

# 汽车热管理之E-Compressor浅谈

Presenter: Ian yu, Nov 2023

# Agenda:

1 什么是E-Compressor

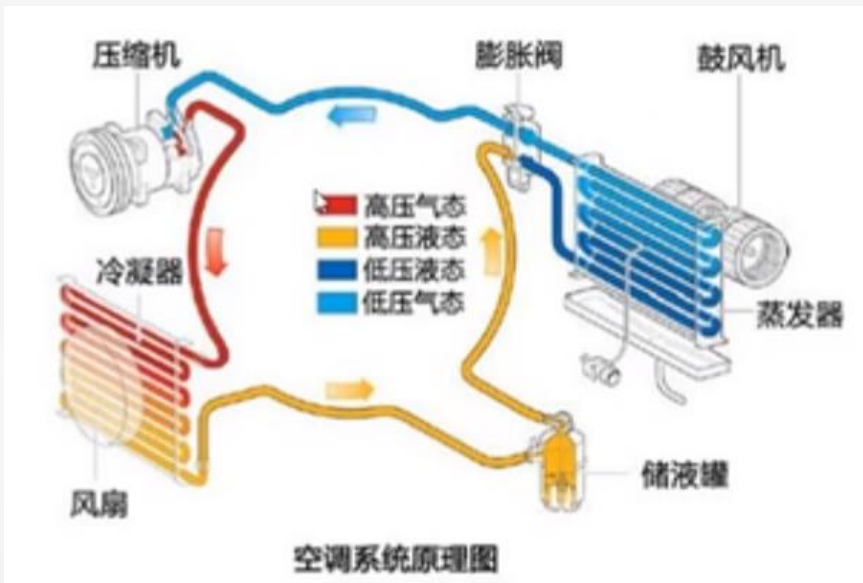
2 E-Compressor头部企业

3 onsemi在E-Compressor上的应用

4 市场发展趋势和展望

# 什么是E-Compressor?

# 什么是E-Compressor?



电动压缩机是新能源汽车舒适系统空调系统的重要组成部分。

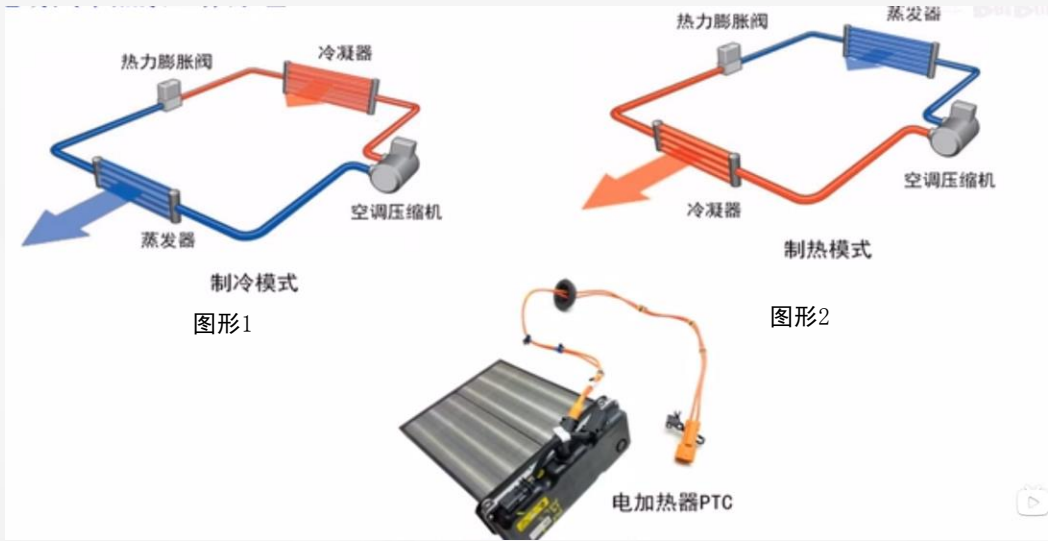
空调系统最根本的原理就是蒸发吸热、冷凝放热,压缩机将低压气态冷媒压缩为高压气态冷媒,经过乘员舱外面的冷凝器,将高压气态冷媒冷却为高压液态冷媒(放热排温度),此为冷凝过程,将热量释放到外部空气中。

传统燃油车的压缩机由发动机通过电磁离合器带动压缩机本体旋转后压缩气体,新能源汽车由于没有发动机,因此由电动压缩机控制器驱动永磁同步电机旋转,从而提供机械能。

电动压缩机是重要的做功器件一般其效率用COP来表示,  $COP = \text{制冷量} / \text{消耗功率}$



# E-Compressor的不同之处？



空调制冷剂如左图形1运行时是制冷模式，其中蒸发器负责给车内降温，空调制冷剂如左图形2运行时是制热模式即热泵，其中冷凝器负责给车内加热。

制冷模式和制热模式，制冷剂流动方向刚好相反，热泵制热效率是PTC的3-4倍，也就是更省电。

制冷模式和传统油车相比，由于没有发动机只能新增一个电动压缩机，另外电池包的温度控制也需要冷却系统，大多采用独立的液冷模式也有少部分是将电池包内部冷却管路连接空调管路共用冷凝器。

