FUTURE TECH DAY

JOURNEY INTO DYNAMIC POWER BY VISHAY

JUNE 5 2019

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OVERVIEW

- See how rewarding advanced technologies are
- Potential cost saving solutions
- View more than 30 thermally enhanced packages, some with industry smallest footprints
- See package advancements to improve Board Level Reliability
- Learn how we match and integrated features such as Schottky body diodes, high side/low side MOSFET's and etc. to increase efficiencies
- Examine the optimized combinations of MOSFETs for lowest On-Resistance
- Further MOSFETs integrations and variety of applications

TO-247	TO-220F	TO-220	D2PAK	DPAK	PowerPAK 8x8	PPAK SO-8L

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POWER CONVERSION BUILDING BLOCKS

WHERE THE VISHAY PRODUCT FAMILIES FIT

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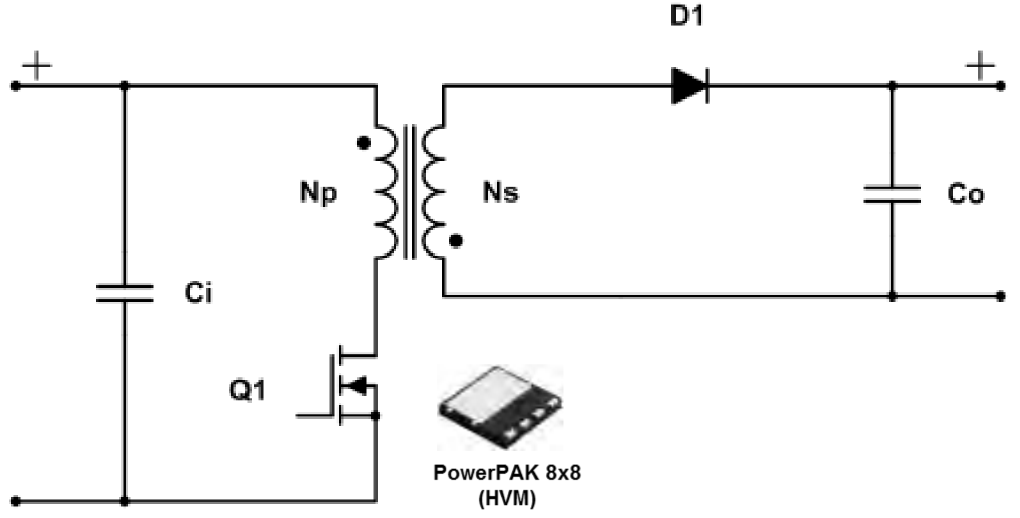
FLY BACK PRIMARY SIDE: ASYNCHRONOUS SECONDARY SIDE



- Low cost isolated AC/DC conversion
- E-Series MOSFET for primary switch
- FRED Pt for secondary side

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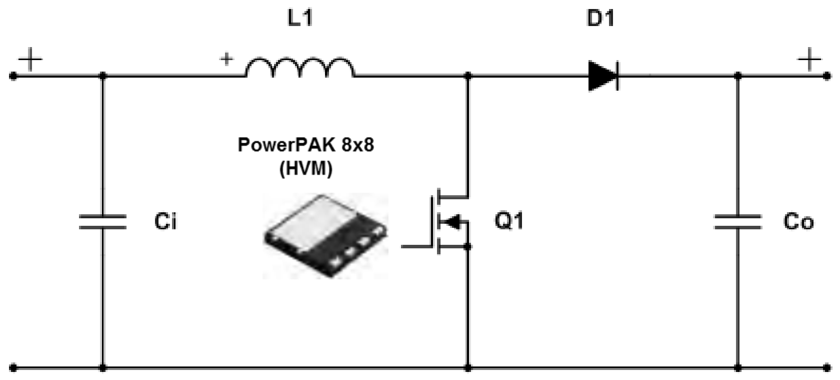
BOOST CONVERTER



- Low cost HV non-isolated AC/DC conversion
- Used for PFC
- E-Series MOSFET for primary switch
- FRED Pt for secondary side

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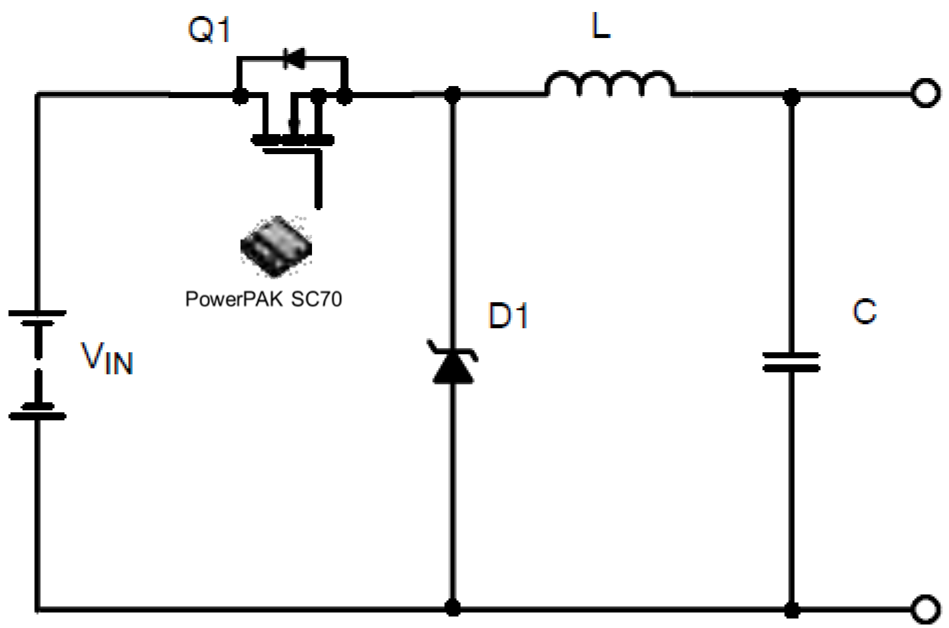
...UCTORS • MOSFETs • OPTOELECTRONICS • RESISTORS

ASYNCHRONOUS BUCK CONVERTER



- Low cost non-isolated DC/DC conversion
- MOSFET and Diode selection dependent on input voltage
- E-Series or TrenchFET for Q1
- FRED Pt or TMBS for D1

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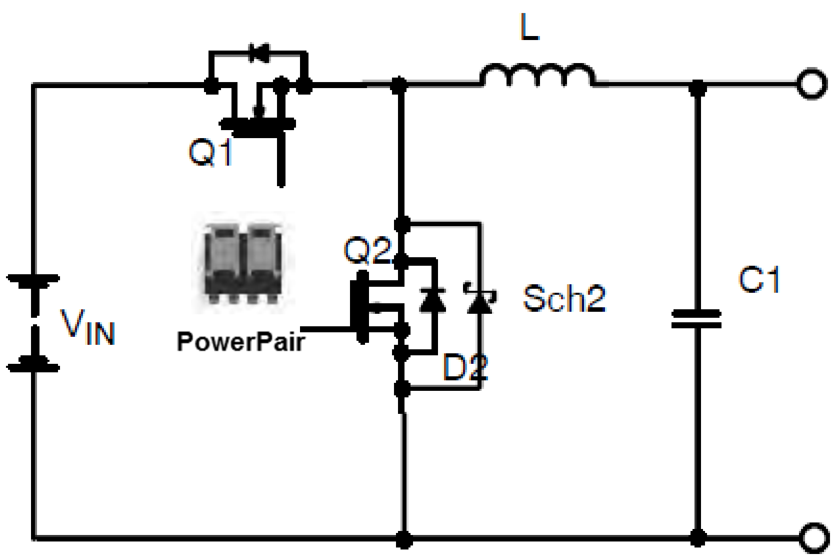
SYNCHRONOUS BUCK CONVERTER



- High Performance non-isolated DC/DC conversion
- MOSFET selection dependent on input voltage
- E-Series, TrenchFET , SKYFET, PowerPair
- MicroBuck
- MicroBrick

microBUCK®

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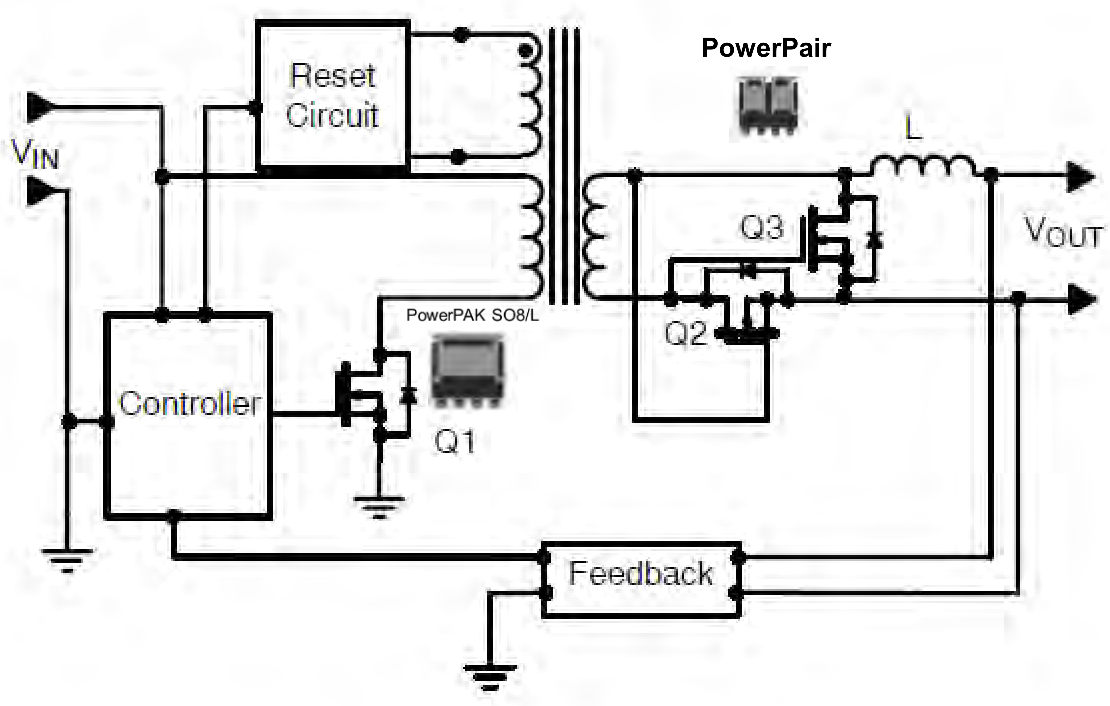
FORWARD CONVERTER



- High Performance isolated DC/DC conversion
- MOSFET selection dependent on voltage
- E-Series or TrenchFET

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48V ISOLATED BI-DIRECTIONAL DC/DC CONVERTER

TARGET APPLICATIONS:

- Bi Directional DC/DC Converter

KEY FEATURES:

- Lowest RDS(ON) in Dual 80V
- Used for Full Bridge
- Lowest Rdson in Single 80V
- Used for rectification
- Size reduction up to 50% vs. conventional D2PAk Solution

Full wave synchronous FET rectifier

Dual PPAK8x8L 80V/4mΩ
SQJQ178E

PPAK8x8L 80V/1.5mΩ
SQJQ184E

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MOSFET DIVISION
SILICONIX

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MOSFET DIVISION OPERATIONS

Front end Locations

Itzehoe Germany

Wafer Fab 2.300m² Class1
Production / R&D Power Mosfet
Fraunhofer Research Institute

Israel

Wafer foundry (ICs, LVM + HVM)

Taiwan

Wafer Foundry (IC, LVM)

San Jose California USA

Mosfet Division Headquarters
Management Team
Research and Development
Quality, Failure Analysis

New Building Opened 4/27
2585 Junction Avenue

Back end Locations

Shanghai China

Assembly & Test 26.800m²
LVM, Auto MOSFET & IC

Manila Philippines

ICs, Hi-Rel, and MOSFET
Test & Assembly

Xian China

High Voltage Test & Assembly
Auto TO Package center of excellence

Kaohsiung Taiwan

Package Development
LVM, Auto MOSFET & IC
Test and Assembly

Assembly SubCon
ASE, AMKOR & UNISEM
China & Malaysia

LVM, HVM & IC Assembly and Test

Division Head Count
2706 people

- 150 in USA
- 350 in Europe
- 2206 in Asia

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Products

PRODUCTS

SEMICONDUCTORS

Die and Wafer
- Die and Wafer

Diodes and Rectifiers
- Diodes and Rectifiers (1118)

Discrete Thyristors
- Phase Control Discrete (70)
- Fast Discrete (15)

IC's - Power and Linear
- Power ICs (70)
- Smart Load Switches (21)
- microBUCK® - Voltage Regulator (15)
- VRPower® (DrMOS) - Power Stage (25)
- Analog Switches and Multiplexers (79)

MOSFETs
- MOSFETs (1788)
- MOSFETs, Automotive (320)
- MOSFETs, Medical (2)

Optoelectronics
- Optoelectronics (664)
- Optocouplers / Isolators (120)
- IR Receivers for Remote Control (92)
- Optical Sensors (34)
- Infrared Emitters (134)
- Photo Detectors (104)
- LEDs (170)
- Solid-State Relays (31)
- IrDA® Transceivers (6)
- LCD/Plasma/Touch/LED Display (106)
- 7-Segment Displays (12)

Power Modules
- Bridge Modules (23)
- Diode Modules (116)
- IGBT Modules (86)
- MOSFET Modules (8)
- Thyristor Modules (26)

PASSIVE COMPONENTS

Capacitors
- Capacitors (449)
- Aluminum Electrolytic (100)
- Ceramic (149)
- Energy Storage (5)
- Film (64)
- Heavy Current Power (28)
- Polymer (6)
- Tantalum (99)
- Thin Film (5)
- Custom Capacitors (6)

Resistors
- Fixed (402)
- Networks and Arrays (114)
- Thermistors (53)
- Varistors (10)
- Trimmers (25)
- Rheostats (6)
- Potentiometers (19)
- Custom Resistors (11)

Magnetics
- Inductors (257)
- Custom Magnetics
- Transformers (9)
- Planar (5)
- Vishay-HIREL

Sensors
- Position: Angular and Linear (77)
- Position: Non-Contacting (18)
- Temperature (53)

Other Components
- Chip Antenna (6)
- Connectors (12)
- Crystals (7)
- Fuses (4)
- Hybrids and Substrates (4)
- Igniters (2)
- LCD/Plasma/Touch/LED Display (106)
- Oscillators (7)

