Residential energy storage systems (ESS) and multi-modular topology for 2nd life batteries

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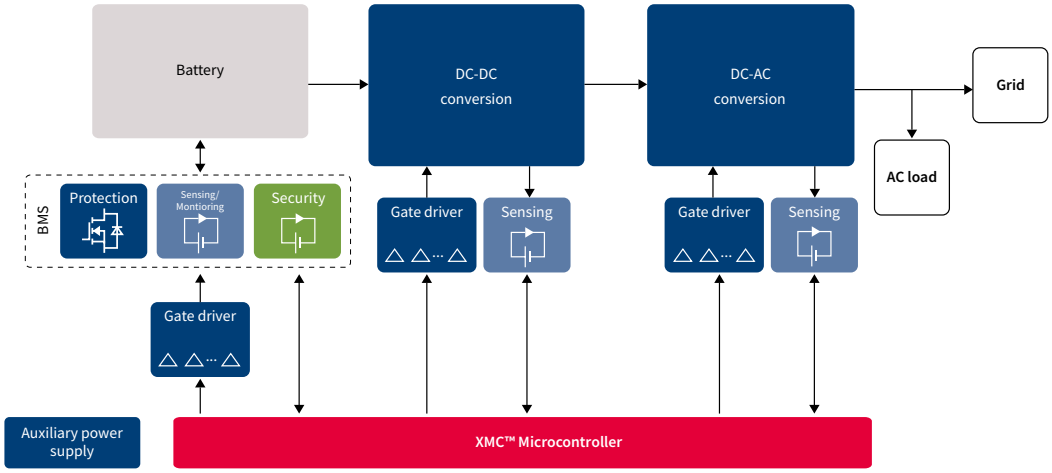
Infineon's energy storage system designs

Energy storage has been an integral component of electricity generation, transmission, distribution and consumption for many decades. Today, with the growing renewable energy generation, the power landscape is changing dramatically. This shift to renewable sources also makes delivering power reliably, where and when it's needed, a bigger challenge than ever before.

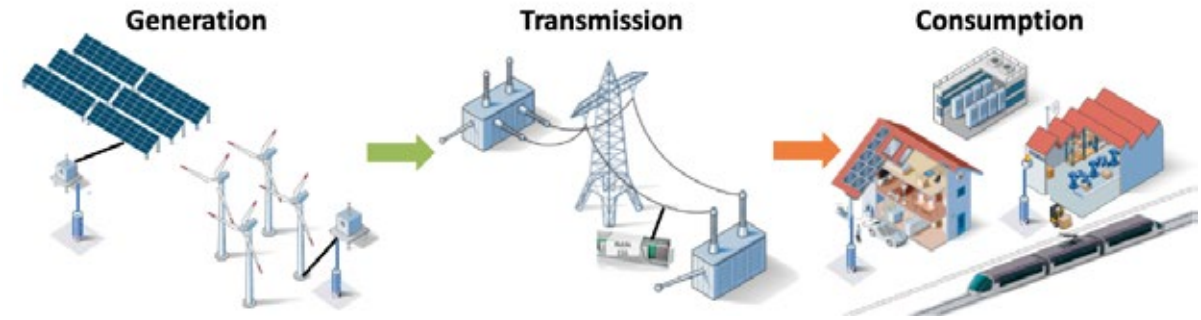
Energy storage systems provide a wide array of technological approaches to manage our supply-demand situation and to create a more resilient energy infrastructure and bring cost savings to utilities and consumers.

Infineon's unique expertise in energy generation, transmission, power conversion, and battery management makes us the perfect partner to advance energy storage solutions (ESS) in terms of efficiency, innovation, performance, as well as optimal cost.

Typical structure of energy storage systems



Battery-based ESS technology can respond to power drop-outs in under a second, making use of clean energy, sourced from collocated solar or wind plants. In such before-the-meter cases, ESS functions as bulk storage coupled with either renewables generation or transmission and distribution systems. In residential and commercial situations, ESS plays a role in behind-the-meter systems.



Infineon's distinctive expertise and product portfolio provide state-of-the art solutions that reduce design effort, improve system performance, empower fast time-to-market and optimize system costs.