制热模式和传统油车相比，油车是通过发动机加热冷却液实现空调制热，电车早先使用PTC制热，后来发展出热泵空调可以有效降低电耗，提高续航能力。

PTC和热泵空调主要区别：PTC可以简单理解为小太阳/热得快，热泵空调是通过冷凝器蒸发箱交换热量实现制热。热泵空调是新能源汽车提高冬季续航的不二选择。

	PTC	热泵
能效/COP	$\leq 1$	2-3
续航	100%	120%

# E-Compressor头部企业

# 头部企业

## 国内电动压缩机厂商



南京奥特佳



上海海立



湖南华强电气



上海华域三电



上海松芝

## 国外电动压缩机厂商

**Panasonic**

松下



三电

**DENSO**  
Crafting the Core

电装

**HANON**  
SYSTEMS

韩国翰昂

国内厂商有: 上海华域三电、上海海立、湖南华强、南京奥特佳、上海松芝、重庆建设、烟台首钢丰田工业空调压缩机、浙江威乐新能源压缩机有限公司等。

国外厂商有: 松下、三电、电装、翰昂

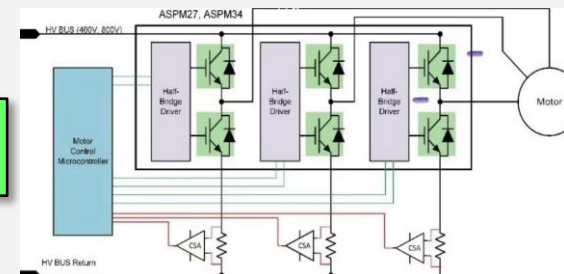
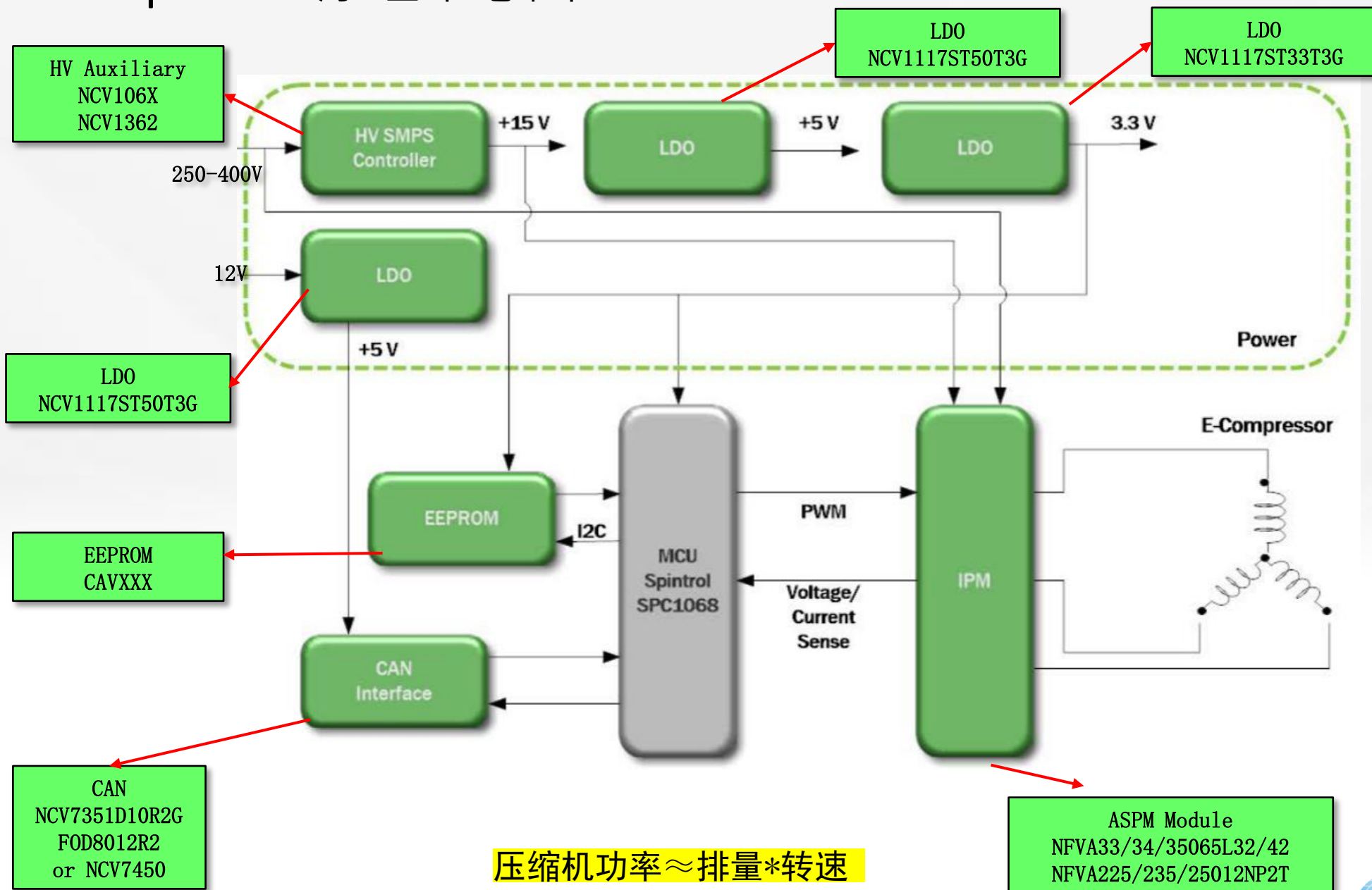
2021年中国E-Compressor产值规模18.43亿元, 同比增长215%, 2022年中国E-Compressor产值规模40.35亿元, 同比增长118.9%