CUSTOM PRODUCTS

Semiconductors
- Die and Wafer
- Modules

Passive Components
- Capacitors
- Inductors
- Resistors

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BROAD-LINE PORTFOLIO

MICRO FOOT®
Down to 0.8x0.8

0.8x0.6

SC75

SC70

Chip FET

SOT23

SOT-223

PowerPAK®
1212-8 SO8

SO8

DPAK

TO-220

TO-247

PowerPAK Options

1000V

400V

40V

0V

-200V

Computing / Consumer Applications

Telecom / DC-DC Applications

Solar, Power Supply & Industrial

Mobile / Portable Applications

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NEW TECHNOLOGIES AND TARGET APPLICATIONS

Common Power Conversion Building Blocks

E-Series®

Improves Efficiency

High single pulse avalanche energy capability

Small package with low $R_{DS(ON)}$ for designs with heat sinking

TrenchFET® IV Medium Voltage & ThunderFET®

Class-leading Efficiency

Enables higher power density

Capable of operating with 5V gate drive

TrenchFET® IV 30V, 40V & 60V

Improves Efficiency, especially at higher switching frequency

1mΩ max SIRA00DP in 6x5 mm²

Improves immunity to gate coupling with excellent Q_{GD} / Q_{GS} ratio

TrenchFET® IV & PowerPAIR®

PPAK family and up to 30A in a single 6x5 mm² Package

Increase power density with integration

Low package parasitic inductance optimized for high frequency switching

P-Channel TrenchFET® Gen III

Very low R_{DS}-A (mΩ-mm2)

Enable more efficient of battery usage

Application specific solutions for battery operated devices

Vishay Provides Complete Portfolio for Power Conversion Designs

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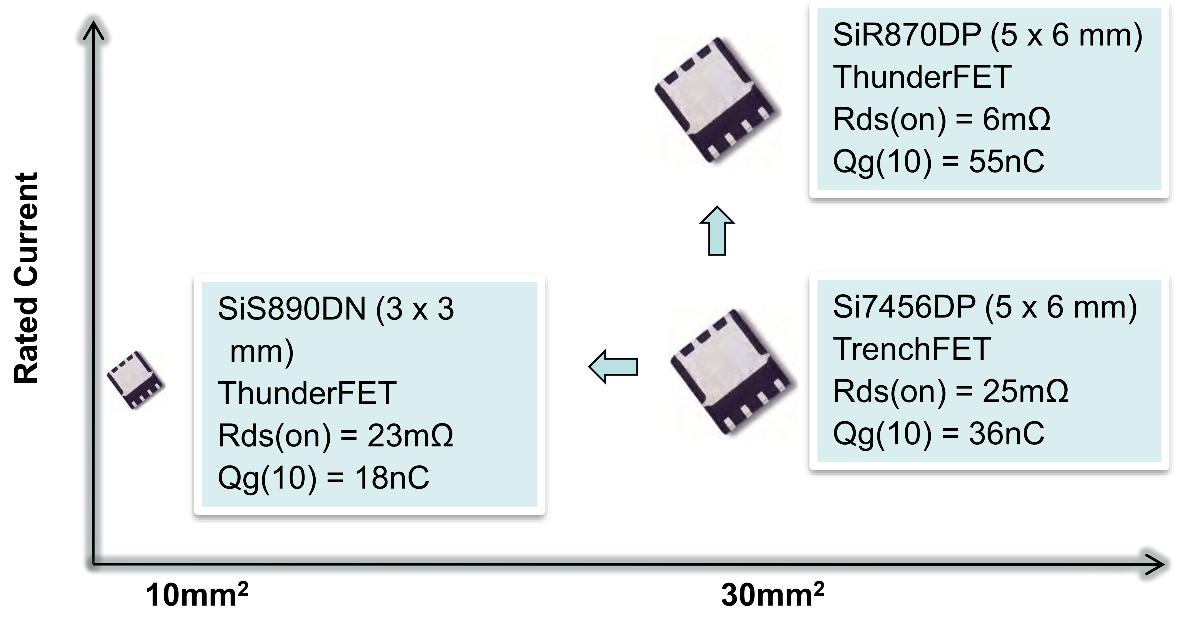
MOSFET Technology Innovation

- Provide lower Rds(on) than currently available
  - Allows higher RMS current and power density in switch mode power supplies
- Provide improved performance in smaller packages than previously available
  - Similar Rds(on) with lower gate charge
  - Allows PCB minimization and increased power density



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MOSFET COMPONENTS OF RESISTANCE

BVdss	30V	100V	600V
Rch:	35%	8%	3%
Repi:	35%	88%	96%
Rsub:	30%	4%	1%
Total Si	1.2mΩ	15mΩ	1.5Ω

New technologies from Vishay : Total Si 0.5mΩ 3mΩ 300mΩ

25 – 30V Gen IV	40 – 150V ThunderFET Gen IV	600 - 650V E Series

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MOSFET PACKAGE TRENDS

Current package		Trend package
SOT23 SSOT23	→	PowerPAK SC70
SO-8	→	PowerPAK 1212W
DPAK	→	PowerPAK SO8/L
D2PAK	→	PowerPAK 8x8/L
D2PAK 7ld	→	PowerPAK 8x8/L BWL PowerPAK 10x12?

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INNOVATION TO REDUCE PACKAGE RESISTANCE

Silicon vs. Package Contrbution to $R_{DS(ON)}$

100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%

PowerPAK SO8 | PowerPAK 8x8L | D2PAK-7Ld | D2PAK | PowerPAK SO8 | PowerPAK 8x8L | D2PAK-7Ld | D2PAK

40V | 60V

■ Silicon Contribution ■ Package Contribution

PowerPAK® 8x8L

D2PAK

D2PAK Height 4.5 mm

PPAK 8x8L Height 1.2 mm

PPAK 8x8L 200 A 64 mm²

D2PAK 120 A 155 mm²

- The resistance from package has far exceeded the resistance of silicon for 40V and 60V devices in transistor-outline packages
  - Over 50% of total resistance comes from the package resistance for D2PAK and TO220
- PowerPAK® SO8 and PowerPAK® 8x8L packages achieve the best R_{DS}, Q_g and Q_{OSS} by minimizing the package resistance and parasitic inductance
  - The die-to-package ratio is increased by 115% from D2PAK to PowerPAK 8x8L
  - The package resistance is reduced by half

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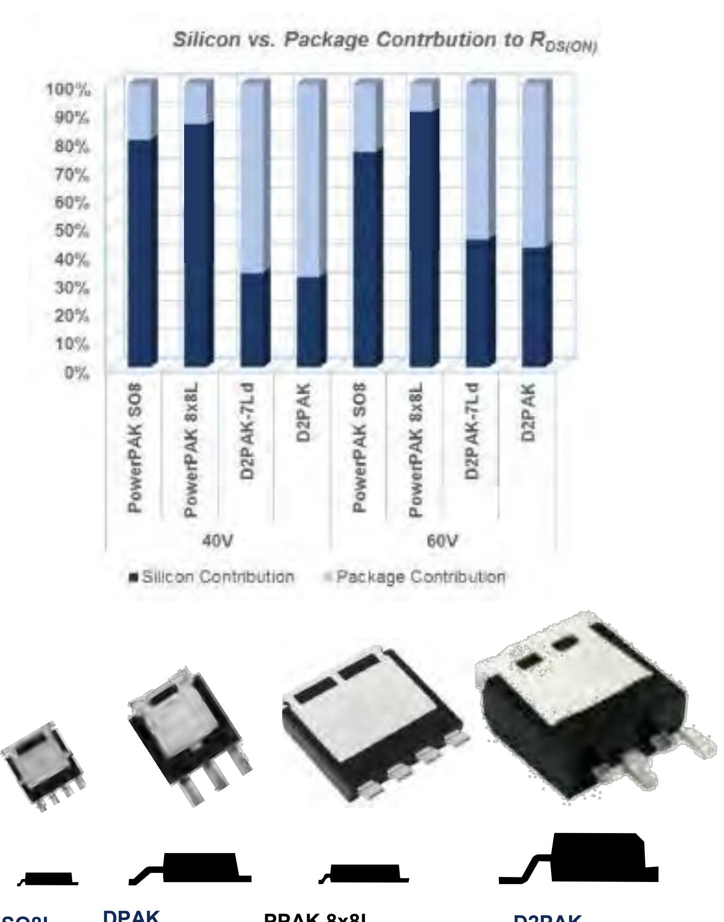
PACKAGING – OPTIMUM SIZE AND FUNCTIONALITY THE STORY BEHIND THE POWERPAK 8X8L

- The latest evolution of the PPAK 8x8L package includes
  - Bond wireless interconnects
  - 15% larger die size
  - Low thermal resistance die and clip attach material
  - Further improved gull wing lead design
  - Optimized mold compound
  - Product plan from 30V to 200V
  - Rds(on) <= 0.6mΩ @ 40V



PPAK SO8L Height 1.1 mm

DPAK Height 2.3 mm

PPAK 8x8L Height 1.7 mm

D2PAK Height 4.5 mm

PPAK8x8L Magnified Side View

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BOARD LEVEL RELIABILITY (BLR) CONSIDERATIONS FOR NEW MOSFET PACKAGES

- Increasing demands for systems with higher power density creates additional challenges for “board level reliability”
  - Temperature cycling
  - Board flexing
  - Vibration
  - Drop incidents
- Smaller die and packages sizes likely to experience greater temperature extremes and faster excursions under extended operating conditions.
- CTE mismatches between materials can result in package deformation and solder joint stress and ultimately failure
- Package designs need to be designed to withstand these stresses

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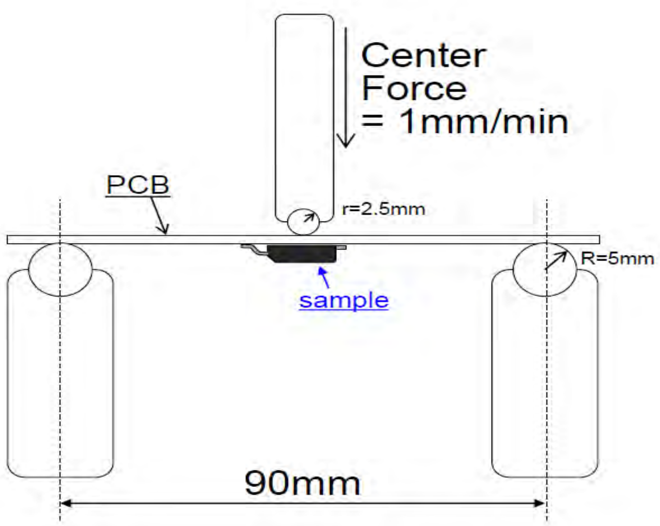
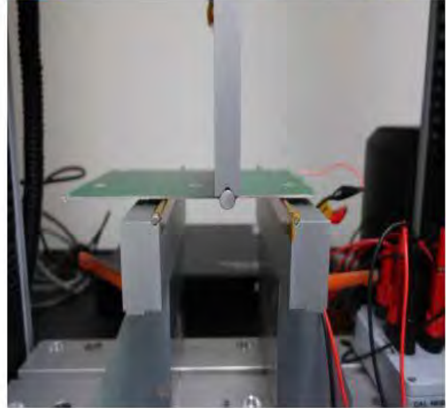
BLR TESTING –PCB FLEXING

Two test conditions

- Single 20 second duration 1mm deflection.
- Incremental 20 second 1mm deflections until failure.



Bending machine:
Instron 5565



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POWERPAK SO8L AND 8X8L
DESIGN FOR BOARD LEVEL RELIABILITY

- Precise Gull Wing lead shape simulated and developed to reduce solder joint stress and improve system reliability during temperature cycling, board flexing, vibration and drop events

180mm

180mm

quarter model

90mm

90mm

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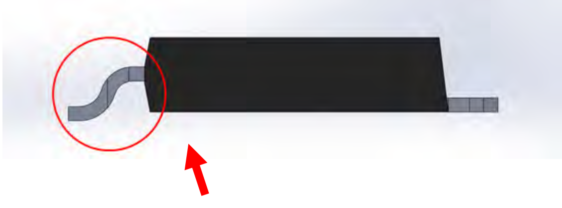
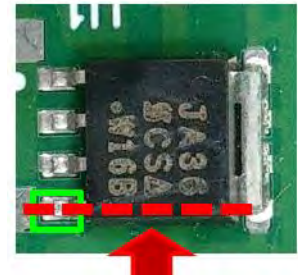
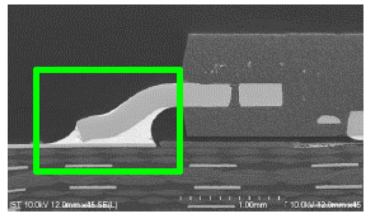
POWERPAK SO8L BLR TESTING – POWER CYCLING







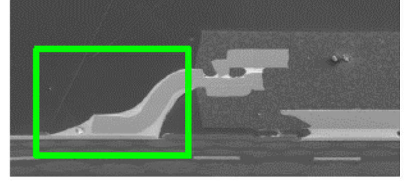
Internal BLR specification

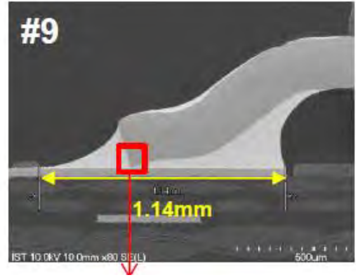
Bending test completed – all passed

Rapid Thermal Cycle test completed – all passed up to 2000 cys

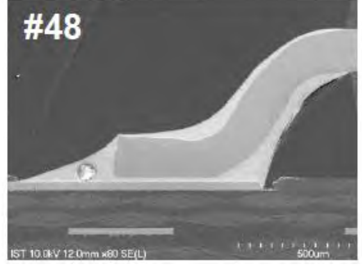
Vibration test completed – all passed

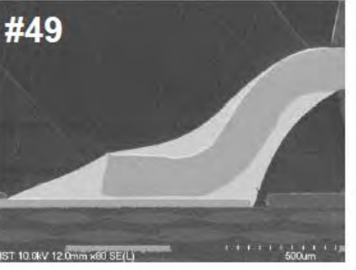
Powered Temperature Cycle test: 2000/ 2600 cys completed





Area to carefully investigate due to burr after singulation





Dual clip design optimized through finite element analysis simulations to reduce stress on die and leads.