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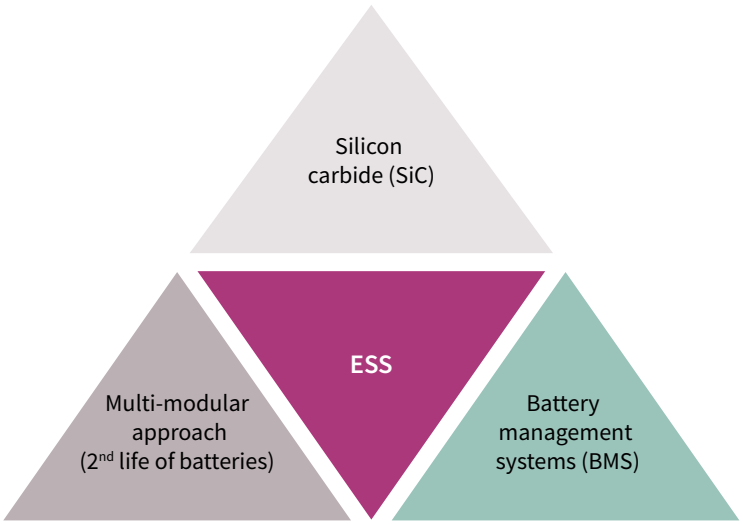
Trends in energy storing systems (ESS)



Multi-modular approach

Promising solution to 2nd life batteries

Innovative approach paving the way of 2nd life batteries in ESS applications

Solutions for:

- Reuse of increasing number of 2nd life batteries
- Battery pack connected to own bi-directional power converter
- Output of converters connected to create high voltage DC bus
- Current drawn from battery does not need to be equal
- Voltage output is controllable
- More flexibility

Silicon carbide (SiC)

Value of SiC in ESS

Improved system efficiency at high current and temperature conditions enabling smaller size and weight

→ lower cost per Watt

Solutions for:

- Smaller size and weight of systems
  - Enables higher frequencies → smaller magnetics
  - Less losses and better thermals (smaller heatsink)
- High power density
- Simplified bi-directional topologies
- Higher efficiency
- Less bill of material content (BOM)
- Robustness and higher system reliability

Battery management system (BMS)

Efficient and safe batteries

BMS fulfills two main functions

- Battery protection
- Battery monitoring

Solutions for:

- Wider safe operating area (SOA)
- Short circuit protection with higher peak current rates
- Turn-on and turn-off solutions tailored to applications needs
- Cheaper solutions with more compact bill of material and more effective parallelization solutions

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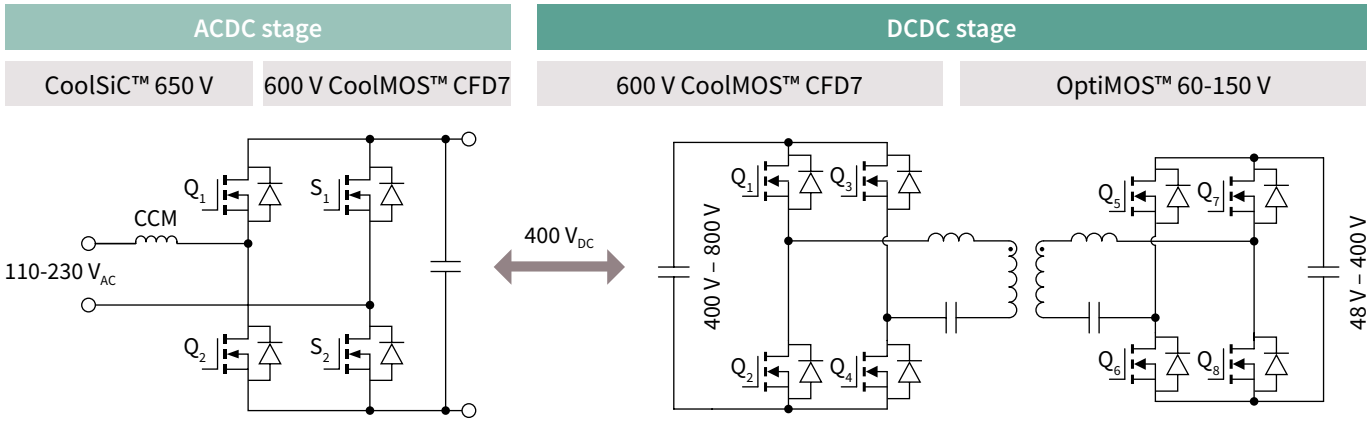
SiC in energy storage systems

Infineon's latest addition to its SiC portfolio, the CoolSiC™ MOSFET 650 V family, is the product of a state-of-the-art trench semiconductor process, optimized to allow no compromises in achieving both - the lowest losses in the application and the highest reliability in operation. While leveraging the strong material characteristics of silicon carbide, Infineon's experts managed to add unique features that increase the device performance, robustness, and ease of use.



