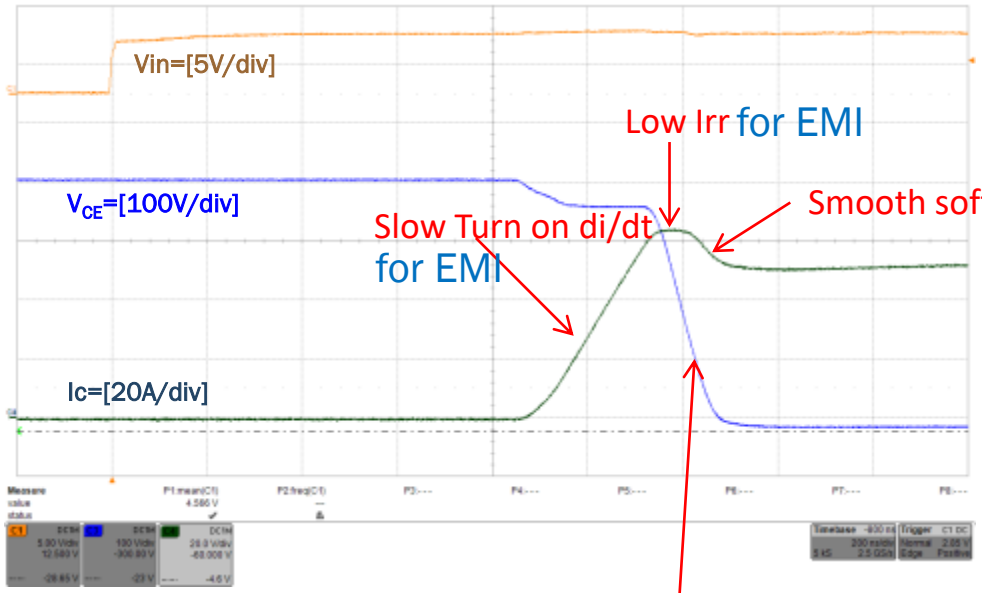
LVIC
- 2A source/4A sink
- Fpwm up to 20KHz
- Protection ;UVLO, OCP, TSU, Fault out
- Thermal Sensing 0°C~150°C via Vts

IGBT
- low conduction and switching losses
- optimized switching dV/dt for motor control
- Short circuit rated

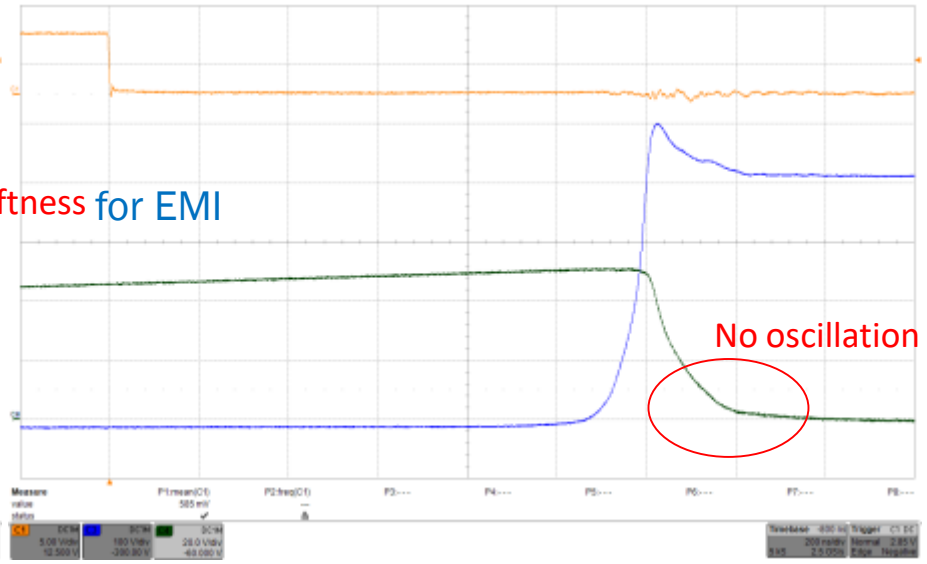
IGBT Switching waveform

✓ Switching waveform at I_C=50A, T_J=150°C w/o snubber Cap. (Normal condition, V_{DC}=400V, V_{CC}=15V)