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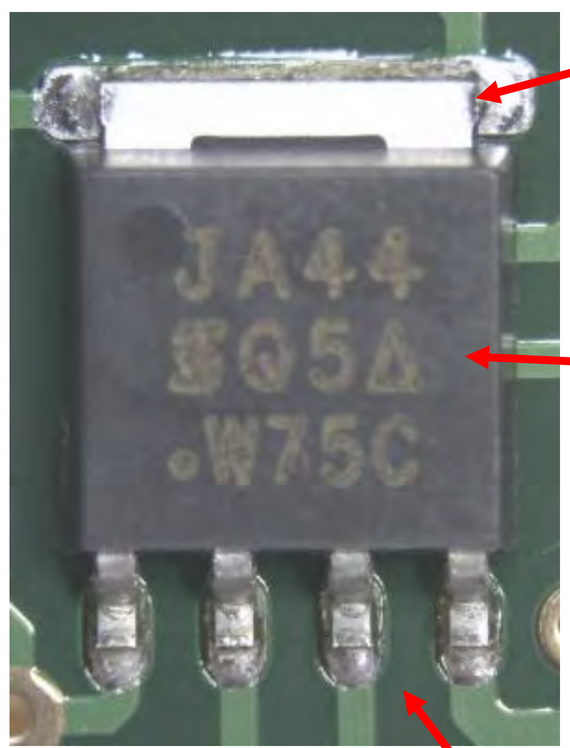
POWERPAK SO8L AND BOARD LEVEL RELIABILITY

PPAKSO-8L
Production Aluminum wire

PPAKSO-8L BWL
New Low Resistance Package



Narrow drain tab for compatibility with other 5x6 package solutions

New advanced material set for extended reliability under temp cycling / power cycling

Re-designed lead shape and thickness for improved board level reliability

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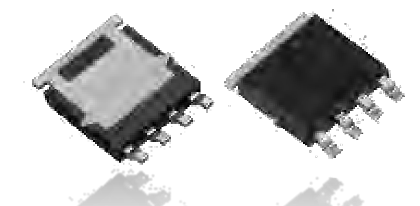
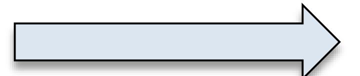
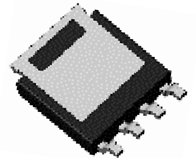
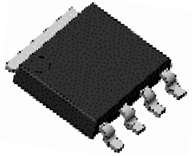
POWERPAK SO8L EVOLUTION









V_{DS} (V)	Part Number	$R_{DS(ON)}$ Max (mΩ)		Q_g (nC) Typ.		Part Number (Next Gen)	$R_{DS(ON)}$ Max (mΩ)		Q_g (nC) Typ.	
		10V	4.5V	$10V_{GS}$	$4.5V_{GS}$		10V	4.5V	$10V_{GS}$	$4.5V_{GS}$
-200	SQJ431AEP	305		55		SQJ191EP	210			
-80	**SQJA81EP**	**15**	**28**			**SQJ181EP**	**13**	**24**		
-60	SQJ459EP	18	24	73	38					
-40	SQJ409EP	7	10	170	90	SQJ141ELP	4.8	6.9		
-30	SQJ407EP	4.4	7.1	169	90	SQJ131ELP	2.8	5.1		
30	SQJ410EP	3.9	4.2	73	33	**SQJA26EP**	**0.7**	**1.15**	125	56
40	SQJ444EP	3.2	4.3	51	27	**SQJ136ELP**	**1.25**	**1.6**	102	40
40	**SQJA76EP**	**2.4**	**-**	**66**	**-**	**SQJA36EP**	**1.3**	**-**	**86**	**-**
60	SQJA62EP	4.5	6.2	55		**SQJA16EP**	**2.7**	**4.3**	65	30
80	**SQJA78EP**	**5.3**	**-**	**62**	**-**	**SQJ180EP**	**3.8**	**-**	**60**	**-**
100	SQJA12EP	8.5	-	49	-	**SQJ110EP**	**5.2**	**-**	60	-
200	SQJA20EP	50	-	17.6	-					

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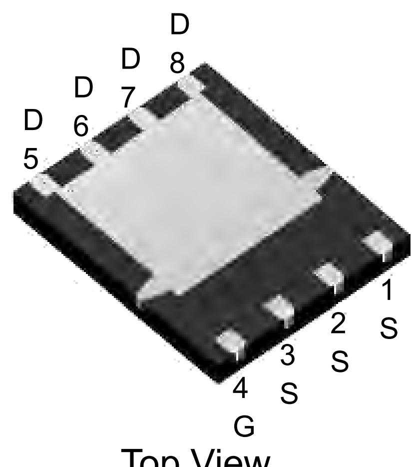
POWERPAK® SO-8 DOUBLE COOLING PACKAGE

Drop-in Upgrade for Conventional PowerPAK® SO-8

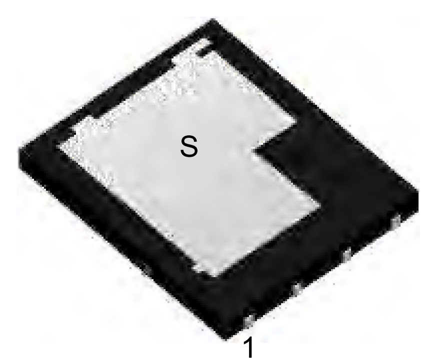
- ✓ The package footprint is compatible to standard PowerPAK® SO-8
- ✓ Internal construction has low resistance with minimized parasitic inductance
- ✓ 25V to 200V devices in product plan

Two Venues for Thermal Transfer

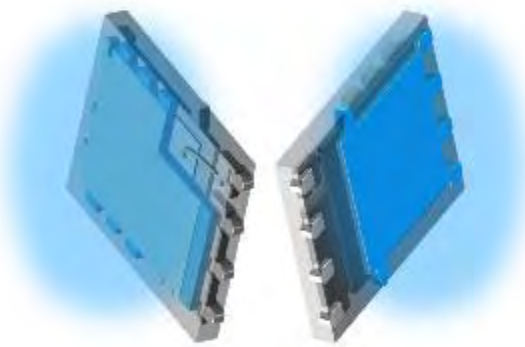
- ✓ Exposed top provides additional avenue for thermal transfer
- ✓ Optimized for mounting heat sinking and implementation of sophisticated thermal management design
- ✓ Increase power density



Top View



Bottom View



Benefits to design:

- Highly efficient electrically and thermally
- Very low R_{DS}-Q_g FOM reduces power loss from conduction and switching
- Multiple paths for thermal transfer
- Increase power density

Target applications:

- Synchronous rectification
- Primary side switching
- OR-ing
- Synchronous buck & POL
- Power supplies
- Motor drive control

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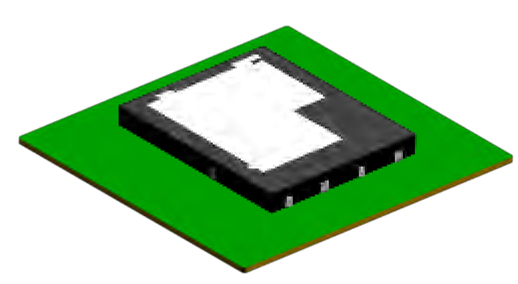
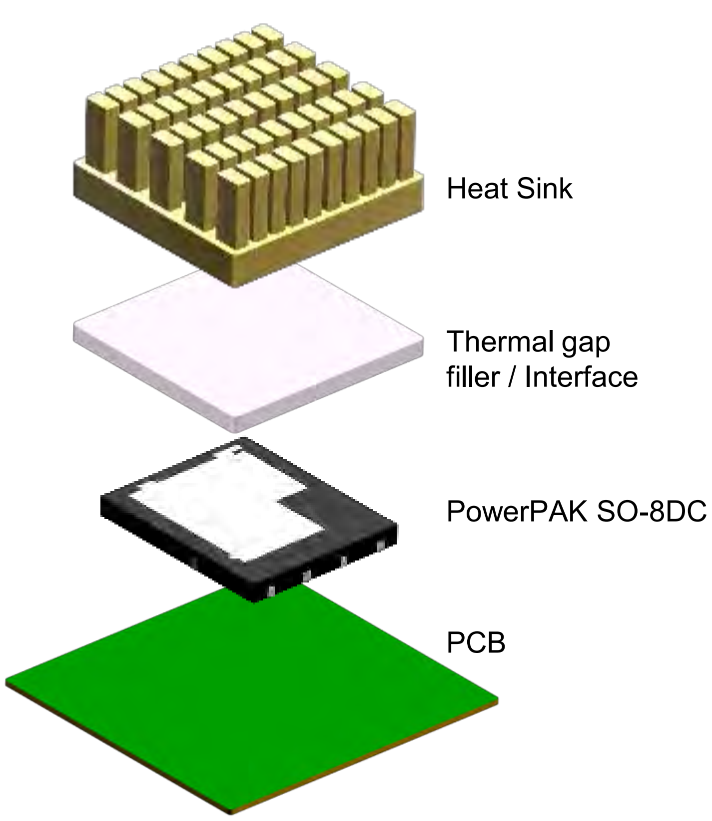
POWERPAK® SO-8 DOUBLE COOLING PACKAGE

Natural Convection



Heat Sink Mounting



- Low R_{DS}-Q_g FOM elevates efficiency and reduces power loss across several elements.

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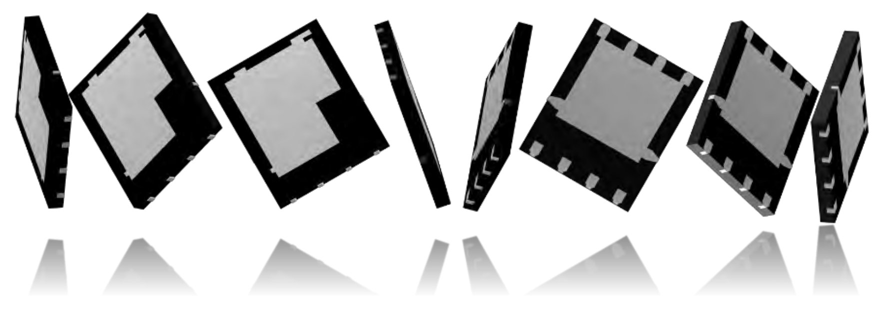
PART LIST FOR POWERPAK® SO-8DC



- 25V to 200V devices with low On-resistance
- Excellent R_{DS}-Q_g and R_{DS}-Q_{oss} for switch-mode power supply designs
- High-performance products that improve efficiency of power conversion and increase power density

Part Number	V_{DS} (V)	V_{GS} (V)	$R_{DS(ON)}$ (mΩ) 10V		$R_{DS(ON)}$ (mΩ) 4.5V		Q_g (nC)		Q_{gs} (nC)	Q_{gd} (nC)	C_{oss} (pF)	Sample
			Typ.	Max.	Typ.	Max.	10V	4.5V				
SiDR220DP	25	16, -12	0.48	0.58	0.65	0.82	134	60.5	24.5	9.1	3356	Now
SiDR140DP	25	20, -16	0.54	0.67	0.75	0.9	113	52.8	17.6	10.7	4310	Now
SiDR392DP	30	20, -16	0.47	0.62	0.71	0.93	125	59.7	25.2	12.3	4280	Now
SiDR390DP	30	20, -16	0.65	0.80	0.9	1.15	102	48	22	4.7	3290	Now
SiDR638DP	40	20, -16	0.73	0.88	0.96	1.16	136	63	30.5	10.6	1530	Now
SiDR402DP	40	20, -16	0.73	0.88	0.96	1.16	110	53	22.5	9.5	1650	Now
SiDR608DP	40	20, -16	1	1.2	1.36	1.8	111	50.5	26	7.8	1244	Q3 2019
SiDR626DP	60	±20	1.4	1.7	-	-	68	-	21	8	992	Now
SiDR680DP	80	±20	2.4	2.9	-	-	69.5	-	19.6	9.1	440	Now
SiDR668DP	100	±20	4	4.8	-	-	72	-	21.6	12	280	Now
SiDR870ADP	100	±20	5.5	6.6	7.5	10.5	53.5	25.2	10	10.6	719	Now
SiDR622DP	150	±20	14.7	17.7	-	-	27	-	9.2	8.2	236	Now
SiDR610DP	200	±20	23.9	31.9	-	-	25	-	6.5	6.8	142	Now

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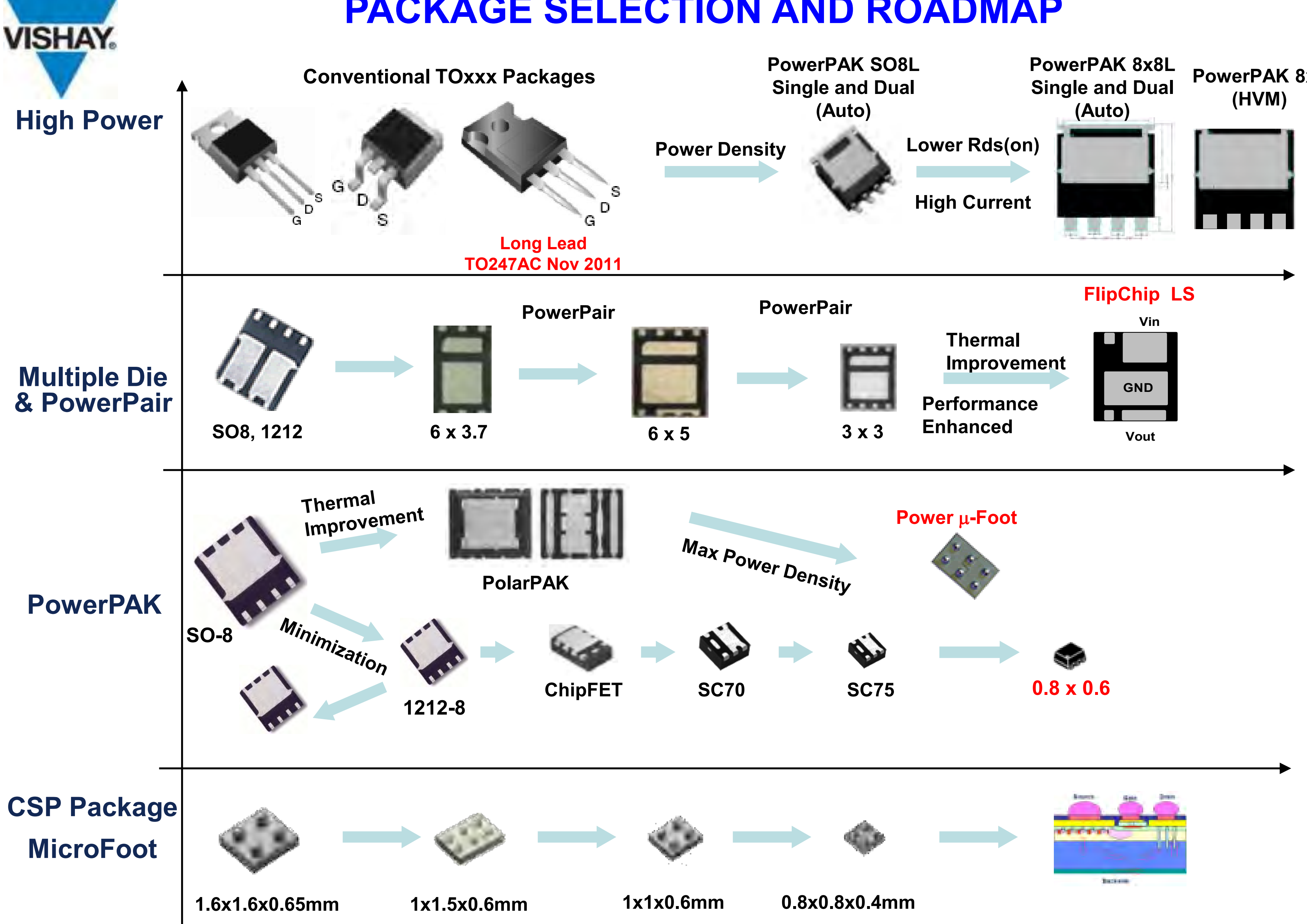
PACKAGE SELECTION AND ROADMAP



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KEY AUTO MOSFET PACKAGING TECHNOLOGIES