乘用车空调压缩机主要包括斜盘式、涡旋式以及旋叶式。斜盘式压缩机是往复式压缩机的主导产品已经发展多年, 工艺比较成熟, 主要用在大排量乘用车, 能耗高。

# onsemi在E-Compressor上的应用



# E-Compressor 原理示意图

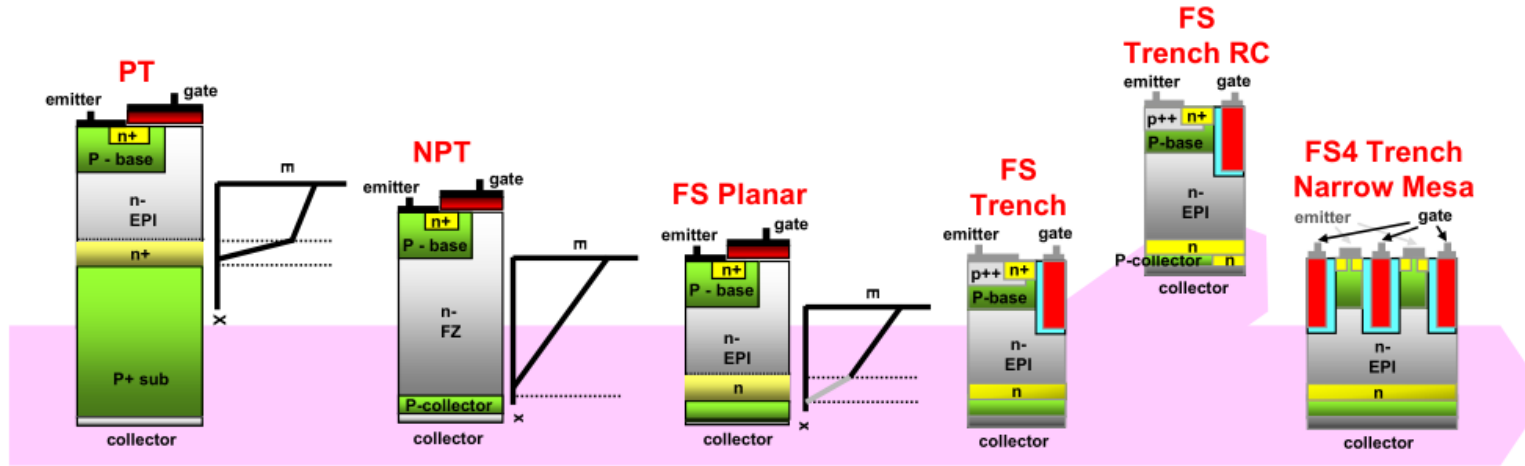


- ASPM
- IGBT
- Gate Driver
- Sensor
- CAN
- Isolation
- Aux
- LDO
- EEPROM

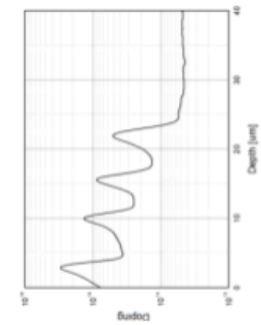
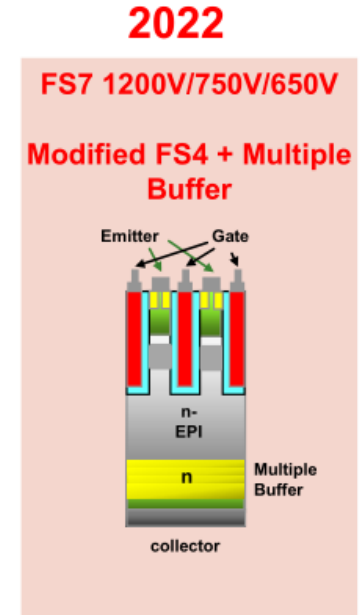
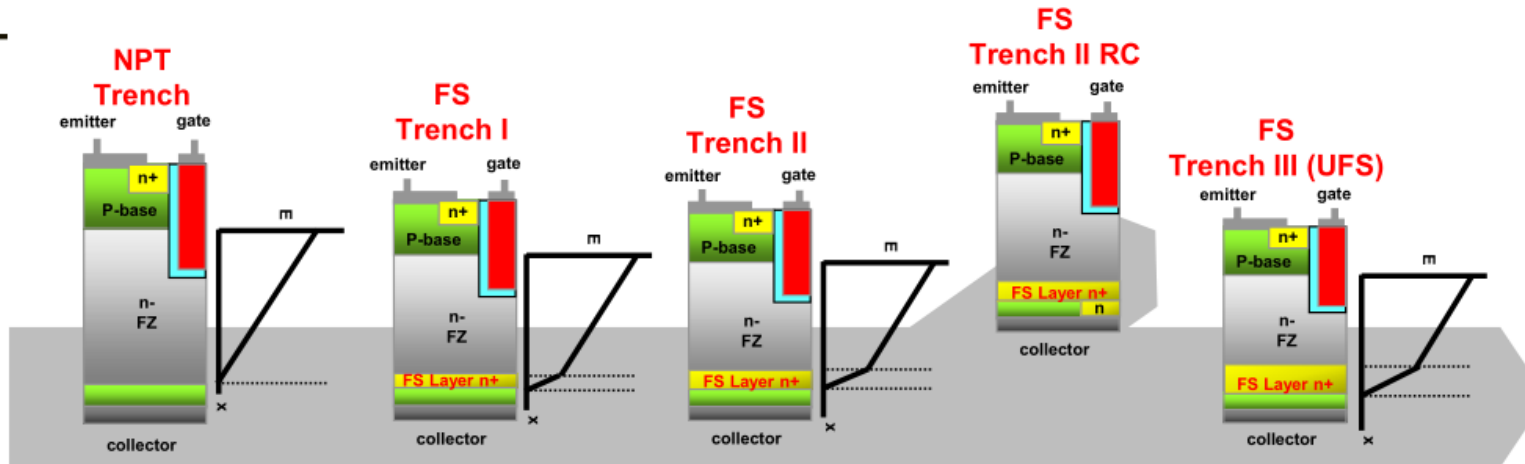


# onsemi IGBT 技术发展演进

## 650V IGBT



## 1200V IGBT



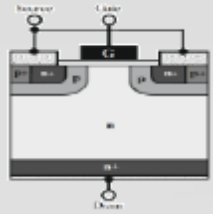
# onsemi EliteSiC Leadership: From Substrate ( 晶圆 ) to Systems ( 系统 )

## Substrates / Epi

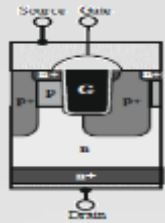


- 150/200mm SiC wafering & epi fully internal in **onsemi** today

## Fab



SiC Planar available today



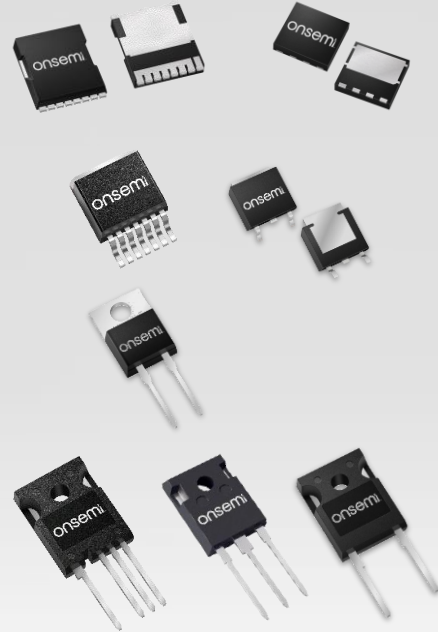
Working on trench for the future



200mm migration ready

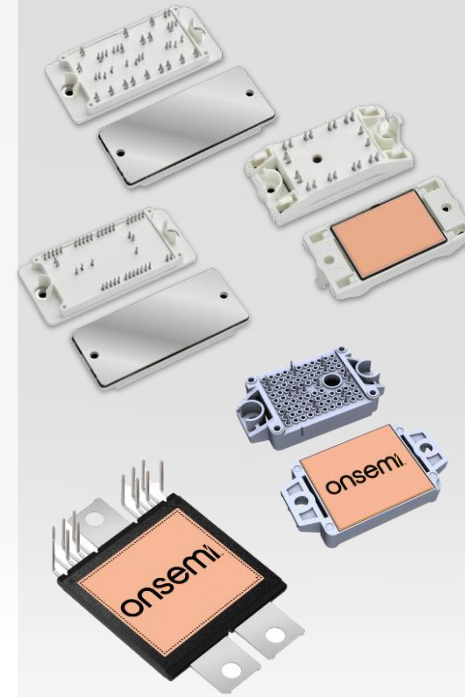
- Fabs ready today for 150mm→200mm migration

## Devices / Die



- Full portfolio of diodes & MOSFETs
- Broad base of packages
- Die only & metal options
- Auto & Industrial devices