✓Turn on



✓Turn off



Fast Turn on dv/dt for low loss

ON's ASPM have superior package thermal performance, so ON ASPM select relatively slow switching waveform for stable EMI /EMC performance instead of fast switching

1200V ASPM® 34

Features

- All-in-one solution ; 6-IGBT & FWD, HVIC in PKG.
- For 800V battery system
- Supports AEC-Q100/101, AQG324
- Transfer-molded module with DBC substrate for better TMCL & PRCL than Gel-filled

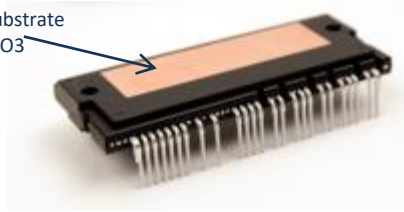
Benefits

- All parts pin-compatible
- Wide product coverage ;10~50A/1200V
- For design convenience, remove side dummy
- Embedded real NTC(47KΩ) & sense IGBT for protection

Specifications

Product	Silicon	Io/A	BV [V]	Rth (j-c)	Substrate	Status (Spl./MP)
NFVA22512NP2T	NPT Trench	25A	1200V	0.81°C/W	DBC(Al2O3)	Available /Dec. 19~
NFVA23512NP2T		35A	1200V	0.73°C/W	DBC(Al2O3)	Available /MP
NFVA25012NP2T		50A	1200V	0.36°C/W	DBC(AlN)	Available / Dec. 19~

Package ; 80 mm × 33 mm × 8 mm



End products

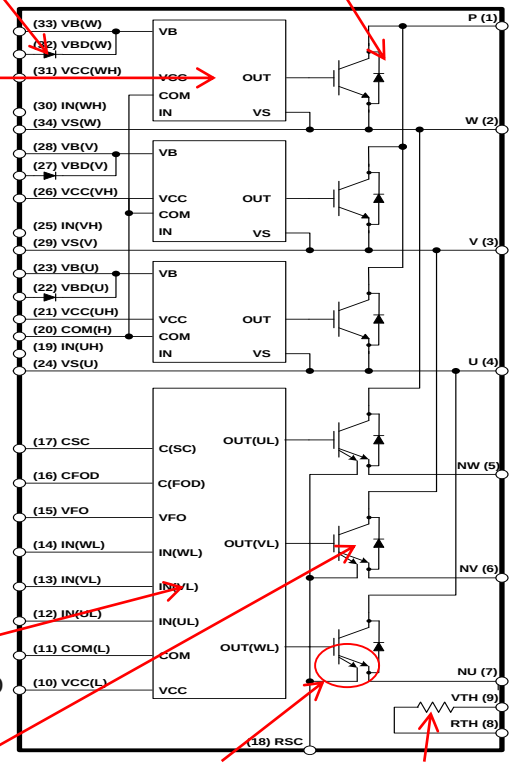
- **Automotive applications**
  - -Electric Air-conditioner Compressor
  - -Automotive Fan
  - -Oil/Water Pump

Block Diagram

BSD
- Pure Diode (No Resistance)
- 1600V/1A

FW-Diode
- Soft recovery for easy drive and low EMI

HVIC
- Fpwm up to 20KHz
- Protection ;UVLO



LVIC
- Fpwm up to 20KHz
- Protection ;
  UVLO, Fault out, Csc, TSD

IGBT
- low conduction and switching losses
- optimized switching dV/dt for motor control
- Short circuit rated