2019 | **>=2020**

High Power Packages >30mm2

TO-Packages
D2PAK / 7Ld
TO-247
PowerPAK® 10x12
JEDEC TO-LL

Customer Co devel

Specific Customization
Reverse-DPAK
Non-plated Tab
PowerPAK® 5x9
Application Specific
PowerPAK® 8x8L Reverse
Top side only cooling
PowerPAK® Double Cooled Solutions

Medium Power Packages 4 – 30mm2

PowerPAK® 8x8L single and dual
Up to 200A, Lower $R_{DS(ON)}$
PowerPAK® 8x8L Bond Wireless
Up to 400A, Lower $R_{DS(ON)}$
SQJQ144AE
June 2019
PowerPAIR® 5x6, 3x3
PowerPAK® SO-8L
PowerPAK® SO-8L BWL
Larger die, Lower $R_{DS(ON)}$
Highest Board level reliability
SQJA36EP – July 2019
Integration
Dual Die High Performance DC-DC
PowerPAIR® 3x3 Flipchip
Further optimization
Flip chip symmetric die
High performance motor drive
PowerPAK® 1212-8
Wet-able flanks
PowerPAK® 1212-8S
Large Die BWL, <1.5mΩ
PPAK SC75
PPAK SC70 Bond Wireless
PowerPAK® SC70
Wet-able flanks
Minimization
PPAK 0806

Bare Die KGD 1- 96mm2

Known Good Die
Die size range: 1mm x 1mm to 8mm x 12mm
25 active part types: 80V Pch to 100V Nch

Continue to offer the latest technologies
Capacity Expansion

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HIGH VOLTAGE MOSFETS

Industrial Power Supply

- E-Series
- TrenchFET 40V to 250V

Enterprise / Telecom Infrastructure

- 25V to 250V
- 12V to 30V load switches and OR-ing

Computing Consumer 12V Systems

- PowerPAIR
- TrenchFET Gen IV

Automotive

- TrenchFET Gen IV
- PowerPAK

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SUPERJUNCTION EVOLUTION

E Series

- Hard switching
- Soft switching

SJ2

- Low Qg and Eoss
- Fit to hard Switching

SJ3

- Low Qg and Eoss
- Optimized output capacitance
- Low Trr/Qrr
- Balance on hard and soft switching topologies

SJ4

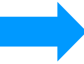
- Lowest Qg and Eoss
- Optimized output capacitance
- Lower Trr/Qrr
- Highest system efficiency
- Fit to hard and soft switching topologies

EF Series

- Soft switching

SJ2

- Fast body diode
- Lower Trr/Qrr
- Low Qg and Eoss
- Dedicated to soft switching topologies



SJ3

- Fast body diode
- Lowest Qrr/Trr
- Low Qg and Eoss
- Optimized output capacitance
- Dedicated to soft switching topologies

SJ4

- Lowest Qg and Eoss
- Optimized output capacitance
- Lowest Trr/Qrr
- Highest system efficiency
- Dedicated soft switching topologies

Automotive E/EF Series

- Hard switching
- Soft switching

SJ2

- Low Qg and Eoss
- Fit to hard and soft Switching

In development

Preferred and active

Not for new design

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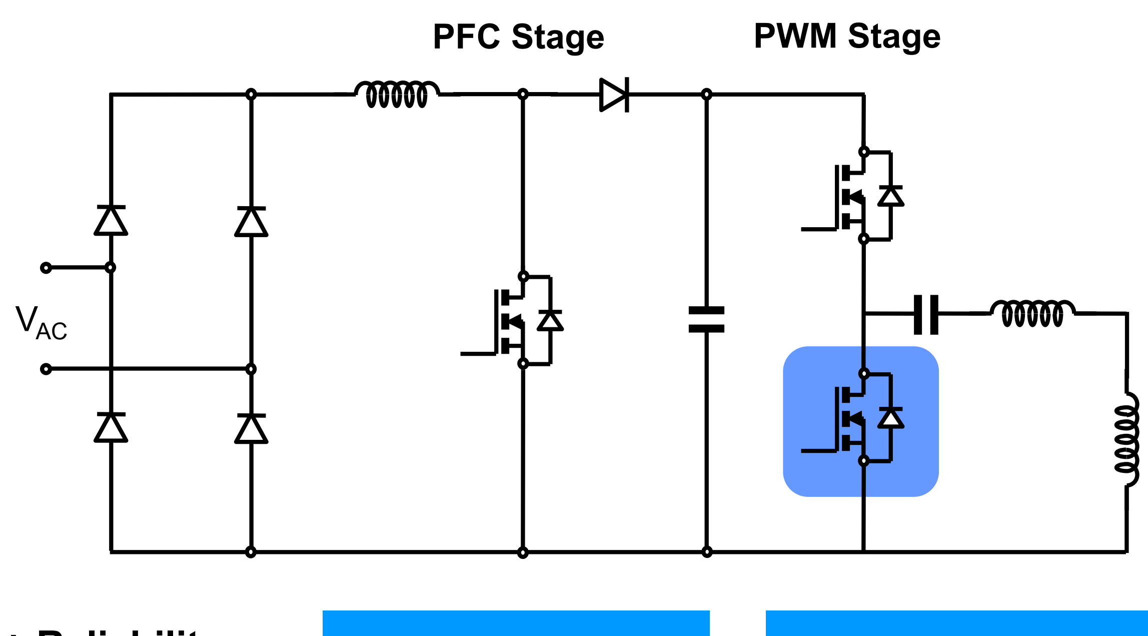
POWER SUPPLIES SOLUTION WITH 600V



Performance + Reliability

- Highest performance

E Series (SJ4) + EF series (SJ3)

Cost benefit + Reliability

- High performance and reasonable price

AEL series (SJ2.5) + EF series (SJ3)

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E SERIES 4th GEN EFFICIENCY BENCHMARK

- SiHP065N60E sets new standard above closest C7 devices
  - Comparable switching times, but lower switching energy loss
- SiHP065N60E TO220 also outperforms original SiHG47N60E TO247 with higher efficiency across total load range.
  - 0.5% efficiency improvement at full load
  - T_j is lower by 5 ~ 6 ^{o}C, even though in a smaller TO-220 package
  - Total gate charge and discharge times are also shorter for SJ4.

Efficiency and Loss vs Output Power for 800W Boost Converter

Total Efficiency | Power Loss | Pout

SiHP065N60E
IPP65R065C7
SiHG47N60E
SiHP065N60E Loss
IPP65R065C7 Loss
SiHG47N60E Loss

Power Loss Difference for SJ4 wrt SJ2

Power Loss Diff (W) | Pout (W)

IPP65R065C7
SiHG47N60E
SiHP065N60E

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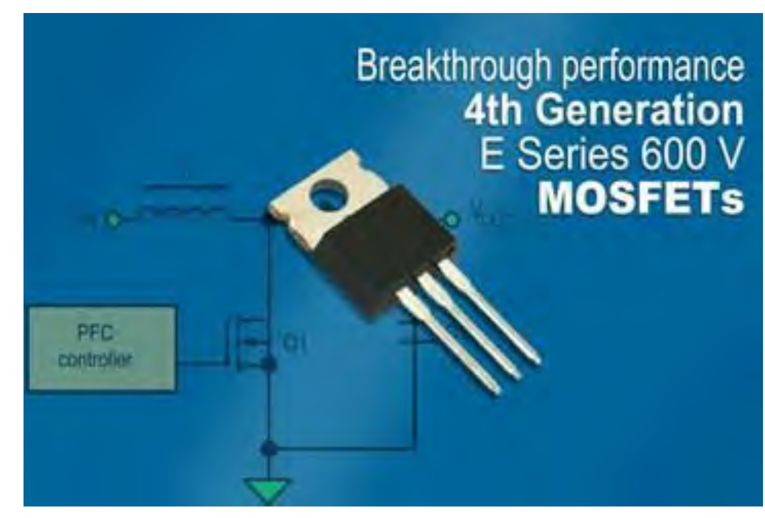
SIHP065N60E – 4TH GENERATION E SERIES

Introducing the SiHP065N60E - 4th Generation 600V E Series Superjunction technology

- Optimized planar MOSFET built on low resistance multi-EPI platform
- Cell density and charge balance recipe tuned to reduce RdsA below 11mΩcm^2
- MOSFET structure designed for reduced gate charge and gate drive related switching losses
- Industry low Rds(on) * Qg figure of merit of 2.8ΩnC



Part Numbers	Gen	V_{DS}	R_{ds} (mΩ)	Q_g	Q_{gs}	Q_{gd}	$C_{o(er)}$	$C_{o(tr)}$	$R_{ds} * Q_g$ FOM	$R_{ds} * C_{o(er)}$ FOM
SiHP065N60E	4th	600	57	49	19	15	93	593	2.8	33.8
SiHG47N60E	2nd	600	53	148	36	57	170	604	7.8	
Competitor I	C7	600	52	68	14	23	101	1050	3.5	54.6

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E SERIES STANDARD MOSFET PORTFOLIO

500 V								
Ron (mΩ) (max)	DPAK	IPAK	D^2PAK	TO-220	TLTO-220F	TO-247AC	PowerPAK® 8x8	PowerPAK® 5x6
380	SiHD12N50E		SiHB12N50E	SiHP12N50E	SiHA12N50E			
280			SiHB15N50E	SiHP15N50E	SiHA15N50E			
184			SiHB20N50E	SiHP20N50E	SiHA20N50E	SiHG20N50E	SiHH20N50E	
145			SiHB25N50E	SiHP25N50E	SiHA25N50E	SiHG25N50E		

600 V								
Ron (mΩ) (max)	DPAK	IPAK	D^2PAK	TO-220	TLTO-220F	TO-247AC	PowerPAK® 8x8	PowerPAK® 5x6
600	SiHD7N60E	SiHU7N60E		SiHP7N60E	SiHF7N60E			
520								SiHJ8N60E
332 (Aug)								SiHJ10N60E
278 (Sep)	SiHD10N60E	SiHU10N60E						
380			SiHB12N60E	SiHP12N60E	SiHA12N60E			
339							SiHH11N60E	
309	SiHD14N60E			SiHP14N60E	SiHA14N60E			
280			SiHB15N60E	SiHP15N60E	SiHA15N60E			
255							SiHH14N60E	
202			SiHB18N60E	SiHP18N60E	SiHA18N60E			
180 (Now)			SiHB22N60AE	SiHP22N60AE	SiHA22N60AE	SiHG22N60AE		
180			SiHB22N60E	SiHP22N60E	SiHA22N60E	SiHG22N60E		
197			SiHB22N60EL	SiHP22N60EL	SiHA22N60EL	SiHG22N60EL		
176							SiHH21N60E	
158			SiHB23N60E	SiHP23N60E	SiHF23N60E	SiHG23N60E		
135							SiHH26N60E	
125			SiHB30N60E	SiHP30N60E	SiHF30N60E	SiHG30N60E		
99			SiHB33N60E	SiHP33N60E		SiHG33N60E		
94 (Now)			SiHB35N60E	SiHP35N60E	SiHA35N60E	SiHG35N60E		
91 (Aug)							SiHH28N60E	
75						SiHG40N60E		
65 (Now)				SiHP38N60E		SiHG47N60AE		
64						SiHG47N60E		
39						SiHG73N60E		
30 (Now)						SiHG80N60E		

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CAPACITORS • DIODES • INDUCTORS • MOSFETs • OPTOELECTRONICS • RESISTORS

E SERIES STANDARD MOSFET PORTFOLIO

650 V								
Ron (mΩ) (max)	DPAK	IPAK	D²PAK	TO-220	TLTO-220F	TO-247AC	PowerPAK® 8x8	PowerPAK® 5x6
868								SiHJ6N65E
600	SiHD6N65E	SiHU6N65E	SiHB6N65E	SiHP6N65E	SiHF6N65E			
598								SiHJ7N65E
380			SiHB12N65E	SiHP12N65E	SiHF12N65E			
363							SiHH11N65E	
280			SiHB15N65E	SiHP15N65E	SiHF15N65E			
260							SiHH14N65E	
180			SiHB22N65E	SiHP22N65E	SiHF22N65E	SiHG22N65E		
170							SiHH21N65E	
150							SiHH24N65E	
145			SiHB24N65E	SiHP24N65E		SiHG24N65E		
122			SiHB28N65E	SiHP28N65E		SiHG28N65E		
105						SiHG33N65E		
72						SiHG47N65E		
47						SiHG64N65E		
29						SiHS90N65E		
800 V								
Ron (mΩ) (max)	DPAK	IPAK	D²PAK	TO-220	TLTO-220F	TO-247AC	PowerPAK® 8x8	PowerPAK® 5x6
2800	SiHD2N80E	SiHU2N80E						
1300	SiHD4N80E	SiHU4N80E		SiHP4N80E	SiHA4N80E			
950	SiHD6N80E	SiHU6N80E		SiHP6N80E	SiHA6N80E			
450				SiHP11N80E	SiHA11N80E	SiHG11N80E		
290				SiHP17N80E	SiHA17N80E	SiHG17N80E		

In development Samples Q4/2016

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LOW VOLTAGE MOSFETS

Industrial Power Supply
- E-Series
- TrenchFET 40V to 250V

Enterprise /Telecom Infrastructure
- 25V to 250V
- 12V to 30V load switches and OR-ing

Computing Consumer 12V Systems
- PowerPAIR
- TrenchFET Gen IV

Automotive
- TrenchFET Gen IV
- PowerPAK

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BENCHMARKING THE LATEST 25V TO 250V

PPAK SO8 Maximum $R_{DS(ON)}$ (mΩ) Benchmarking
New Generation vs. Old vs. Competitor

R_{DS}-C_{oss} (mΩ-pF) FOM Benchmarking
New Generation vs. Old vs. Competitor

Leadership $R_{DS(ON)}$-C_{oss} FOM from 40V to 250V elevates performance of synchronous rectification.

- Reduced $R_{DS(ON)}$ minimizes conduction related power loss. Unlocks performance of compact packages and increases power density
- Low C_{oss} to decrease key switching loss contributor. Further reduces power loss per device.
- These design philosophies greatly impact the efficiency in switch-mode power supplies, motor drives and load switching.