## Modules



- Case & transfer molded options
- Full portfolio of hybrid & full SiC modules
- Single & dual cooling, direct & indirect

## Systems



- Deep application & system know-how for automotive & industrial
- EMEA, US, Asia based apps support

# onsemi SiC MOSFET and Diode Families

Family	Series	Optimization	650V	900V	1200V	1700V	Primary Applications
M1	M1	Low RDS(ON) High SCWT			..120SC1	..170M1	
M2	M2	Low RDS(ON) High SCWT	..065SC1	..090SC1			
M3	M3S	High speed			..120M3S		
	M3T	Low RDS(ON) High SCWT			..120M3X SCWT dependent		

Family	Optimization	650V	900V	1200V	1700V	Primary Applications
D1	High IFSM	..650A		..120A	..170A	
D2	Low QC	..650B				
D3	Low QC x VF			..120C		



# onsemi ASPM(Automotive Smart Power Module) Roadmap

## Specifications

	Product	Silicon	Io/A	BV [V]	Gate driver	Rth(j-c)	Substrate	Sample/MP
	NFVA35065L32		50A	650V	Integrated	0.35°C/W	DBC(AIN)	Available
650V ASPM® 27 V2	NFVA34065L32	FS3 IGBT	40A	650V	Integrated	1.40°C/W	DBC(Al2O3)	Available
	NFVA33065L32		30A	650V	Integrated	1.55°C/W	DBC(Al2O3)	Available
	NFVA36065L42		FS4 IGBT	60A	650V	Integrated	0.33°C/W	DBC(AIN)
NFVA35065L42	50A	650V		Integrated	1.30°C/W	DBC(Al2O3)	Available	
NFVA33065L42	30A	650V		Integrated	1.50°C/W	DBC(Al2O3)	Available	
	NFVA22512NP2T		25A	1200V	Integrated	0.81°C/W	DBC(Al2O3)	Available
1200V ASPM® 34	NFVA23512NP2T	FS3 IGBT	35A	1200V	Integrated	0.73°C/W	DBC(Al2O3)	Available
	NFVA25012NP2T		50A	1200V	Integrated	0.36°C/W	DBC(AIN)	Available



# 汽车高压辅助系统智能模块

## 650V ASPM 27-V2

Fpwm: 20KHZ

Product	Silicon	Io/A	BV [V]	Rth(j-c)	Substrate
NFVA35065L32	FS3 Trench IGBT *SCWT ~3us	50A	650V	0.35°C/W	DBC(AIN)
NFVA34065L32		40A	650V	1.40°C/W	DBC(AI2O3)
NFVA33065L32		30A	650V	1.55°C/W	DBC(AI2O3)

## 650V ASPM 27-V3

Fpwm: 40KHZ

Product	Silicon	Io/A	BV [V]	Rth(j-c)	Substrate
NFVA36065L42	FS4 Trench IGBT *SCWT ~3us	60A	650V	0.33°C/W	DBC(AIN)
NFVA35065L42		50A	650V	1.30°C/W	DBC(AI2O3)
NFVA33065L42		30A	650V	1.50°C/W	DBC(AI2O3)

44 x 26.8 x 5.5mm



## 1200V ASPM 34

Product	Silicon	Io/A	BV [V]	Rth(j-c)	Substrate
NFVA25012NP2T	NPT Trench IGBT *SCWT ~3us	50A	1200V	0.36°C/W	DBC(AIN)
NFVA23512NP2T		35A	1200V	0.73°C/W	DBC(AI2O3)
NFVA22512NP2T		25A	1200V	0.81°C/W	DBC(AI2O3)

80 x 33 x 8.0mm

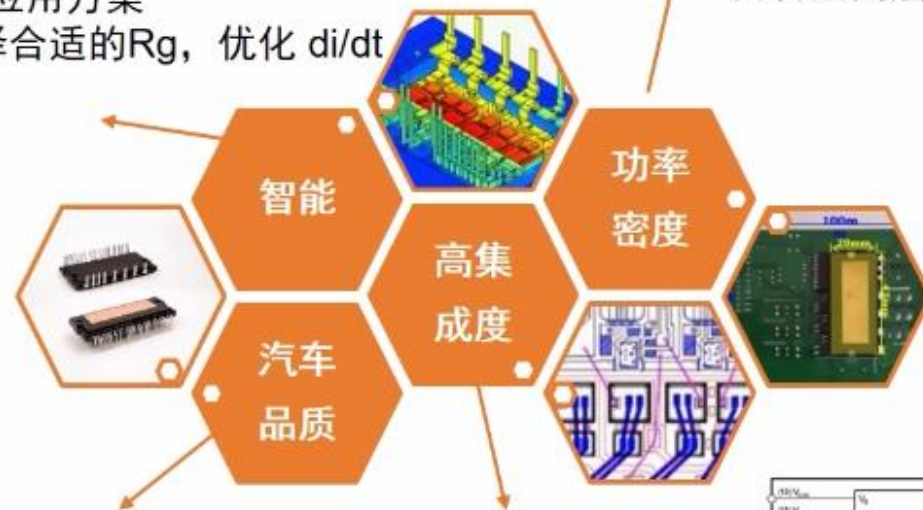


## 智能电源方案

- 内置门极驱动-  
最佳应用方案

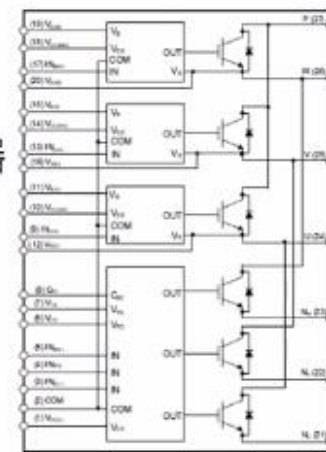
: 选择合适的Rg, 优化 di/dt

- 最低热阻- 结到散热器  
- 内含隔离层



- 符合AQQ324 车规  
及 TICO 特定的 Rel 标准.  
- 自2008年以来, 汽车模块领域的记录

- 一体化- HVIC,  
LVIC, IGBT, 整流器



# 器件图解-ASPM27 & ASPM34

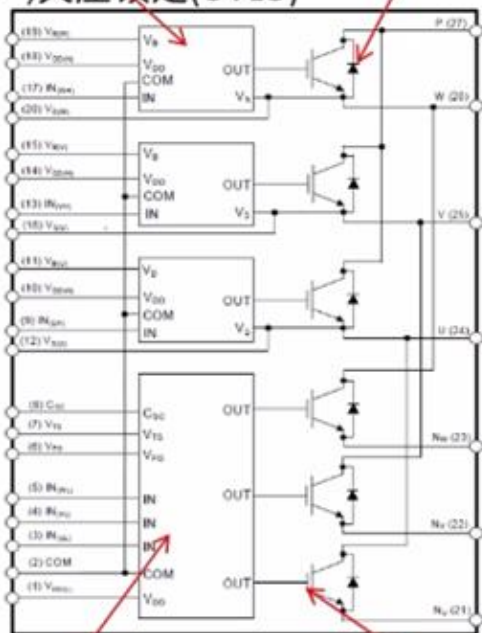
## ASPM27 (V2 & V3)