Sense block for SC protection

Real NTC

Public Information

Climate e Compressor

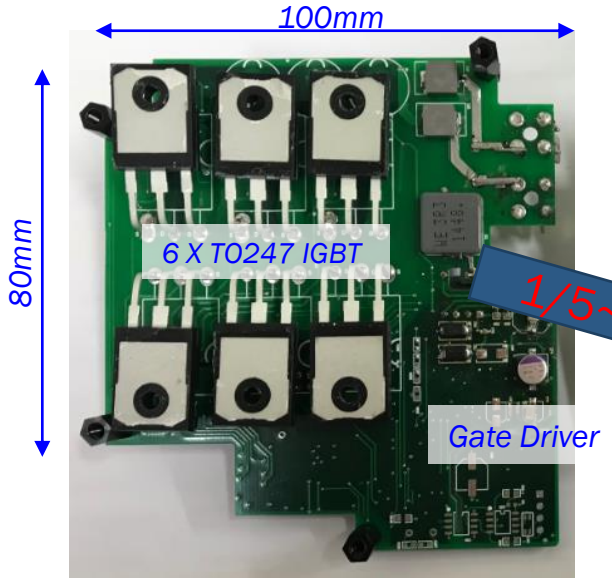
Market needs

- High thermal performance
- Increase target power (5KW → 7KW) for bigger vehicle body
- Tiny size package product due to compressor size shrink
- Cost effective solution
- Strong isolation voltage (+4.3KVdc)