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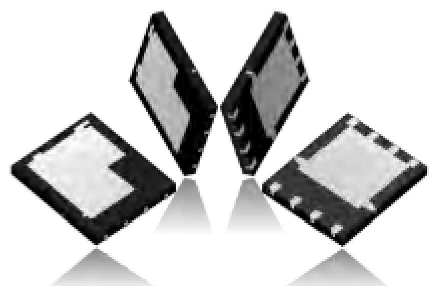
1 mΩ, 30V TRENCHFET® IV IN AN ARRAY OF PACKAGES

COMPACT AND THERMALLY ENHANCED PACKAGES

Most Compact	Broadest Selection	Thermally Advanced
		
PowerPAK® 1212-8S & 1212-8	**PowerPAK® SO-8**	**PowerPAK® SO-8DC**
3.3 x 3.3 mm²	**6 x 5 mm²**	**6 x 5 mm²**
1 mΩ (SiSS04DN)	**0.47 mΩ (SiRA80DP)**	**0.47 mΩ (SiDR392DP)**

Target Applications (PowerPAK® 1212-8S & 1212-8)

- OR-ing
- Synchronous buck
- Synchronous rectification
- DC/DC
- Battery management
- 12V or 5V systems

Target Applications (PowerPAK® SO-8)

- OR-ing
- Synchronous buck
- Synchronous rectification
- DC/DC
- Motor drive control
- Battery management
- 12V systems

Target Applications (PowerPAK® SO-8DC)

- OR-ing
- Synchronous buck
- Synchronous rectification
- DC/DC
- Motor drive control
- Battery management
- 12V systems

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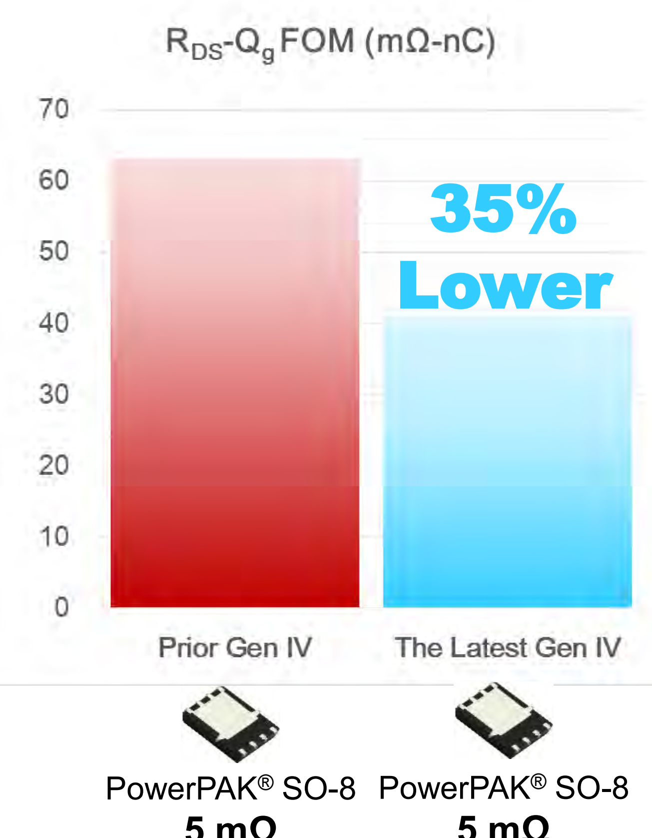
EVOLUTION OF 30V TRENCHFET® IV

CONTINUOUS IMPROVEMENT FOR PERFORMANCE PUSH

R_{DS}-Q_g FOM Evolution Pushes for Higher Efficiency

Lower Q_g reduces power loss from gate driving and increases efficiency.

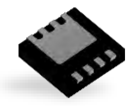


Smaller Size, Higher Power Density

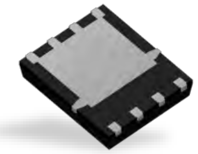
Class leading devices in 2 x 2 mm² and 3 x 3 mm² packages

$R_{DS(ON)}$ specs match or exceed prior generations in larger footprints

3 x 3 mm²



SiSS04DN
Gen IV
10.89 mm²
30V, 1.2 mΩ Max



SiR158DP
Prior Gen
31.6 mm²
30V, 1.8 mΩ Max

65% Footprint Reduction

2 x 2 mm²

SiA468DJ
Gen IV
4.41 mm²
30V, 11.4 mΩ Max (4.5V)

SiSA18ADN
Prior Gen
10.89 mm²
30V, 12 mΩ Max (4.5V)

59% Footprint Reduction

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PLANS FOR 30V TRENCHFET® GEN V

Features and Benefit:

- $R_{DS(ON)}$-Q_g FOM = 24 mΩ-nC
- 4 mΩ + 2.4 mΩ pairing in 3 X 3
- The highest power density
- 65% smaller than 6 X 5

Target Applications:

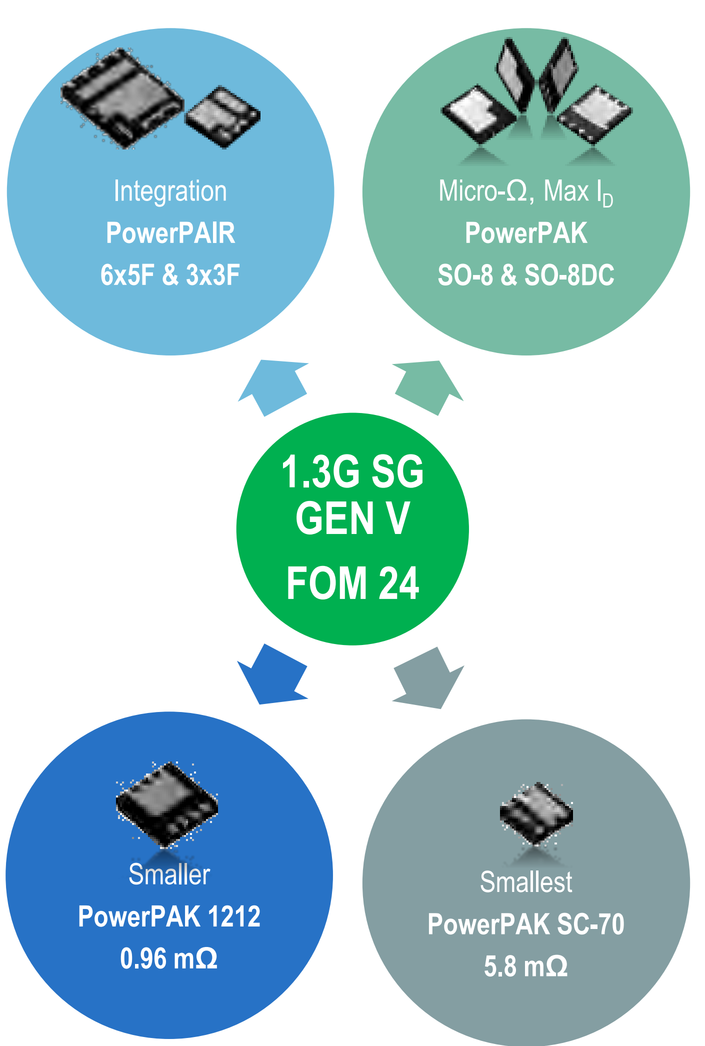
- Synchronous buck
- Buck-boost

Features and Benefit:

- Sub-1 mΩ maximum $R_{DS(ON)}$
- Low Q_g – well suited for switching faster than 500 kHz
- 65% smaller than 6 X 5

Target Applications:

- Synchronous rectification
- Synchronous buck
- OR-ing
- Power and load switch



Features and Benefit:

- 460 µΩ maximum $R_{DS(ON)}$
- The highest output current

Target Applications:

- OR-ing
- Power and load switch
- Synchronous rectification
- Motor drive control

Features and Benefit:

- 5.8 mΩ maximum $R_{DS(ON)}$
- 60% smaller than 3 X 3

Target Applications:

- Synchronous rectification
- Synchronous buck
- Buck-boost
- Power and load switch

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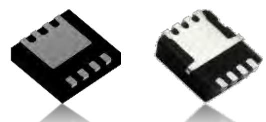
1-mΩ GRADE DEVICES IN 3X3 AND 6X5 mm² FOOTPRINT



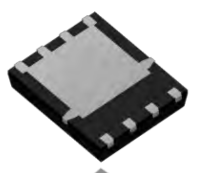
PowerPAK® 1212-8S & 1212-8

3.3 x 3.3 mm²

- ✓ Typical $R_{DS(ON)}$ is less than 1 mΩ
- ✓ Compact size for device paralleling
- ✓ Fits into tight space / Enable more optimized layout

Target Applications

OR-ing, Synchronous buck, Synchronous rectification, µTCA



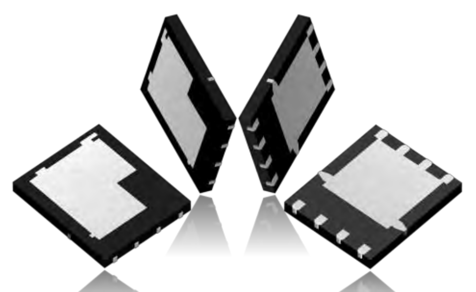
PowerPAK® SO-8

6 x 5 mm²

- ✓ Typical $R_{DS(ON)}$ is as low as 0.49 mΩ
- ✓ Low R_{DS}-Q_g FOM for both power path and switch-mode power supplies

Target Applications

OR-ing, Synchronous rectification, Motor drive, Battery systems, 12V systems



PowerPAK® SO-8DC

6 x 5 mm²

- ✓ Typical $R_{DS(ON)}$ is as low as 0.49 mΩ
- ✓ Dual-side cooling feature enables heat sink mounting
- ✓ Thin profile – 0.56 mm height

Target Applications

OR-ing, Synchronous rectification, Motor drive, Battery systems, 12V systems

Product Category	V_{DS} (V)	V_{GS} (V)	$R_{DS(ON)}$ Max (mΩ) @ V_{GS} = 10V	4.5V	2.5V	Q_g @4.5V (nC)	PowerPAK® SO-8DC	PowerPAK® SO-8	PowerPAK® 1212/1212S	Sample
Sub-1 mΩ Grade	25	+16 | -12	0.58	0.82	-	61	**SiDR220DP**	**SiRA20DP**		Now
	25	+20 | -16	0.67	0.9	-	52.8	***SiDR140DP****	**SiR140DP**		Now
	30	+20 | -16	0.65	0.93	-	49.2	**SiDR392DP**	**SiRA80DP**		Now
1-mΩ Grade	30	+20 | -16	0.94	1.35	-	38		**SiRA60DP**		Now
	20	+12 | -8	1.1	1.45	4.2	18.2			**SiSA40DN**	Now
	25	+16 | -12	1.2	1.83	-	24.3		**SiRA32DP**	**SiSS02DN**	Now
	30	+16 | -12	1.2	1.85	-	28.7		**SiRA62DP**	**SiSS04DN**	Now
	25	+20 | -16	1.23	1.87	-	26.1			**SiSS08DN**	Now
	30	+20 | -16	1.38	2.03	-	24.6			**SiSS06DN**	Now

▪ Lowest $R_{DS(ON)}$ in the industry

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25V & 30V GEN IV SKYFET®

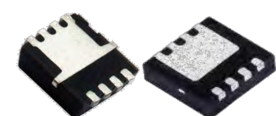
Features and Benefits

ADVANCED PACKAGE CONSTRUCTION

- ✓ Optimized source clip with very low resistance
- ✓ Maximizes performance of the silicon.
- ✓ Improves performance of low-side “free wheeling” MOSFET in synchronous buck converter and synchronous rectification.
- ✓ Technology is available in single-configured PowerPAK® SO8 and PowerPAK® 1212 and the low-side MOSFET in PowerPAIR® 6x5.

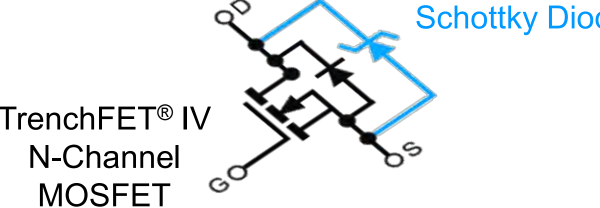
PowerPAK® SO8
6 x 5 mm²

PowerPAK® 1212 / 1212S
3 x 3 mm²



MONOLITHIC SCHOTTKY DIODE

- ✓ Schottky diode is integrated to a high-performance TrenchFET® IV on single chip.
- ✓ Device features all the benefit of efficient switching from TrenchFET® IV
- ✓ Improves reverse recovery.
- ✓ Lower forward voltage V_F than body diode.
- ✓ Schottky diode design is specifically tuned to optimize efficiency of applications based on load current without excessive leakage.



V_{DS} (V)	V_{GS} (V)	PowerPAK® SO-8	PowerPAK® 1212 / 1212S	$R_{DS(ON)}$ Max (mΩ) @		Q_G @ 4.5V_{GS} (nC)	Q_{GS} (nC)	Q_{GD} (nC)	C_{OSS} (pF)	I_F (A) Typ. @V_F = 0.7V	Sample
				V_{GS} = 10V	V_{GS} = 4.5V						
25	+20/-16	**SiRC16DP**	*Not available in this package*	0.96	1.4	31.5	12.1	5.6	1950	30	Now
30		**SiRC18DP**	*Not available in this package*	1.1	1.54	35	11.8	8.4	2400	30	Now
30	+16/-12	**-**	**SiSS60DN**	1.31	2.01	25.9	12.6	5.6	1785	30	Now
		-	**SiSS66DN**	1.38	2.19	24.7	11.2	5.8	1792	30	Now
30	+20/-16	**SiRC04DP**	**SiSC04DN**	2.45	3.5	16.6	6.7	2.9	1050	18	Now
		SiRC10DP	**-**	3.5	5.2	11.2	4.6	2	760	>10	Now

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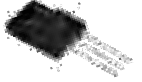
PORTFOLIO FOR INDUSTRIAL MARKET

Specifications									Package Offering							
Package Isometric																
CH	V_{DS} (V)	V_{GS} (V)	$R_{DS(ON)}$ (mΩ) Typ.	$R_{DS(ON)}$ (mΩ) Max.	Q_G (nC)	Q_{GS} (nC)	Q_{GD} (nC)	V_{TH} Typ. (V)	TO-247 AC	TO-220F	TO-220	D2PAK	D2PAK-7L	DPAK	Release Status
N	40	±20	1.27	1.6	150	32	11	2	-	-	SUP40010EL	SUM40010EL	-	-	Now
			1.5	1.8	130	33.6	6.7	1.7	-	-	SUP40012EL	SUM40012EL	-	-	Now
	60	±20	1.45	1.75	141	43.6	19.1	3	-	-	-	SUM50010E	-	-	Now
			1.66	2	141	43.6	19.1	3	-	-	SUP50010E	-	-	-	Now
			1.6	2.1	130	43	20	2	-	-	SUP50020EL	SUM50020EL	-	-	Now
	80	±20	1.75	2.1	152	48.4	24	3			SUP60020E	SUM60020E	-	-	Now
			2.6	3.2	108	32	13	3	-	-	SUP60030E	SUM60030E	-	-	Now
	100	±20	2.4	2.9	142	47	18.5	3	-	-	-	SUM70030E	-	-	Now
			2.65	3.2	142	47	18.5	3	-	-	SUP70030E	-	-	-	Now
			3.2	4.0	76	23	17	3	-	-	SUP70040E	SUM70040E	SUM70040M	-	Now
			4.8	5.8	42	14.5	13.2	3	-	SUA70060E	SUP70060E	SUM70060E	-	-	Now
			7.4	8.9	33	8.8	7.5	3	-	SUA70090E	SUP70090E	SUM70090E	-	SUD70090E	Now
	150	±20	4.5	5.4	117	33	33	3	SUG80050E	-	-	-	-	-	Now
			7.5	9	63	19.5	20.5	3	-	-	SUP80090E	SUM80090E	-	-	Now
			38	46	10.4	2.7	2.7	3	-	-	-	-	-	SUD80460E	Now
	200	±20	7.6	9	130	40	29	3	SUG90090E	-	-	-	-	-	Now
			12.3	15	58	17.6	17.2	3	-	-	SUP90142E	SUM90142E	-	-	Now
			13.8	17	64	16.7	16.9	3	-	-	SUP90140E	SUM90140E	-	-	Now
			18.5	22	48	14	11	3	-	-	SUP90220E	SUM90220E	-	-	Now
			31.2	37.5	21	6	5.3	3	-	-	SUP90330E	SUM90330E	-	SUD90330E	Now
	250	±20	26	31	60	17	16	3	-	-	SUP10250E	SUM10250E	-	-	Now
P	-100	±20	8	10	102	29	28	-2	-	-	SUP70101EL	SUM70101EL	-	-	Now