### HVIC

- 2A 源电流 / 4A 汲电流
- Fpwm 达 40KHz
- 保护 ; 欠压锁定(UVLO)

### 二极管

- 软恢复, 易于驱动, 低EMI



### LVIC

- 2A 源电流 / 4A 汲电流
- Fpwm 达 40KHz
- 保护 ; UVLO, OCP, TSU, 故障输出
- 热检测  
0°C~150°C 经由 Vts

### IGBT

- 低导通损耗和开关损耗
- 为电机控制提供优化的开关 dV/dt
- 额定短路值

## ASPM34

### BSD

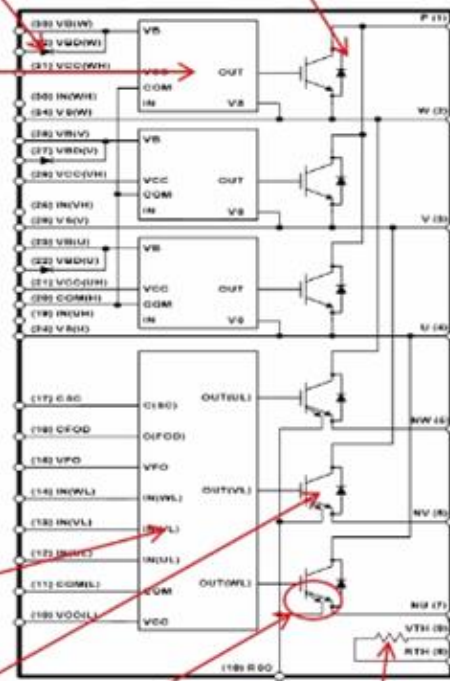
- 纯二极管(无电阻)
- 1600V/1A

### FW-二极管

- 软恢复, 易于驱动, 低EMI

### HVIC

- Fpwm 达 20KHz
- 保护 ; UVLO



### LVIC

- Fpwm 达 20KHz
- 保护 ; UVLO, 故障输出(Fault out), Csc, TSD

用于短路保护的检测块

Real NTC

### IGBT

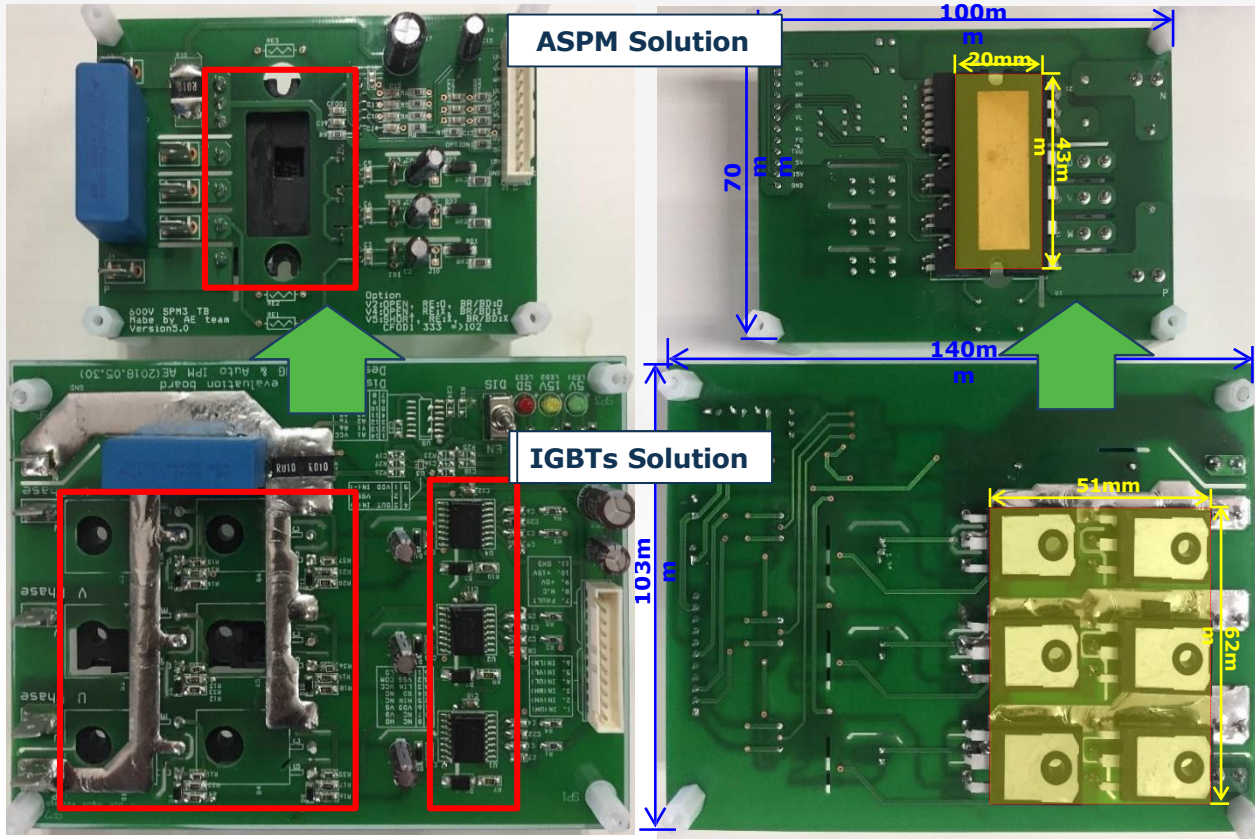
- 低导通损耗和开关损耗
- 为电机控制提供优化的开关 dV/dt
- 额定短路值