IPM Solution

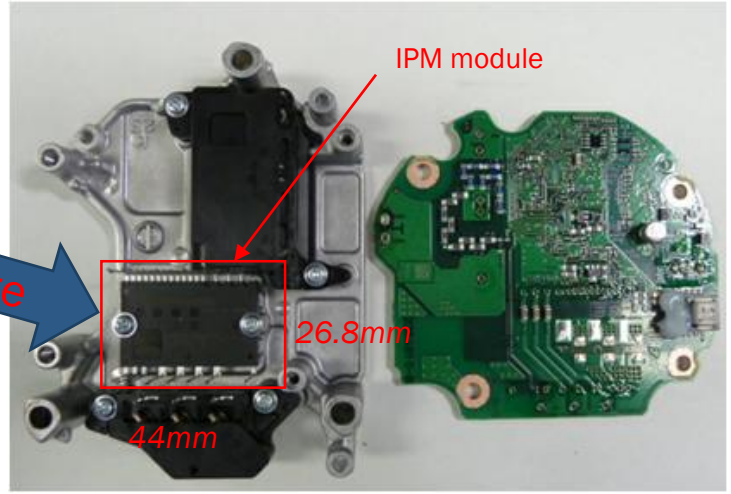
- ASPM27 V2 for 650V
- ASPM34 for 1200V

<ASPM27>



<3-phase Discrete solution>

1/5~1/4 Size

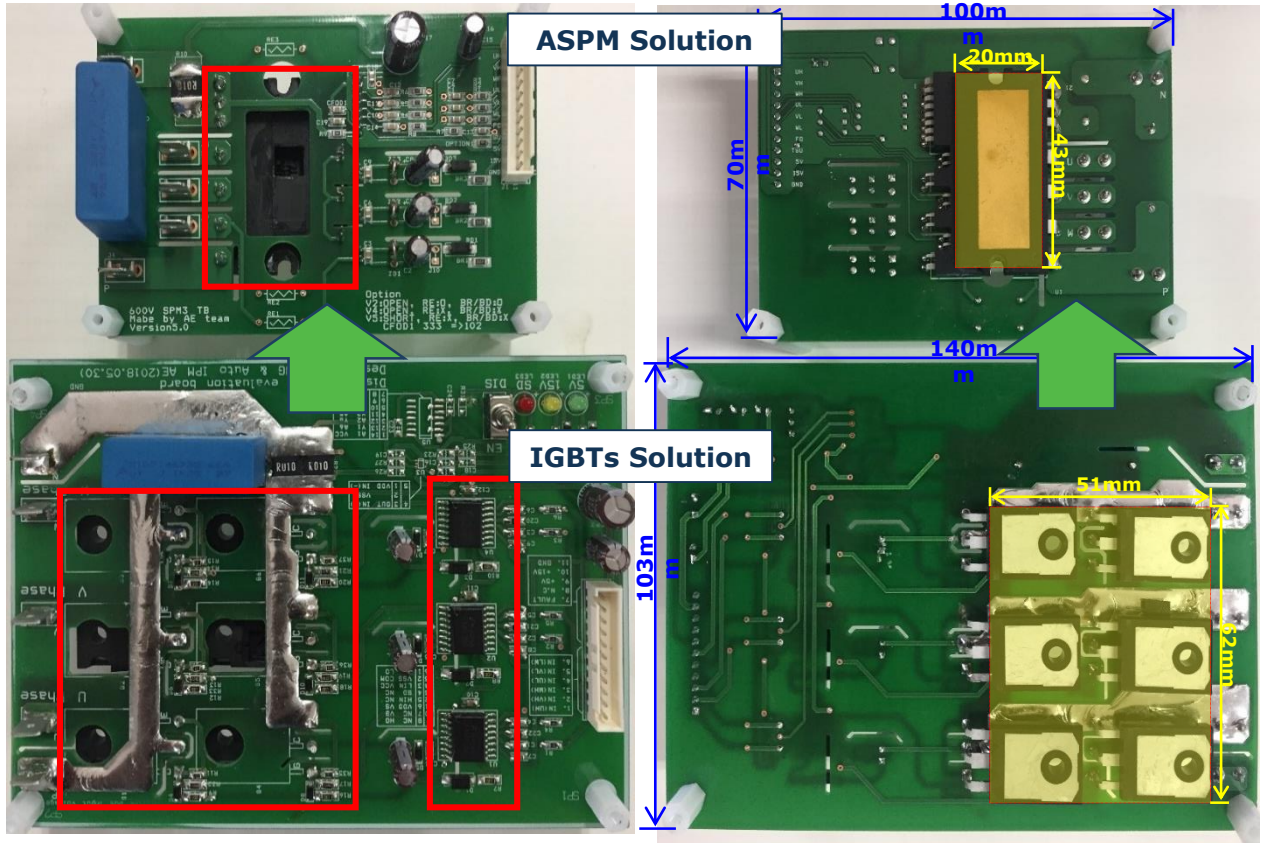


<PCB w/ power module solution >

<e-compressor>

ASPM vs. Discrete IGBTs solution

< Top side > **< Bottom side >**



< Advantages of IPM >

- Minimizing internal wiring to reduce stray L
- No need consider power pin distance
  - ✓ Achieved super-compact foot print
- Superior Isolation
  - ✓ 2.5KV @60HZ, Sinusoidal, 1min
- The super easy assembly process
  - ✓ IPM Solution : Only 2 screws
  - ✓ Discrete IGBTs Solution : 6 IGBTs + 3 Driver ICs + Gate resistors + 6 Screws

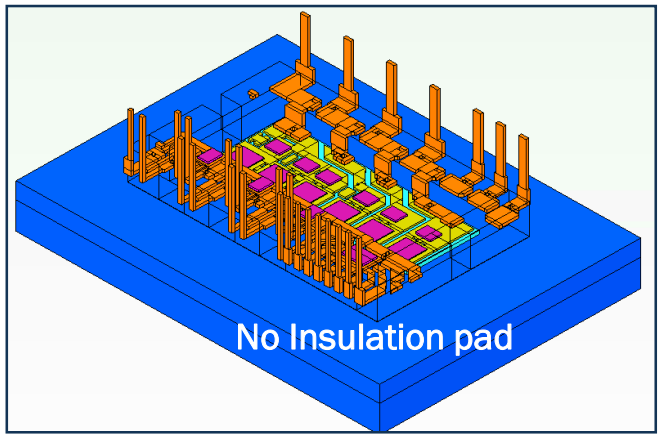
[PCB and H/S size comparison]

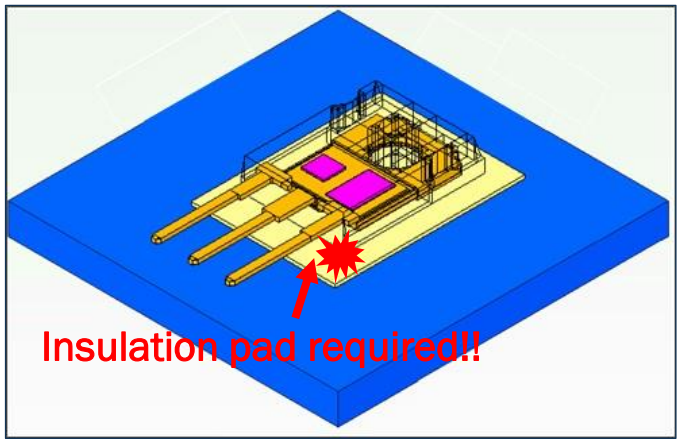
	ASPM Solution	Discrete Solution
PCB Size[mm]	100*70	140*103
*H/S Size[mm]	20*43	51*62