Stage	Product type	Power	Product	Part number	$R_{DS(on)}$
ACDC	MOSFET	2 kW	CoolSiC™ 650 V	IMZA65R107M1H	107.0 mΩ
			600 V CoolMOS™ CFD7	IPW60R055CFD7	55.0 mΩ
		5 kW	CoolSiC™ 650 V	IMZA65R048M1H	48.0 mΩ
			600 V CoolMOS™ CFD7	IPW60R040CFD7	40.0 mΩ
		7 kW	CoolSiC™ 650 V	IMZA65R027M1H	27.0 mΩ
			600 V CoolMOS™ CFD7	IPW60R031CFD7	31.0 mΩ
	Driver ICs		Functional isolated EiceDRIVER™ 2EDF	2EDF7275K	–
			Functional isolated EiceDRIVER™ 2EDF*	2EDF9275F	–
	Microcontroller		XMC™ Microcontroller	XMC4400-F100K512 BA	–
DCDC	MOSFET	2 kW	600 V CoolMOS™ CFD7	IPW60R055CFD7	55.0 mΩ
			OptiMOS™ 150 V	BSC093N15NS5	9.3 mΩ
		5 kW	600 V CoolMOS™ CFD7	IPW60R040CFD7	40.0 mΩ
			OptiMOS™ 150 V	IPT059N15N3	5.9 mΩ
		7 kW	600 V CoolMOS™ CFD7	IPW60R031CFD7	31.0 mΩ
			OptiMOS™ 150 V	IPT059N15N3	5.9 mΩ
	Driver ICs		Reinforced isolated EiceDRIVER™ 2EDi	2EDS8265H	–
			Functional isolated EiceDRIVER™ 2EDF	2EDF7275F	–
	Microcontroller		XMC4200 Microcontroller	XMC4200-F64K256 BA	–

*Recommended for CoolSiC™ MOSFETs

Full CoolSiC™ portofolio, consisting of 1200 V and 650 V:
www.infineon.com/coolsic
www.infineon.com/cms/en/product/power/gate-driver-ics/eicedriver-for-sic-mosfets/

www.infineon.com/energy-storage-systems

PCS

For more details on the product, click on the part number.

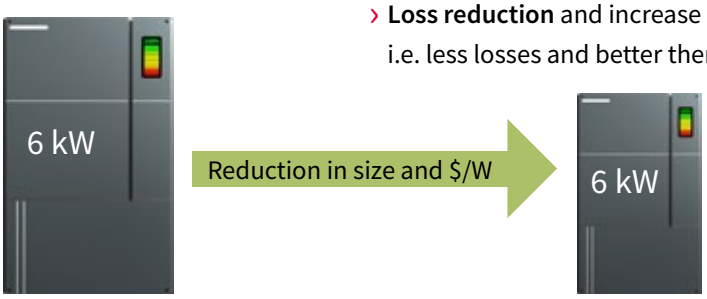
Value of SiC in ESS

Challenges and requirements

- Smaller size and weight reduction → power density
- Improved system efficiency
- Cost reduction → lower costs per Watt
- Bi-directionality and reliability

Benefits and value added

- CoolSiC™ **doubles the power density** (W/Kg) compared to silicon (IGBT)
- **Overall system cost reduction**
  - Higher switching frequency enables smaller transformers / inductors → smaller magnetics
  - Same power can fit in a smaller box size
- **Simpler topologies** with less control effort
- **Higher robustness** and better **system reliability**
- **Loss reduction** and increase in efficiency at high operating temperatures, i.e. less losses and better thermals (smaller heatsink)