# ASPM vs Discrete IGBTs solution-设计

< 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

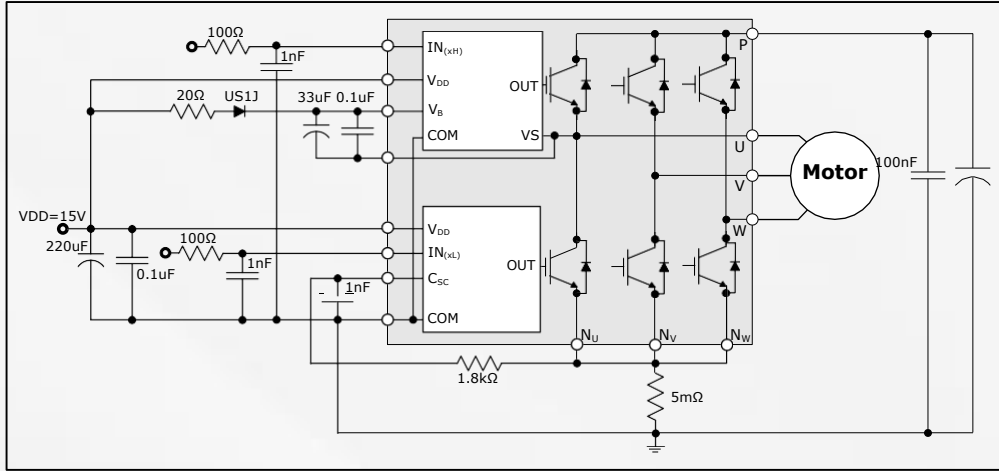
[PCB and H/S size comparison]

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

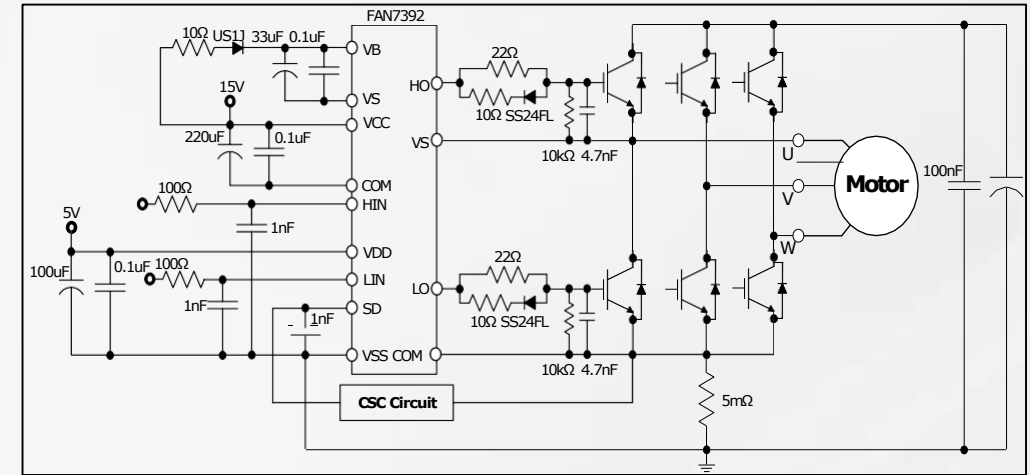
\*H/S Size : Contacted area

# ASPM vs Discrete IGBTs solution-热阻

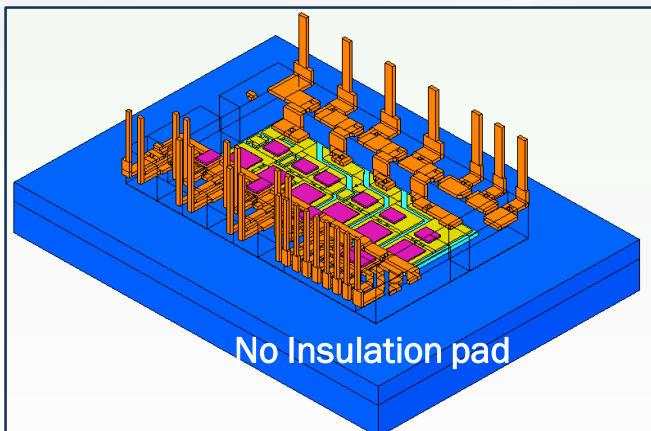
## > ASPM



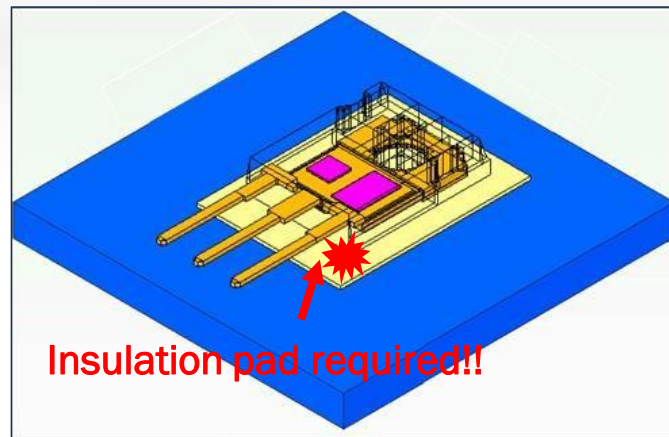
## > Discrete



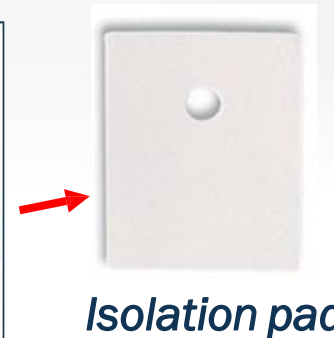
- Thermal resistance comparison under real operation



$R_{th\_JC}$  of IGBT : **IPM  $R_{th\_JC}$  Only**



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



Isolation pad

[ Measured  $R_{th}$  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

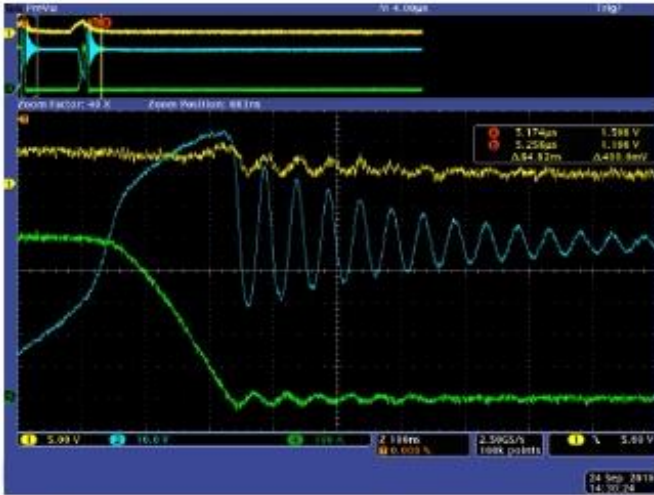
- Thermal resistance comparison :  $R_{th}$ s of Discrete 50A is equivalent to 30A rating ON's ASPM