- Extended temperature range – maximum T_J is 175 degree-C

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80V TO 250V DEVICES IN NEXT GEN POWERPAK® SO-8S

	Now		2020	
250V	SiR692DP 63 mΩ		250V (DT) 39 mΩ Class-leading $R_{DS(ON)}$	
200V	SiR610DP 31.9 mΩ		200V (DT) 20 mΩ Class-leading $R_{DS(ON)}$	
150V	SiR622DP 17.7 mΩ	150V (DT) 9.3 mΩ Class-leading $R_{DS(ON)}$		Gen V 6.3 mΩ Disruptive
100V	SiR668DP 4.8 mΩ	SiRS700DP 100V 3.3 mΩ Class-leading $R_{DS(ON)}$		Gen V 2.4 mΩ Disruptive
80V	SiR680DP 2.8 mΩ	80V (250 SG) 1.9 mΩ Class-leading $R_{DS(ON)}$		Gen V 1.6 mΩ Disruptive

34% Larger Die
10-mil clip
Wire-free internal design
-RE3 for BLR

- The $R_{DS(ON)}$ is maximum value – 30% improvement in the same package footprint
- Samples for 3.3 mΩ 100V device is expected in Q4 2019
- The target release schedule for Gen V 80V to 150V platforms is Q4 2019

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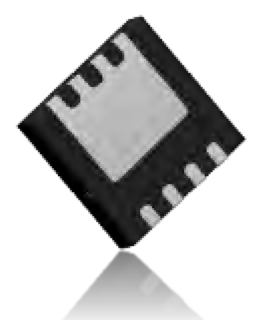
LEADERSHIP IN MINIMIZATION AND INTEGRATION WITH 3X3

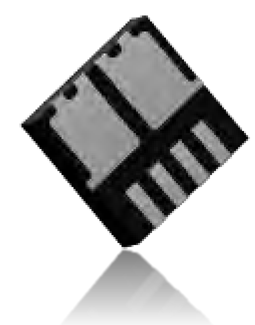


PowerPAK 1212-8S

Single Configuration
Industry Best $R_{DS(ON)}$
High current capability
Thermally enhanced

3.3 x 3.3 x 0.75 mm³

OR-ing, Synchronous rectification, DC/DC, Load switching

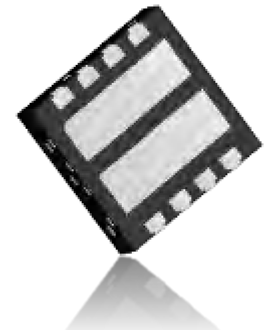


PowerPAK 1212CD

Integrated Common-drain Solution
Exceptional R_{S-S} Spec

3.3 x 3.3 x 0.75 mm³

Battery switching, power and load switching

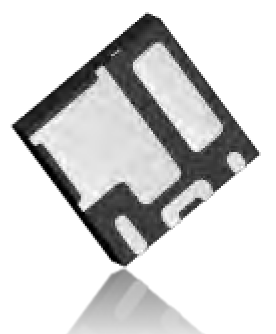


Symmetrical PowerPAIR 3x3

Integrated half-bridge for switching
High efficiency
Purposefully configured for 50% duty cycle

3.3 x 3.3 x 0.75 mm³

Synchronous buck, half-bridge, Wireless charger, Motor drive control



PowerPAIR 3x3F

Integrated half-bridge for switching
High current per phase capability
Increase power density of your design

3.3 x 3.3 x 0.75 mm³

Synchronous buck, High-current DC/DC

Compact, Leadership FOM and Integration

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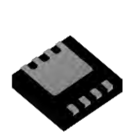
INCREASE POWER DENSITY WITH POWERPAK® 1212-8S

FLAGSHIP MEDIUM VOLTAGE DEVICES IN 3 X 3 PACKAGE

Compact Solutions Increase Power Density

- 65% reduction for PCB real estate of MOSFET
- Equal or lower $R_{DS(ON)}$ of devices in 6 X 5 mm² packages
- Smaller dimension fits into tight design space

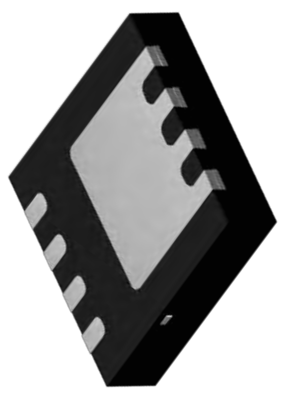


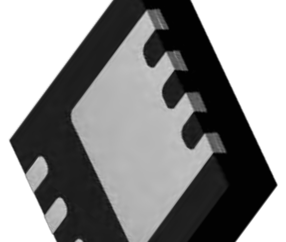
SiSS12DN
TrenchFET Gen IV

10.89 mm²
1.98 mΩ Max

SiR640ADP
Prior Generation

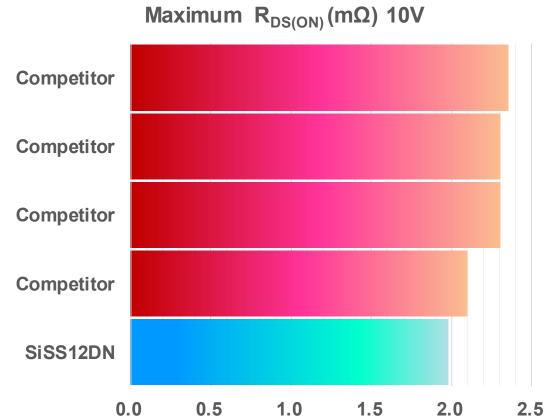
31.6 mm²
2 mΩ Max





Industry Low Maximum $R_{DS(ON)}$ and R_{DS}-C_{OSS} FOM

- Selected devices feature industry low $R_{DS(ON)}$
- Superior FOM's improve efficiency of switching applications



Polarity	V_{DS} (V)	V_{GS} (V)	$R_{DS(ON)}$ (mΩ) Max @V_{GS}= 10V	4.5V	2.5V	Q_g (nC) @V_{GS}= 10V	4.5V	Q_{gs} (nC)	Q_{gd} (nC)	C_{OSS} (pF)	Part Number	Sample Schedule
N	**40**	+20 / -16	1.98	2.74	-	59	28.7	10.2	7.6	680	**SiSS12DN***	Released
	60	±20	4	-	-	28.8	-	8.7	5.1	565	**SiSS22DN***	Released
	80	±20	7.3	-	-	26.9	-	7.7	2.9	171	**SiSS32DN***	Released
	100	±20	12.8	-	-	28	-	8.8	4.2	161	**SiSS46DN**	Released
	125	±20	29.8	-	-	10.2	-	3.2	2.7	157	**SiSS70DN***	Released
	150	±20	42	-	-	10.85	-	3	3	120	**SiSS72DN**	Released
	200	±20	76	-	-	9.5	-	2.2	2.6	54	**SiSS94DN***	Q3 2019
	250	±20	173	-	-	10.4	-	3	3.3	45	**SiSS92DN***	Released
P	**-150**	±20	128	-	-	11.7	-	3.4	3.5	122	**SiSS73DN***	Released

**Industry lead $R_{DS(ON)}$ or R_{DS}-C_{oss} FOM*

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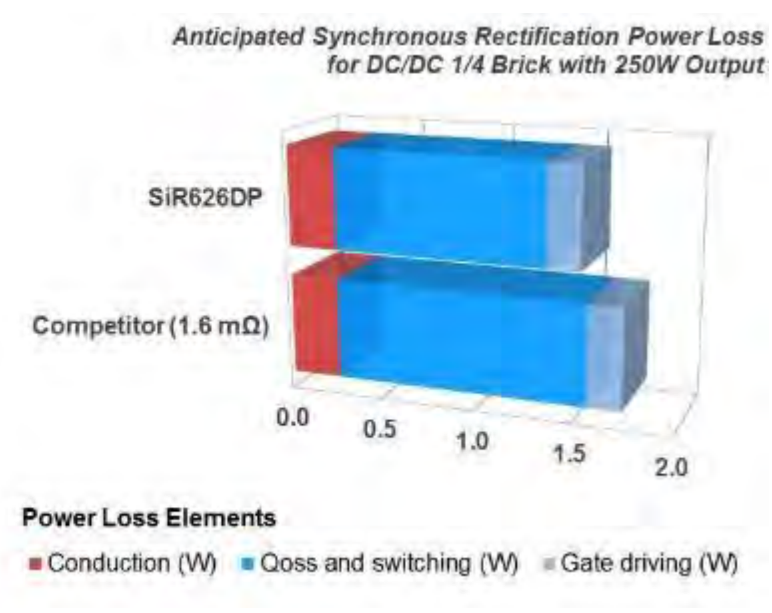
THEORETICAL BENEFIT OF LOW R_{DS}-C_{OSS} FOM

SIR626DP AS A SUBJECT FOR INVESTIGATION

Part Numbers	SiR626DP	*Competitor*
Package	**PowerPAK SO-8**	*DFN 6x5*
V_{DS} (V)	**60**	*60*
V_{GS} (V)	**±20**	*±20*
$R_{DS(ON)}$ (mΩ) Typical @10V	**1.4**	*1.4*
Q_g (nC) @10V	**68**	*71*
C_{oss} (pF)	**992**	*1200*
Q_{oss} (nC)	**68**	*81*



- The analysis projects the power loss of all elements in synchronous rectification. The model is a 250W DC/DC converters which step down from 48V and 12V at 250 kHz of switching frequency.

- The model predicts that SiR626DP will have 14% less power loss due to the improved Q_{oss}.
  - Both devices have similar conduction related loss as $R_{DS(ON)}$ values are very similar.
  - Q_{oss} is 16% lower than the device from competitor. The associated loss occurs even at zero-amp load as the parameter charges and discharges in each switching cycle.

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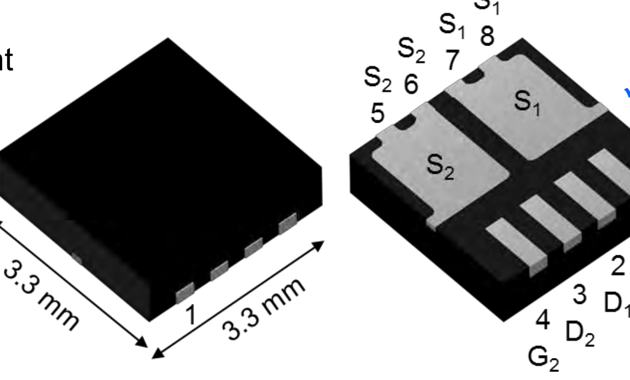
POWERPAK® 1212SCD, COMMON-DRAIN FLIP-CHIP

Ideal Form Factor for Mobile Applications

- ✓ 3.3-by-3.3 mm² package footprint
- ✓ 0.8 mm package profile



Flip-Chip Configuration

- ✓ Configuration increases the die-to-package ratio to 60%
- ✓ Reduces $R_{S1\text{-}S2}$ significantly comparing to conventional packages
- ✓ $R_{S1\text{-}S2} \leq 3.5\ m\Omega$

Advanced Interconnection

- ✓ 8-mil drain clip
- ✓ Maximize the performance of silicon
- ✓ Wire-free construction minimizes parasitic inductance

Simplify PCB Layout

- ✓ Enlarged source pads create larger contact to PCB
- ✓ Configuration enables higher current load

V_{DS} (V)	V_{GS} (V)	$R_{S\text{-}S(ON)}$ (mΩ) Max @V_{GS}= 10V	$R_{S\text{-}S(ON)}$ (mΩ) Max @V_{GS}= 4.5V	Q_g (nC) @V_{GS}= 10V	Q_g (nC) @V_{GS}= 4.5V	Q_{gs} (nC)	Q_{gd} (nC)	Part Number	Sample Schedule
25	+16 / -12	3.5	5.6	37	16.9	7.6	3	**SiSF02DN**	Released
30	+16 / -12	4	6	36	17	5.9	3.4	**SiSF04DN**	P7 2019
30	+20 / -16	4.5	6.95	26	12.5	6.1	3.1	**SiSF06DN**	Q2 2019
		5	7	35	16.1	7	2.5	**SiSF00DN**	Released
60	+16 / -12	13.2	18	21	10	3.2	2.8	**SiSF20DN**	Released

Target applications – Bi-directional switch, battery and load switching

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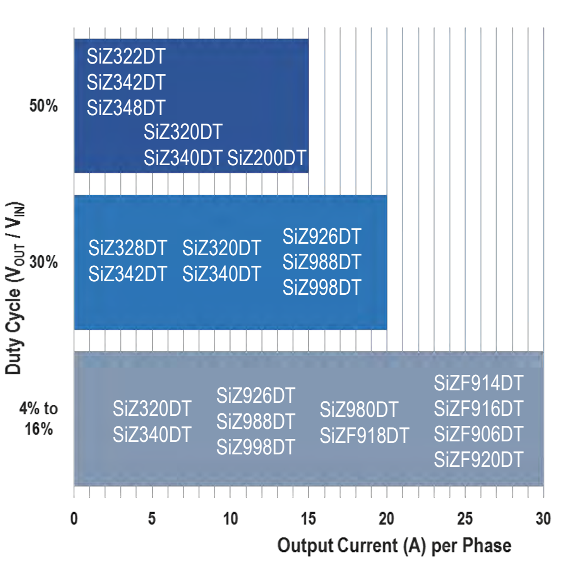
PowerPAIR® MOSFET Power Stage

Integrated MOSFET Half-Bridge for 4.5V to 21V Input

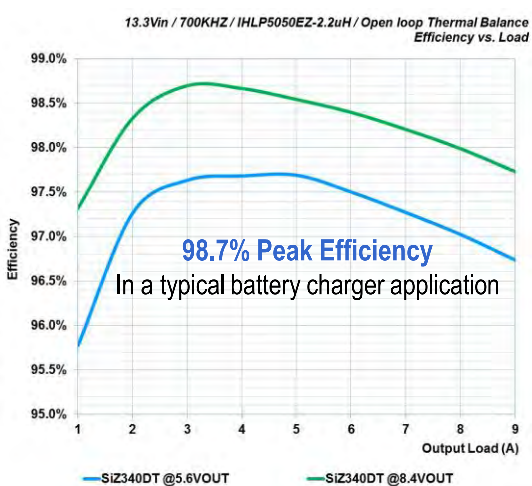
- Internally Connected switch node
- Reduces 36% or more PCB real estate comparing to designs using discrete devices