*H/S Size : Contacted area

Thermal Isolation Comparison

- Thermal resistance comparison under real operation





Isolation pad

[Measured Rth of isolation pad]

No.	R_{th_Sheet} [°C/W]
1	0.915
2	0.936
3	0.920
4	0.894
5	0.949
Ave.	0.923

R_{th_JC} of IGBT : **IPM R_{th_JC} Only**

R_{th_JC} of IGBT : **IGBT R_{th_JC} + Isolation pad R_{th} = 1.373°C/W**

- Thermal resistance comparison

DUT	Junction to case thermal resistance [°C/W]	
	IGBT	Diode
NFVA33065L32	Max. 1.40	Max. 2.40
NFVA34065L32	Max. 1.19	Max. 1.96
NFVA35065L32	Max. 0.35	Max. 1.02
50A/600V IGBT (W/ R_{th_Sheet})	Max. 1.373 **0.45+0.923	Max. 1.723 **0.8+0.923

Thermal Resistance

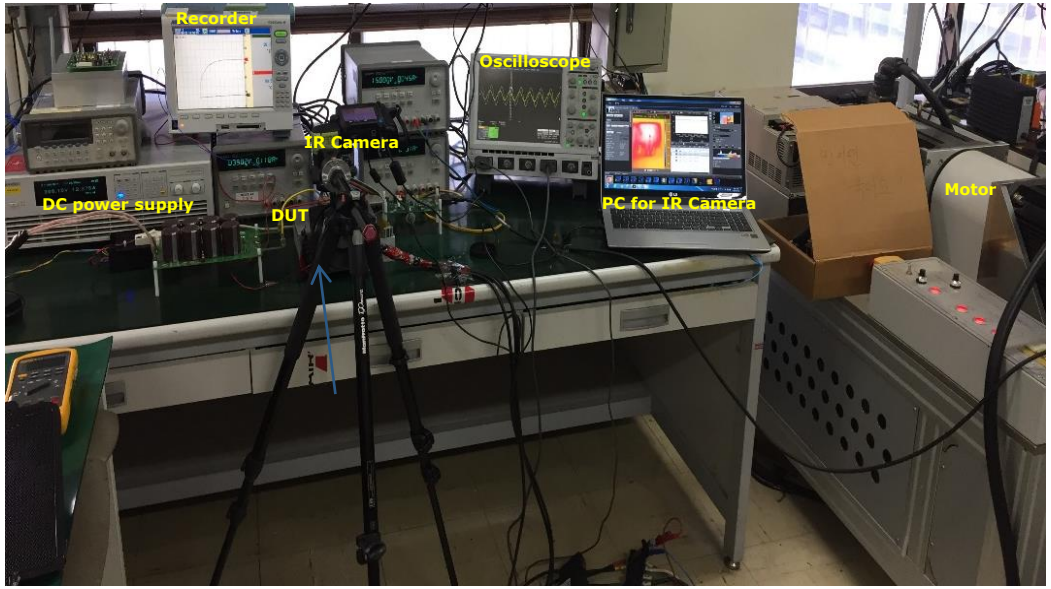
Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction – case	R_{thJC}		0.45	K/W
Diode thermal resistance, junction – case	R_{thJCD}		0.8	

< 50A/650V IGBT>

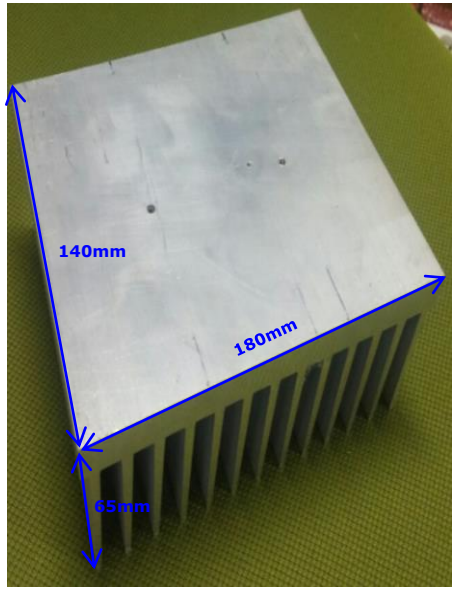
Setup for Thermal Characteristics Comparison