SJ MOSFET and IGBT

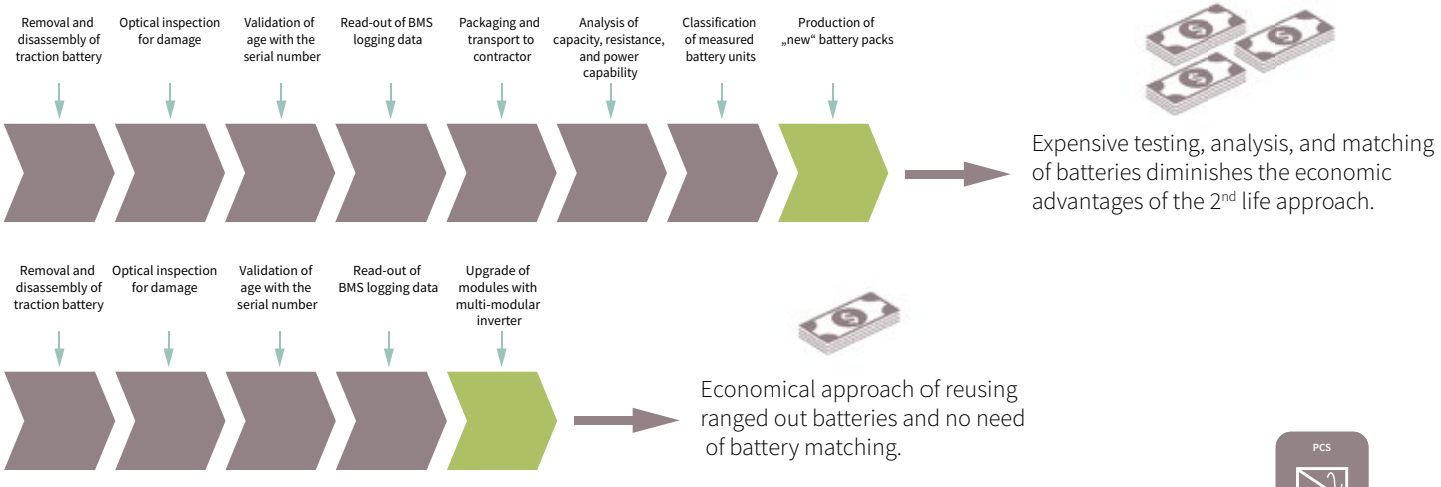
CoolSiC™ MOSFET

Multi-modular approach

In times of increasing popularity of e-mobility solutions (particularly electric cars) it can be expected that in the future the world will have to cope with a significant number of used EV-batteries. A major advantage of modularly cascaded, multilevel architectures is the ability to enable 2nd life of batteries – applicable for example to batteries that have reached the end of their lifecycle and cannot be used in EVs any longer.

To overcome this limitation, modularly cascaded, multilevel architectures that utilize the benefit of highly efficient, low-voltage MOSFETs like Infineon's market leading OptiMOS™ family have been developed. Each battery pack is connected to its own bi-directional power converter and the outputs of these converters are then connected in series to create the high-voltage DC-bus. By doing so, an equal current can be supplied from the outputs of each of these stages. The current drawn from each battery to the contrary must not be equal. The voltage output for each stage becomes controllable. It is possible to bypass stages should their battery state of charge (SOC) drop below the minimum level. With this added flexibility it is now possible for advanced control schemes to balance the SOC of different batteries among all the packs by placing a heavier load on those packs with higher SOC.

Enabling 2nd life of batteries



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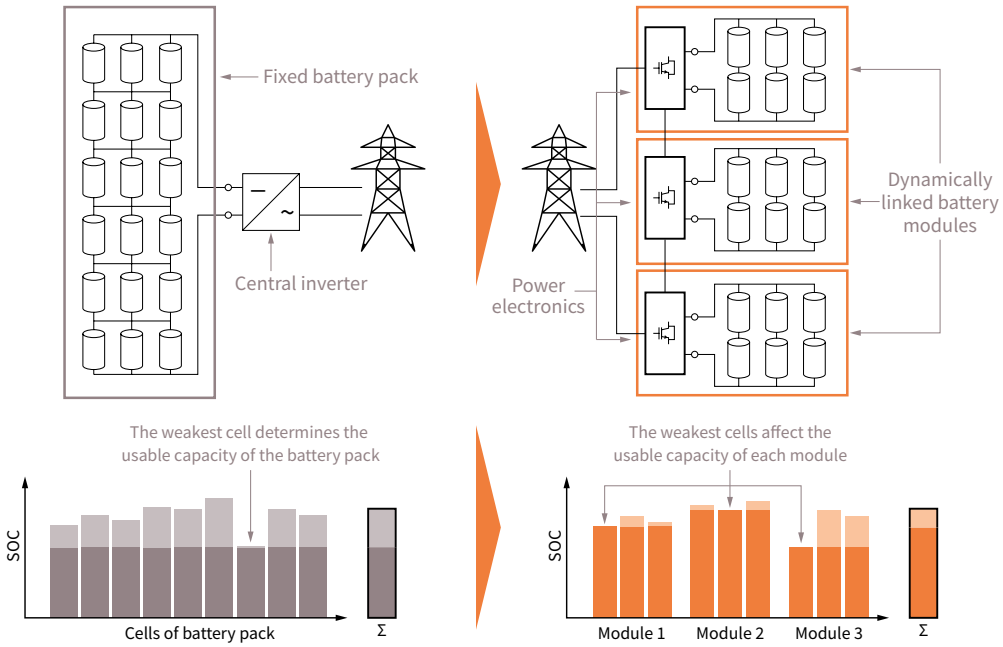
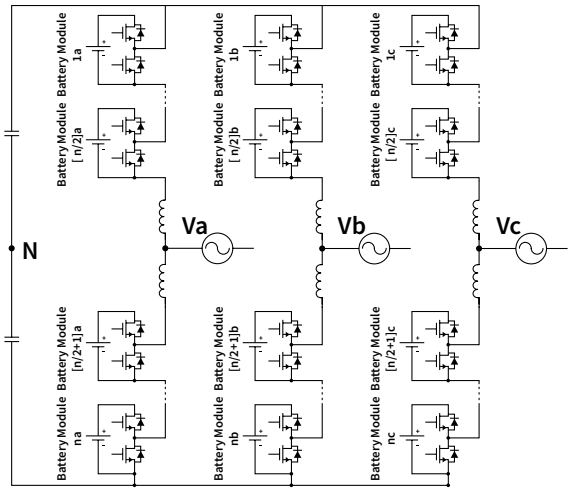
Battery utilization – IGBT based systems vs. multi-modular approach