# ASPM vs Discrete IGBTs solution-其他

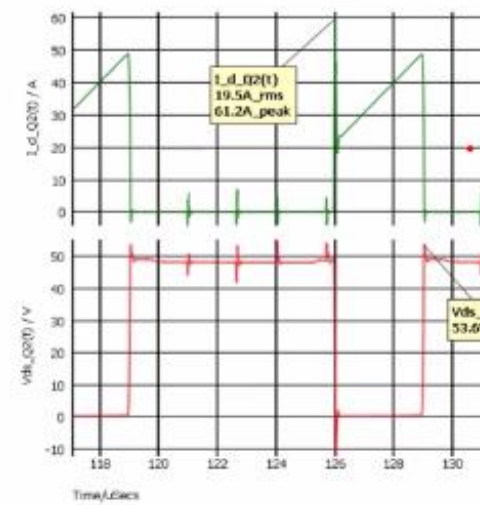
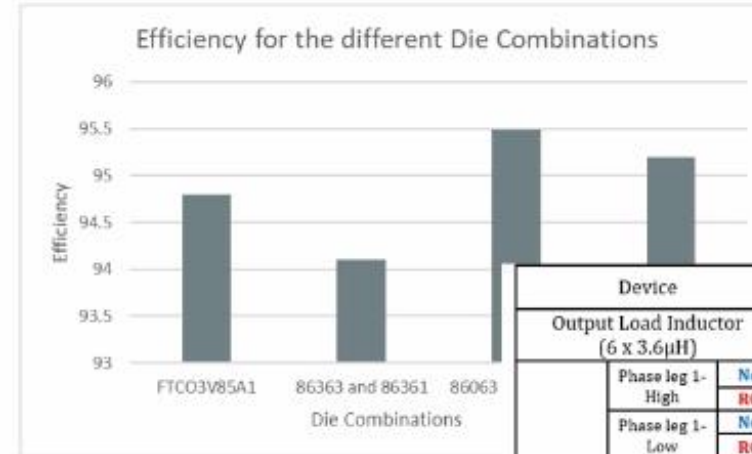
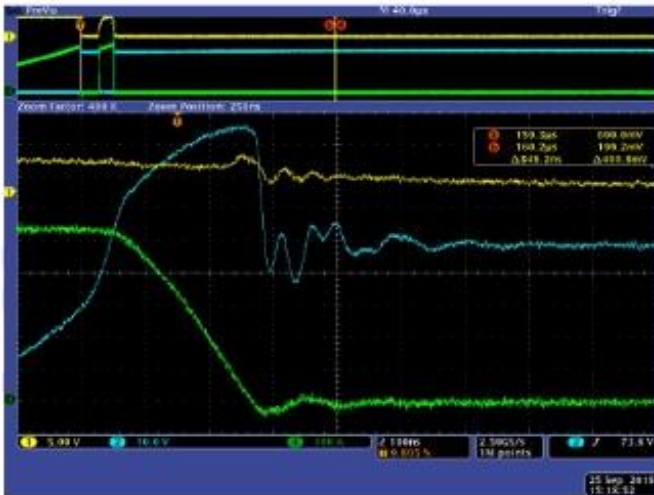
内置缓冲器，增强EMI性能

开发最适合客户要求的电气性能，配以定制的应用支援

无缓冲器



模块内置缓冲器



Device		Current (Arms/unit)	P <sub>sw</sub> (W/unit)	P <sub>con</sub> (W/unit)	P <sub>total</sub> /unit (W/unit)	P <sub>total</sub> (W)
Output Load Inductor (6 x 3.6µH)		36.5Arms	3W		18W	
MOSFET	Phase leg 1-High	No	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	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 <sub>on</sub> +1.3W <sub>off</sub> = 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, $E = \frac{2902W}{(2902W+136.6W)} \times 100\% \approx 95.5\%$			
		RC Snubber	Total Converter Power Dissipation = 151W and Converter Efficiency, $E = \frac{2960W}{(2960W+151W)} \times 100\% \approx 95.2\%$			



# onsemi汽车模块之AQG324认证

## + 客户的特定要求(针对定制)

### 采用符合AEC的器件

- Q101/Q100 – 分立器件 / IC
- Q200 – 无源 (供应商)

### 硅级可靠性:

- 阻断电压的能力
- 裸芯钝化层
- 裸芯边缘密封
- 门极氧化物

### 封装级可靠性:

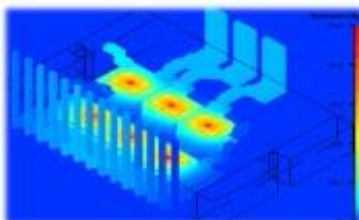
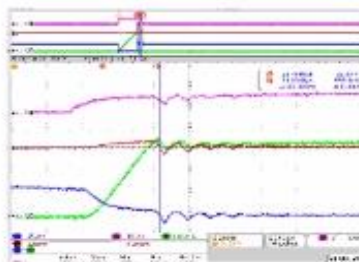
- 热堆完整性
- DCB和焊点
- 接口和接触电阻
- 模具化合物和外壳
- 邦定连接
- 信号引脚和电源片的鲁棒性

Standard	Industrial grade		Automotive grade	
	JEDEC	AEC-Q100/101	AQG324	
HTRB		$T_J=175^{\circ}\text{C}$ , max reverse of rated bias, 1000hrs/IDSS leakage drift <500%, non-leakage <20%	$T_J=175^{\circ}\text{C}$ , 80% reverse of rated bias, 1000 hrs / IDSS leakage drift < 500%	
HTGB +/-		$T_J=175^{\circ}\text{C}$ , max gate rated bias, 1000hrs/IGSS leakage drift <500%, non-leakage <20%	$T_J=175^{\circ}\text{C}$ with bias, positive/negative 100% gate rated bias, 1000 hrs / IGSS leakage drift < 500%	
H3TRB	$T_A=130^{\circ}\text{C}/85\%R$ H, 100V 96 hrs	$T_A=85^{\circ}\text{C}/85\%RH$ , 80% of reverse blocking voltage 1000 hrs / Leakage drift <1000%, non-leakage <20%	$T_A=85^{\circ}\text{C} / 85\%RH$ , 80% of rated V or max 1000 hrs / pre and post CSAM, IDSS leakage drift < 1000%	
Power Cycling Test	$\Delta T_J \geq 100^{\circ}\text{C}$ Load current: $\Delta T_J$ dependent	$\Delta T_J \geq 100^{\circ}\text{C}$ Load current: $\Delta T_J$ dependent	PC (sec) Load current > 0.85 Nominal current, On time < 5 sec MAX $\Delta T_J \geq 40\%$ than MIN $\Delta T_J$ PC (min) Load current > 0.85 Nominal current, On time > 15 sec MAX $\Delta T_J \geq 40\%$ than MIN $\Delta T_J$	
HTSL/LSTSL	N/A	N/A	$T_A \geq 150^{\circ}\text{C} / T_A < -40^{\circ}\text{C}$ , 1000 Hrs	
Parasitic stray inductance	N/A	N/A	- IEC60747-15:2012 chapter 5.3.2 (double pulse test)	
Insulation test (Insulation resistance measurement)	N/A	N/A	- Preconditioning: 8 h at $(5 \pm 2)^{\circ}\text{C}$ - Conditioning: 8h at $(23^{\circ}\text{C} \pm 5)$ , $(90 +10/-5)\%$ RH, 86-106 kPa	
Insulation test (Blocking capability test)	N/A	N/A	- After Insulation resistance measurement - Preconditioning: $(30 \pm 2)^{\circ}\text{C}$ up to complete warm-up - Conditioning: 48 h at $(23 \pm 2)^{\circ}\text{C}$ , $(93 \pm 5)\%$ RH, 86-106 kPa	
Thermal shock	N/A	N/A	$40^{\circ}\text{C} \sim 125^{\circ}\text{C}$ , < 30sec transition, Dwell time: >15 min 1000 cycles / SAT/ISO/Dynamic	
Vibration	N/A	N/A	Vibration profile A,B,D.. according to Installation location	
Mechanical shock	N/A	1500 g's for 0.5mS 5 blows, 3 orientations	Peak acceleration: $500 \text{ m/s}^2$ Shock duration: 6msec, half-wave x 10 times ( $\pm X, \pm Y, \pm Z$ )	