Optimized MOSFET Pair for High Efficiency

- Increase power density by 25% or more with TrenchFET® IV
- 5% efficiency improvement from TrenchFET® III



Enable PCB Real Estate Reduction
Achieve Higher Efficiency
Increase Power Density



Wide Range of Solutions

- Various package footprints – 3x3, 3.3x3.3, 6x3.7 & 6x5 mm²
- Solutions for 4% duty and PowerPAIR® 3x3S with symmetrical FETs for 50% duty

Flip-chip PowerPAIR® for High-Current Applications

- PowerPAIR® 6x5F for 30A-per-phase designs simplifies placement of input capacitor
- Separation of "Power" and "Signal" partition

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NEXT GENERATION POWERPAIR® 6 X 5

"Kelvin" Source Increases Performance of High-Side

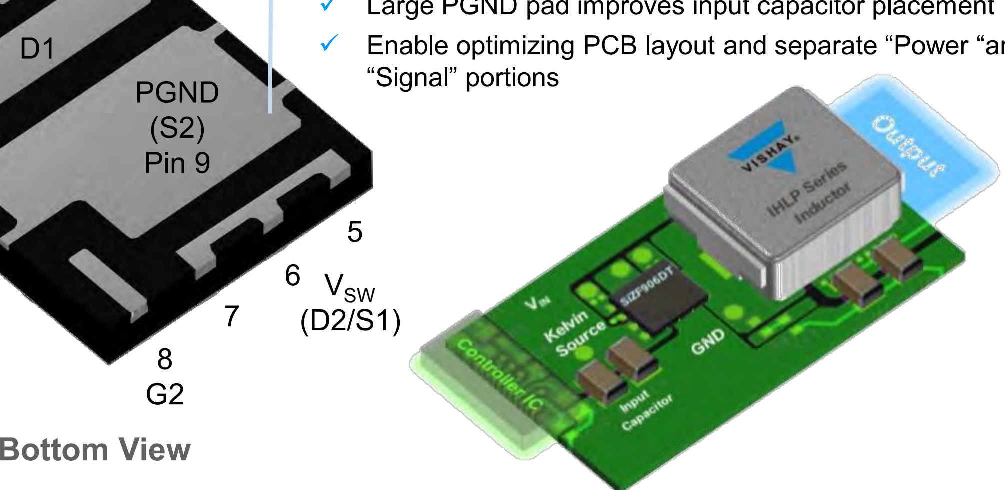
- ✓ D1/S2 on pin 2 provide "Kelvin" source
- ✓ Remove L x di/dt negative voltage from connecting directly to switch node
- ✓ Allow high side MOSFET to receive full output voltage from gate driver and reduce power losses
- ✓ Results in lower $R_{DS(ON)}$ and faster switching

Enhanced Package Construction

- ✓ Clip is designed to minimize parasitic inductance internally
- ✓ Low-side MOSFET is in flip-chip configuration to enable a large contact to PGND on PCB
- ✓ Configuration allows usage of silicon with a typical $R_{DS(ON)}$ as low as 1.2 mΩ (V_{GS} = 4.5V)

Optimize Board Layout

- ✓ Large PGND pad improves input capacitor placement
- ✓ Enable optimizing PCB layout and separate "Power "and "Signal" portions



Bottom View

TrenchFET® IV & SKYFET®

- ✓ Bespoke $R_{DS(ON)}$ pairing achieve high efficiency for over 30A per current phase
- ✓ Flip-Chip low-side MOSFET features SKYFET with monolithic Schottky to improve reverse recovery
- ✓ Q_{gd} / Q_{gs} ratio < 0.5 to enhance immunity to gate-coupled noise and shoot-through

Product Line Up

Device	V_{DS} (V)	V_{GS} (V) HS	V_{GS} (V) LS	$R_{DS(ON)}$ Max (mΩ) @ 4.5V_{GS} HS	$R_{DS(ON)}$ Max (mΩ) @ 4.5V_{GS} LS	Q_g @4.5V_{GS} (nC) HS	Q_g @4.5V_{GS} (nC) LS	Q_{gs} (nC) HS	Q_{gs} (nC) LS	Q_{gd} (nC) HS	Q_{gd} (nC) LS	Sample
SiZF908DT	25	20/-16	16/-12	4.5	1.25	10.6	38	4	14.4	1.7	6.4	Q3 2019
SiZF914DT	25	20/-16	16/-12	6.6	1.62	6.6	25.5	2.7	7.8	1.2	4	**Now**
SiZF920DT	30	20/-16	16/-12	5.3	1.45	9	38.6	4.4	17	2	9.2	**Now**
SiZF906DT	30	20/-16	20/-16	5.3	1.58	11	46	5.1	17.1	1.3	7.2	**Now**
SiZF916DT	30	20/-16	16/-12	6.7	1.75	7	29.3	3	10.2	1.5	5.2	**Now**
SiZF918DT	30	20/-16	16/-12	6.7	2.7	7	17.3	3	6.1	1.5	3.5	**Now**

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MICROBUCK

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microBUCK® – Monolithic Product Offering

Common Features:
- Constant On Time Topology
- High Efficiency Light/Full Load

Advanced Ripple Control

Value Proposition:
- Scalability
- All Ceramic solution
- Fast Transient
- Ease of use

SiP12108 – 5A
- ***MLP3x3-16L***
- ***SYNC Buck***
- ***Released***

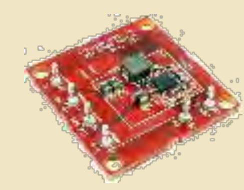
SiP12107 – 3A
- ***MLP3x3-16L***
- ***SYNC Buck***
- ***Released***

- 2.7~5.5V operation
- QFN16 (3x3)
  - SiP12107 – 3A
  - SiP12108 – 5A
- CM COT
- Up to 4MHz Fsw
- Simple Compensation
- Light load Mode: Auto (selectable)
- SiP12108A with UVP Disable

SiP12110 – 6A
- ***MLP3x3-16L***
- ***SYNC Buck***
- ***Released***

SiP12109 – 4A
- ***MLP3x3-16L***
- ***SYNC Buck***
- ***Released***

- 4.5~15V operation
- QFN16 (3x3)
- Max Load
  - SiP12109 – 4A
  - SiP12110 – 6A
- CM COT
- Up to 1.5MHz Fsw
- Simple Compensation
- Light Load Mode: PSM



SiP12116 – 3A
- ***DFN10-3x3***
- ***SYNC Buck***
- ***Released***

SiP12117 – 3A
- ***DFN10-3x3***
- ***SYNC Buck***
- ***Released***

- 3V~15V operation
- DFN10 (3x3)
- Max Current: 3A
- V2 COT CTRL
- 650KHz Fsw, fixed
- No Compensation need
- Light Load mode
  - SiP12116 – PWM
  - SiP12117 – PSM

SiP12112 – 3A
- ***SO8 (EP)***
- ***SYNC Buck***
- ***Released***

SiP12111 – 3A
- ***SO8 (EP)***
- ***SYNC Buck***
- ***Released***

- 4.5~15V operation
- SO-8 (Exposed PAD)
- Supports 3A
- V2 COT CTRL
- 1MHz Fsw, Fixed
- No Compensation need
- Pin 9 function
  - SiP12111 – PGood
  - SiP12112 – Softstart

2012 2013 2014 2015 2016 Time

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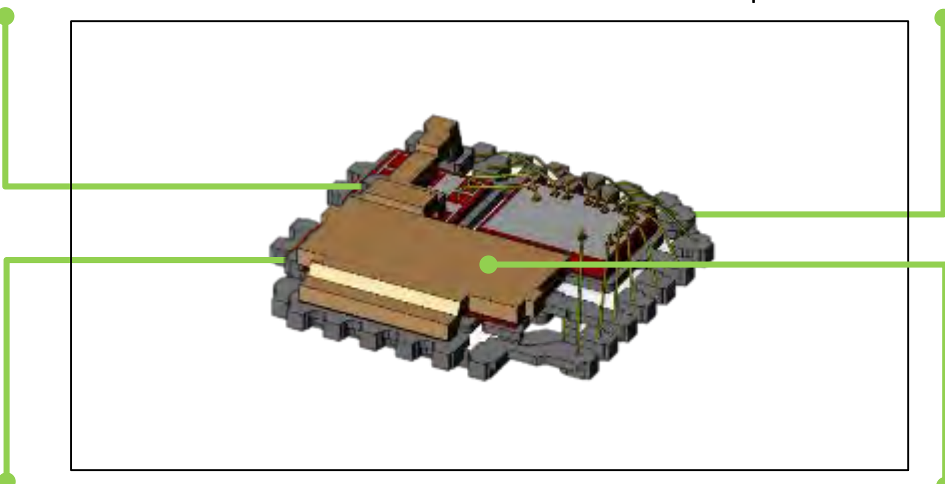
microBUCK® INNOVATION

CONTROLLER

- V2 COT CTRL
- Wide operating voltage
- Low operation current =highest => high efficiency at light load.
- Internal compensation to minimize component count and design complexity
- Full protections (OC, OV, OT and UV)
- Fast Transient Response

HS FET

- Vishay GEN4 Trench FET – 25V ~ 72V
- Achieves very low on-resistance with high-density process
- Very low QSW and QGD reduce switching related power loss in fast switching designs



LS FET

- Vishay GEN4 Trench FET - 25V ~ 72V
- Achieves very low on-resistance with high-density process
- The ratio of QGD/QGS is less than 0.5 improves switching characteristics and enhance immunity to gate coupled noise and shoot-through
- SKYFET® with monolithic Schottky improves reverse recovery characteristics

-

Package

- Thermally enhanced QFN package
- PGND is now a large pad rather than the SW node
- A single clip forms the SW node connection resulting in reduced source inductance (100pH versus 250pH) and hence lower switching losses

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microBUCK® Product Roadmap

Max Input Voltage (V)

70

60

40

20

AUTOMOTIVE GRADE

SiCQ482
4.5 ~ 65 V_{in}, 6A

SiCQ481
4.5 ~ 65 V_{in}, 10A

HV microBUCK

SiC464/9
4.5 ~ 60 V_{in}, 2A

SiC463/8
4.5 ~ 60 V_{in}, 3A

SiC462/7
4.5 ~ 60 V_{in}, 6 A

SiC461/6
4.5 ~ 60 V_{in}, 10A

SiC474
4.5 ~ 55 V_{in}, 3A

SiC473
4.5 ~ 55 V_{in}, 5A

SiC472
4.5 ~ 55 V_{in}, 8 A

SiC471
4.5 ~ 55 V_{in}, 12A

LV microBUCK

SiC438
3.0 ~ 28 V_{in}, 8 A

SiC437
3.0 ~ 28 V_{in}, 12 A

SiC431
3.0~ 24 V_{in}, 20 A

SiC453
4.5 ~ 20 V_{in}, 15 A

SiC450
4.5 ~ 20 V_{in}, 40 A

PMBus

Released

Sampling

In development

3

6

12

20

30

Output Current (A)

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MicroBUCK® Selection Guide

	SiC461/2/3/4	SiC466/7/8/9	SiC47x	SiC43x	SiC45x	SiCQ48x
Automotive Grade	Commercial Grade					**Automotive Grade**
Target Input Range	36V – 60V		36V – 54V	4.5V – 24V	4.5V – 16V	36V – 65V
Output Current Range	2A – 10A		3A – 12A	8A – 24A	15A – 40A	6A – 10A
PMBus	NO				YES	NO
Compensation	External	Internal	External	Internal	Internal	External
Package Size	MLP 5x5			MLP 4x4	MLP 5x7	MLP 5x5 w/ wettable flank

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MICROBRICK

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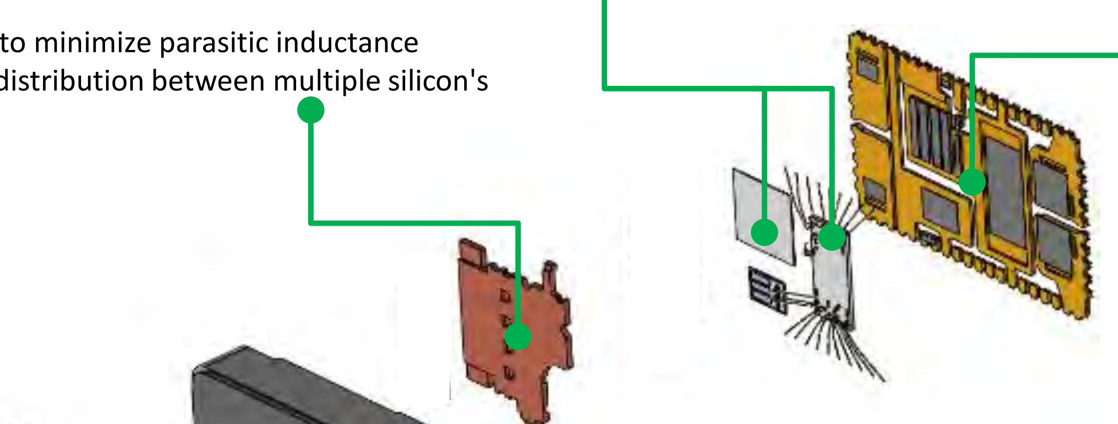
MicroBRICK® 3D Package Technology at a Glance

Lead Frame
- Thermally enhanced lead frame
- Mechanically rugged for MCM package
- Minimize conduction loss

IC and MOSFETs
- Leveraging silicon's from MicroBUCK® product families
- Latest Gen 4.5 MOSFET Technology
- State-of-the-art controller IC

Thick Cu Clip
- Single source clip to minimize parasitic inductance
- Improve thermal distribution between multiple silicon's



Integrated Magnetics
- Customized inductor for optimum performance
- Extremely low profile (<2.5mm)
- Vishay proprietary material for minimum core losses