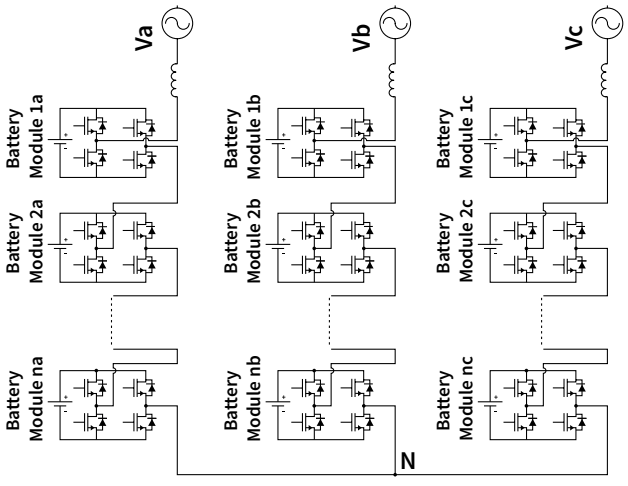
Solutions of a modular multi-level system

Cascaded, modular, multi-level three-phase inverter (100-250 kW)

Half-bridge



Full-bridge



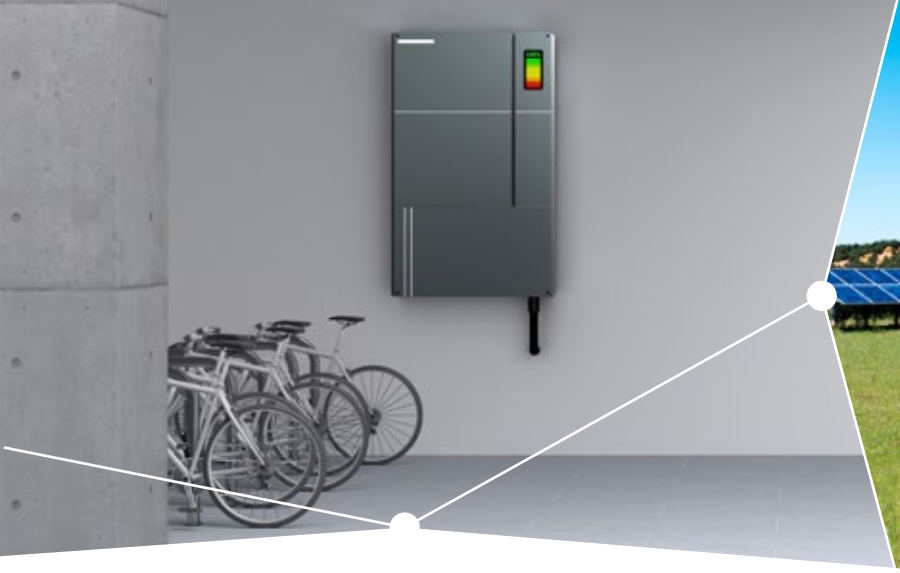
Product type	Battery module voltage	Product	Part number*	$R_{DS(on)}$
MOSFET	48 V	OptiMOS™ 5 80 V	IPT012N08N5	0.7 mΩ
	60 V	OptiMOS™ 5 100 V	IPT015N10N5	1.5 mΩ
	> 60 V	OptiMOS™ 5 150 V	IPB048N15N5	4.8 mΩ
Driver IC	Isolated EiceDRIVER™		2EDF7275F	–