- DUT : *ASPM27* (Module) *VS* **50A/650V IGBT**(Discrete IGBT)
- Conditions : VDC=300V, VDD=15V, Fsw=20kHz, Fo=80Hz, Tdead=2us, SPWM, I_O=30Apeak(21.2Arms), M.I=0.58, P.F=0.97

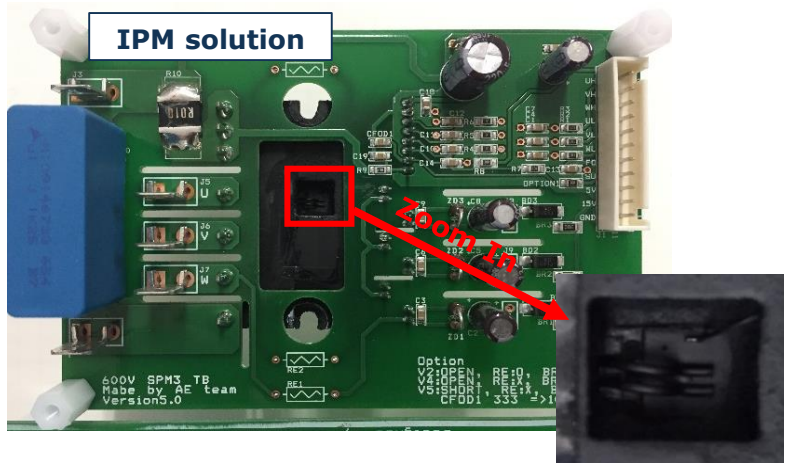
  Heatsink, Cooling fan, 11kW Servo motor, Mounting Torque : 0.7N•m

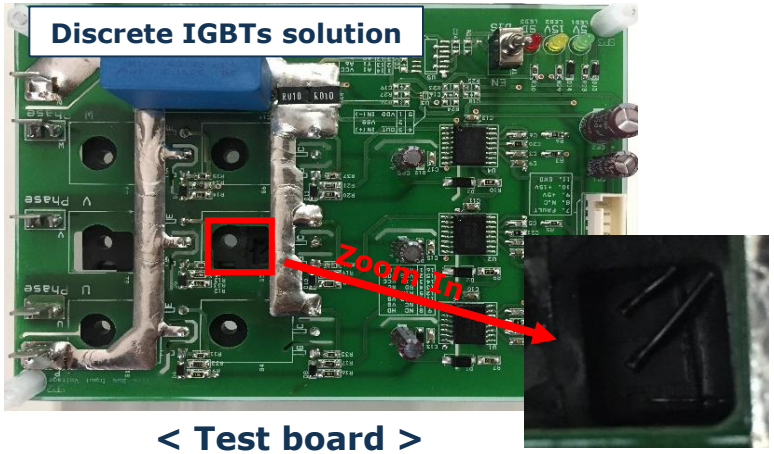


< Test Bench >



< Heat sink >





< Test board >

Summary

- IPMs vs. Discrete solution

Methods	DUT	R_{th_Jc} [ºC/W]	I_O [Apeak]	P_D [W]		T_C [°C]	T_J [°C]
				IGBT	Diode		
MATLAB simulation	NFVA33065L32	1.40	30				
	NFVA34065L32	1.19		27.19	5.58	100	132.4
	NFVA35065L32	0.35		26.22	5.53	100	109.7
	50A/600V IGBT	1.373 (With isolation pads)		23.43	5.99	100	132.2
Motor test	NFVA33065L32	1.40		-		100.5	141.3
	NFVA34065L32	1.19				99.4	134.2
	NFVA35065L32	0.35				99.2	113.5
	50A/600V IGBT	1.373 (With isolation pads)				99.6	132.2

- IPMs solution vs. Discrete IGBTs solution(Under real operation)
  - ✓ *NFVA34065L32 : ΔT_{JC}=34.8º C* ≈ **50A/600V IGBT** *: ΔT_{JC}=32.6º C*
  - ✓ *NFVA35065L32 : ΔT_{JC}=14.3º C* << **50A/600V IGBT** *: ΔT_{JC}=32.6º C*

THANK YOU