Molding Compound
- Highly thermally-conductive for heat dissipation

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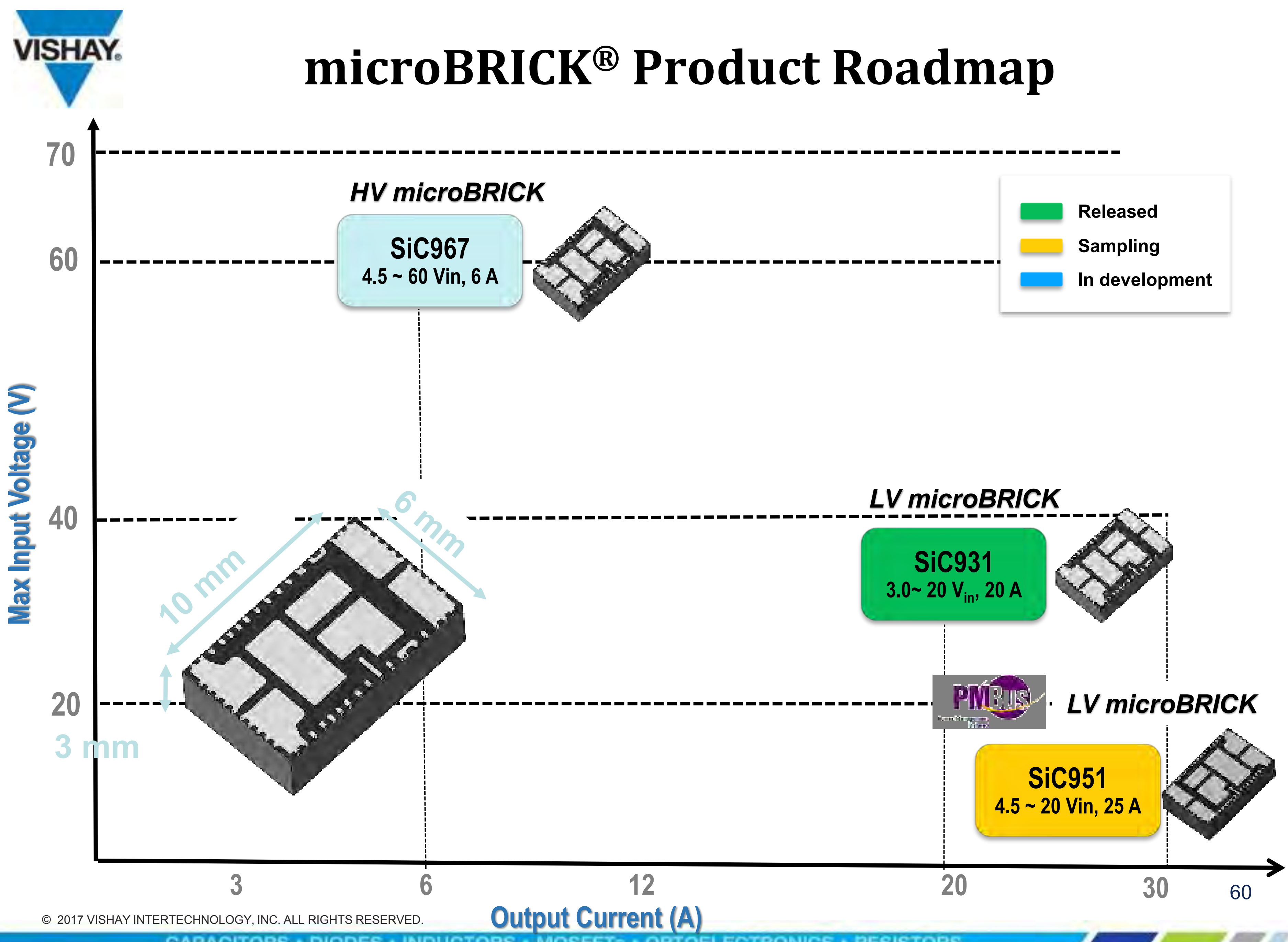

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SiC931, 4.5V to 24V, 20A MicroBRICK™ DC/DC Regulator Module

Product Highlights:

- **VERSATILE**
  - Operation from 4.5 V to 24 V input voltage
  - Adjustable output voltage down to 0.6 V
  - Output voltage tracking and sequencing with pre-bias start up
  - ±1 % output voltage accuracy from -40 °C to +125 °C
- **HIGHLY EFFICIENT**
  - 95 % peak efficiency at 1.5MHz
  - 1 µA supply current at shutdown
  - 50 µA operating current, not switching
- **HIGHLY CONFIGURABLE**
  - Four programmable switching frequencies available: 600 kHz, 1 MHz, 1.5 MHz, and 2 MHz
  - Adjustable soft start and adjustable current limit
  - Programmable modes of operation: forced continuous conduction or power save mode
- **ROBUST AND RELIABLE**
  - Cycle-by-cycle current limit
  - Output overvoltage protection
  - Output undervoltage / short circuit protection
  - Power good flag and over temperature protection

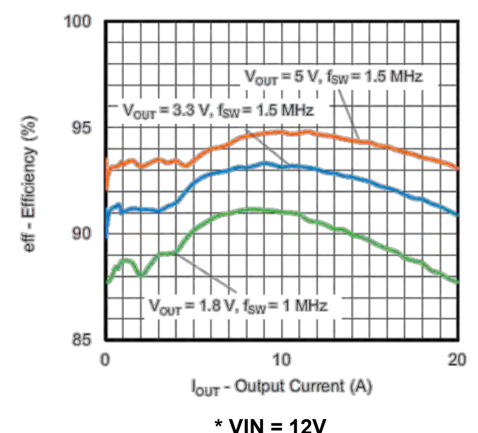
Package & Application

- **HIGH POWER DENSITY**
  - **Integration of high current output inductor**
  - **10.6 mm x 6.5 mm x 3 mm low profile MLP package**

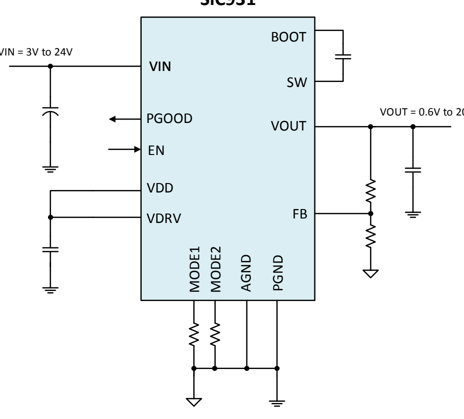
10.6 mm
6.5 mm
3 mm

- **APPLICATIONS**
  - **FPFA Power**
  - **Telecommunication**
  - **High Performance Computing**

Application Diagram



* VIN = 12V



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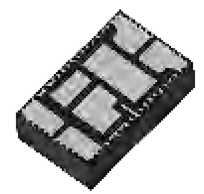
SiC951, 4.5V to 20V, 25A MicroBRICK™ DC/DC Regulator Module



Product Highlights:

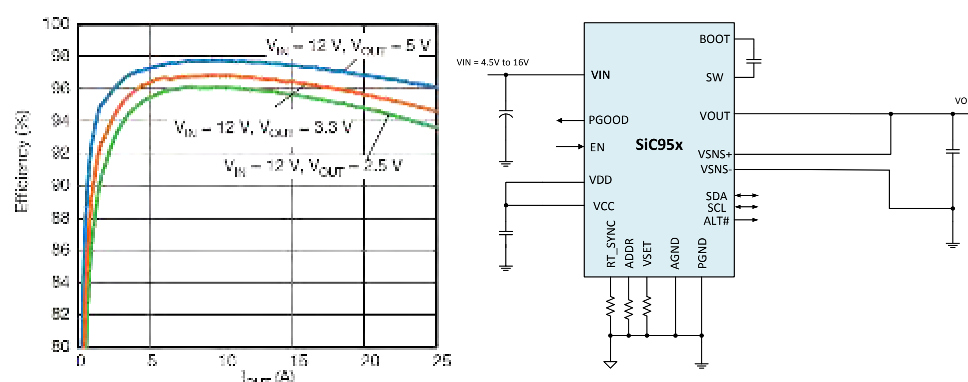
PMBus

- **VERSATILE**
  - Operation from 4.5 V to 20 V input voltage
  - Adjustable output voltage down to 0.3 V
  - 25A continuous current capability
  - Constant ON time control for superior transient response
  - Internal 5V LDO for driver bias
  - Internal compensation
  - PMBus 1.3 bus with telemetry
  - 1% output accuracy over temperature
- **HIGHLY EFFICIENT**
  - Industry benchmark 30V FETs
  - 98 % peak efficiency
  - 1 μA quiescent current
  - 50 μA operating current
- **HIGHLY CONFIGURABLE**
  - Adjustable switching frequency from 600kHz to 2MHz
  - Adjustable soft start and current limit
  - Programmable modes of operation: forced continuous conduction or power save mode
- **ROBUST AND RELIABLE**
  - Cycle-by-cycle current limit
  - Output over-voltage protection
  - Output under-voltage/short circuit protection
  - Power good flag
  - Over temperature protection

Package & Application

- **HIGH POWER DENSITY**
  - **Integration of high current output inductor**
  - **10.6 mm x 6.5 mm x 3 mm low profile MLP package**
- **APPLICATIONS**
  - **Enterprise server with 12V bus**
  - **Artificial intelligence and machine learning**
  - **High performance computing**
  - **Telecommunication & Networking**

Efficiency & Application Diagram



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VR POWER DR MOS

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VRPOWER® (POWER STAGE) OVERVIEW

Smart PowerStage

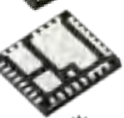
40A - 80A

- Pico Dead-time Control
- IMON +/- 2%
- TMON +/- 3%

Gen 4.5
Gen 5
MOSFET

4mm x 5mm

5mm x 6mm

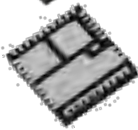


5mm x 5mm

PowerStage Plus

35A - 60A

- Advanced Dead-time Control
- HS OCP Protection
- Phase Short Protection
- Over Temperature Protection
- Temperature Reporting



3.5mm x 4.5mm

5mm x 5mm

5mm x 6mm

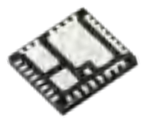
ECO PowerStage

30A - 60A

- 4.5V – 24V Input Voltage
- 3.3V / 5V PWM Interface
- High Frequency up to 2Mhz
- Adaptive Dead-time Control
- ZCD / SMOD interface
- Low Iq (3μA)

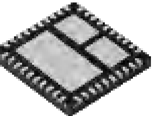
Gen 4
MOSFET

3.5mm x 4.5mm



5mm x 5mm

5mm x 5mm DC



6mm x 6mm

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POWER STAGE PACKAGE PORTFOLIO

MLP 3.5x4.5

- 35A DC
- 45A Peak
- 8W Thermal
- Up to 2MHz
- ePS or PS+

Consumer

MLP 4x5

- 40A DC
- 50A Peak
- 10W Thermal
- Up to 2MHz
- SPS or PS+

Server/Cloud

MLP 5x5

- 60A DC
- 80A Peak
- 12.5W Thermal
- Up to 2MHz
- SPS or PS+

Server/Cloud

Consumer

MLP 5x6

- 80A DC
- 100A Peak
- 15W Thermal
- Up to 2MHz
- SPS or PS+

Server/Cloud

All multi-sourceable packages!

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ANALOG SWITCH

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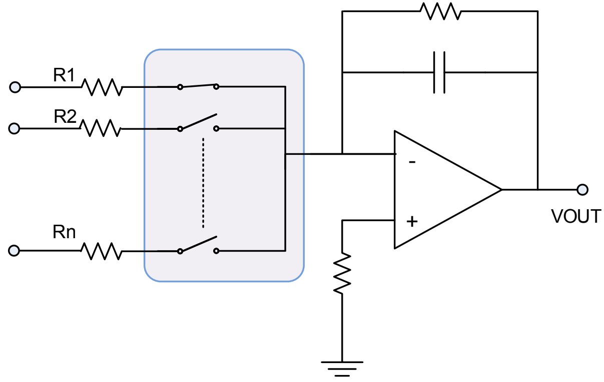
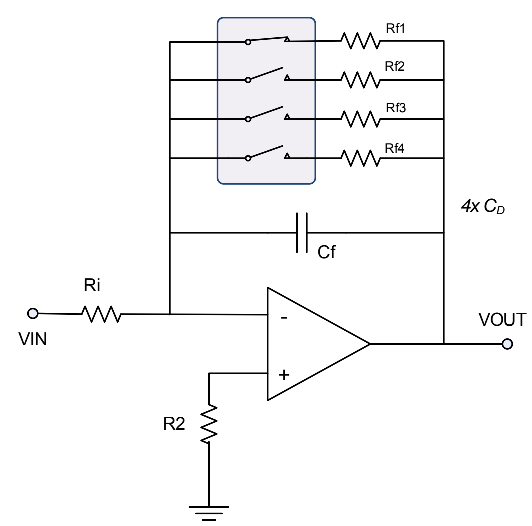
TYPICAL APPLICATION DESIGNS

Typical functional circuits/blocks:

- Signal switching, routing, and multiplexing
- ADC, DAC input and output mux and demux
- Sample and hold
- Programmable gain control
- Filtering control
- Test calibration
- Level translation/Pulse generator
- Power/Load Switching
- Force & Sense
- Reed relay replacement



Signal switching/multiplexing



Programmable Gain Control

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ANALOG SWITCH AND MULTIPLEXER – PRODUCT OFFERING

Analog switches and multiplexers are processed with technologies optimized for common analog block designs with power supplies where voltage ranges between ±15, +12, ±5V, +5V, and 3V.

Product designs attempting to address either low resistance or low parasitic charge injection - switching performance.

Operation Voltage Range	Switching Performance Optimized **Low Capacitance & Charge Injection** *Devices provide fast switching speed, low parasitic, low switching noise/glitch*	Switch Resistance Optimized **Low R_{ON}** *Devices provide low insertion loss, low resistance variation error*	Application Specific
±15V	DG506B/DG507B *16-ch, 3pC* DG201B/DG202B DG211B/212B *Quad SPST* DG508B/DG509B *8-ch, low C & Q*	DG406/DG407 *16-ch,* DG451/2/3 DG411/2/3 DG441/2/3 DG408/DG409 *8-ch,* DG1411E/2E/3E *4-ch, 1.5Ω* DG447/8/9 DG467/8/9 DG1408E/1409E *8-ch, 3Ω* DG417/8/9	
±8V	DG4051E/2E/3E *8-ch* DG611E/612E/613E *4-ch, 1pC charge* DG604E *4-ch, 4:1 mux* DG636E *4-ch, dual SPDT*	DG9408E/9E *8-ch, 3.2Ω* DG9424E/5E/6E *4-ch, 1.6Ω*	
+5V	DG9232E/3E/4E *2-ch, 1pC, 17Ω* DG2523/4, DG2525, *8-ch, Quad SPDT, 0.4Ω, 26pF CON*	DG2735A *4-ch, dual SPDT, 0.3Ω*	DG2730, 2723 *USB High Speed 4-ch, dual SPDT 900MHz BW PWR down safe*

Legend: Multiplexer (light green) / Switch (dark green)

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High Pulse Load
MELF
MLCC
Surface Mount
Polymer
CECC
Power Inductors
IHLP®
AS9100
DC-Link
NTC
EMI / RFI
AEC-Q200
Through-Hole
Magnetics
ESA / ESCC
Passives
Capacitors
Tantalum
Film
UL
DLA
Fuses
Vishay
ENYCAP™
Aluminum
Energy Storage
Thick Film
Planar Transformers
High Temperature
Medical
PTC
High Voltage
Die and Wafer
Sensors
Thyristors
microBUCK®
Integrated Circuits
Diodes and Rectifiers
eSMP®
Accuracy
Mobility
TVS
FRED Pt®
Low Profile
MOSFETs
Semiconductors
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