# onsemi汽车模块的优势



- ### 电气性能
- 大电流
  - 低电感 / 阻抗
  - 缓冲器电路改善EMI
  - 选择合适的Rg, 优化 di/dt
  - 内置高压隔离



- ### 紧凑, 热阻Rth低
- 结到散热器之间的热阻低
  - 更小占位
  - 优化电气性能, 降低损耗

### 经证实的可靠性



# 市场发展趋势和展望



# 市场发展趋势和展望

2023年8月，新能源汽车产销分别完成84.3万辆和84.6万辆，环比分别增长4.7%和8.5%同比分别增长22%和27%，市场占有率达到32.8%。

单位：万辆、%



动力类型	产量	同比	销量	同比
燃料电池	0.3	29.1	0.3	51.3

1-8月市场集中度	企业名称	8月销量(万辆)	环比(%)	同比(%)	1-8月销量(万辆)	同比增长(%)	市场份额(%)
前三家55.1%	比亚迪	27.4	4.7	57.1	179.1	83.2	33.3
	特斯拉	8.4	30.9	9.4	62.5	56.3	11.6
	上汽	9.1	2.1	-12.4	54.3	-9.5	10.1
前五家68.1%	吉利	6.3	10.9	42.5	36.4	67.6	6.8
	广汽	4.9	-3.1	60.3	33.8	97.4	6.3
前十家87% 同比53.8%	长安	4.1	2.3	120.8	25.8	92.9	4.8
	东风	4.1	4.2	-23.3	25.4	-9.3	4.7
	理想	3.5	2.3	663.8	20.8	176.1	3.9
	长城	2.6	-9.1	119.5	14.8	71.3	2.8
	一汽	2.2	48.2	6.1	14.6	47.5	2.7

注：数据来源中国汽车工业协会

# 市场发展趋势和展望

High Power  
Faster Switching

~ 1200V

Size, Weight

Cost Effective

Reliability  
Qualification

## Market



- 5kW ~ 10kW power
- 40KHz Switching

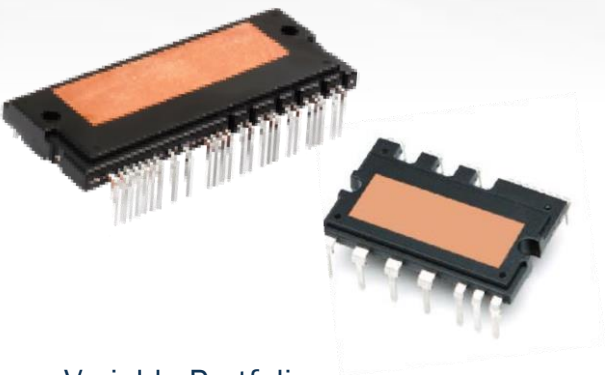
- 200V~800V BAT range
- Voltage up & Current down

- Weight & Size reduction for better efficiency

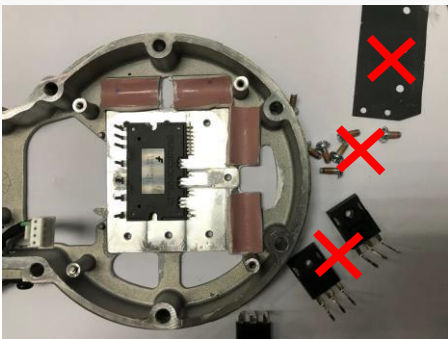
- Keep cost down request
- Discrete IGBT vs ASPM

- Simple assembly process
- Higher temp. guarantee
- Scrap cost minimization

## Strategy



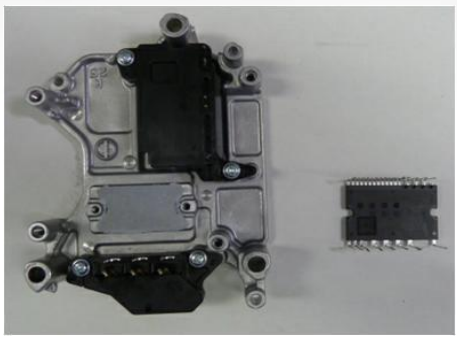
- Variable Portfolio
  - . 650V, 30A~60A (Slow & Fast ver.)
  - . 1200V, 25A~50A



- PKG size reduction plan
  - . SPM ONE (650V, 30A~50A)
  - . ASPM32 (1200V,25A~50A)



- Cost down activity
  - . EFK(12") transfer
- PKG cost down



- AEC-Q & AQG324 (w/175degC)
- Satisfy 4.3KV Iso. test
- Wafer level Tri-Temp. test
- Reinforced Assy. process flow



## Key Takeaway :

- 安森美提供ASPM模块（AQG324认证）和不同电压等级的分立器件适用于不同功率段的E-Compressor设计。
- 安森美第三代半导体器件包含MOSFET、Diode等产品，电压等级650V~1200V以及Discrete & Module包装供设计选用。
- 安森美第三代半导体器件从Substrates（晶圆）到System（系统）提供一条龙服务，产品设计、品质及产能均有自己掌握。

Thank you