*more products available:
www.infineon.com/optimos
www.infineon.com/gatedrivers

www.infineon.com/energy-storage-systems

PCS

For more details on the product, click on the part number.

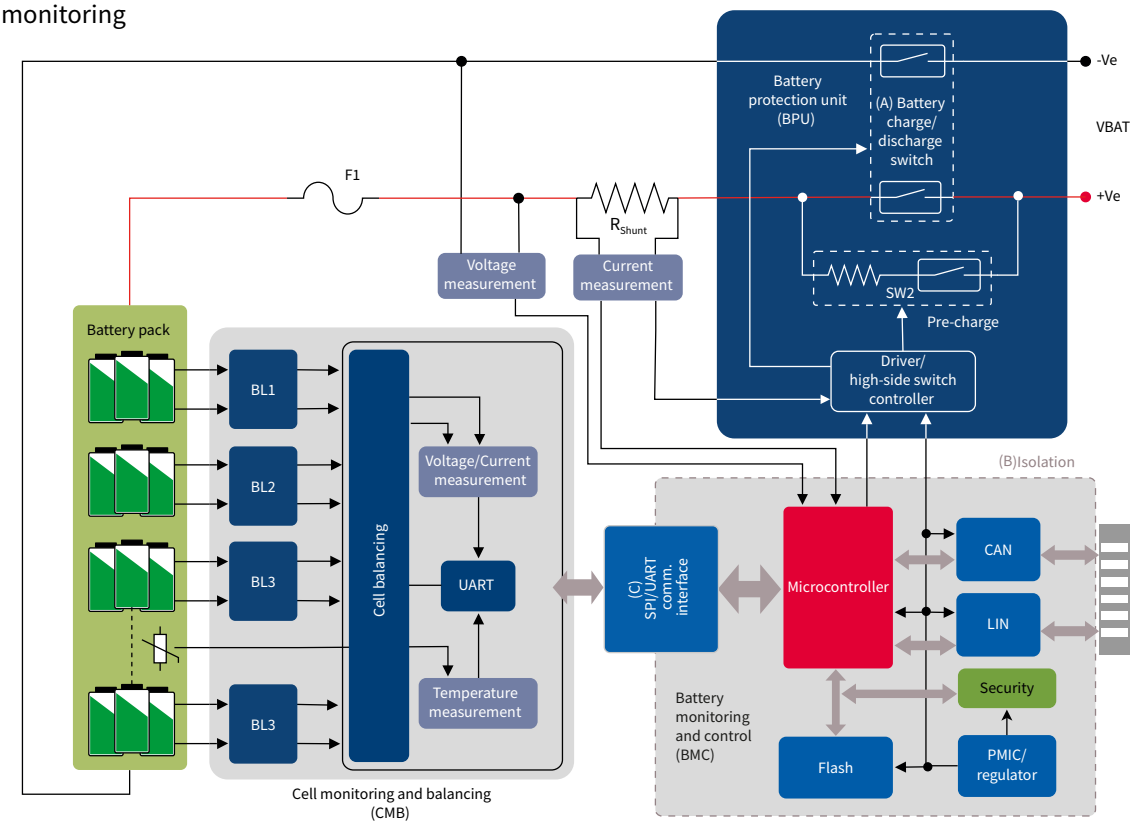


Battery management system

Infineon's battery management product family and reference designs help you layout your battery management system to perfectly fit your application. Careful considerations of charging and discharging processes in battery protection and cell monitoring will support you throughout your design. With our solutions and design resources for battery management systems you will overcome design challenges and succeed in developing more efficient, longer-lasting, and more reliable battery-powered applications.

In ESS a battery management system fulfills two top level functions, namely:

› Battery protection
› Battery monitoring



(A) MOSFETs are used for <60 V ESS and contactors are used for high-voltage and grid-scale ESS
(B) Isolation required only in high-voltage / grid-scale ESS
(C) SPI UART interface is required for communication between the battery modules in rack

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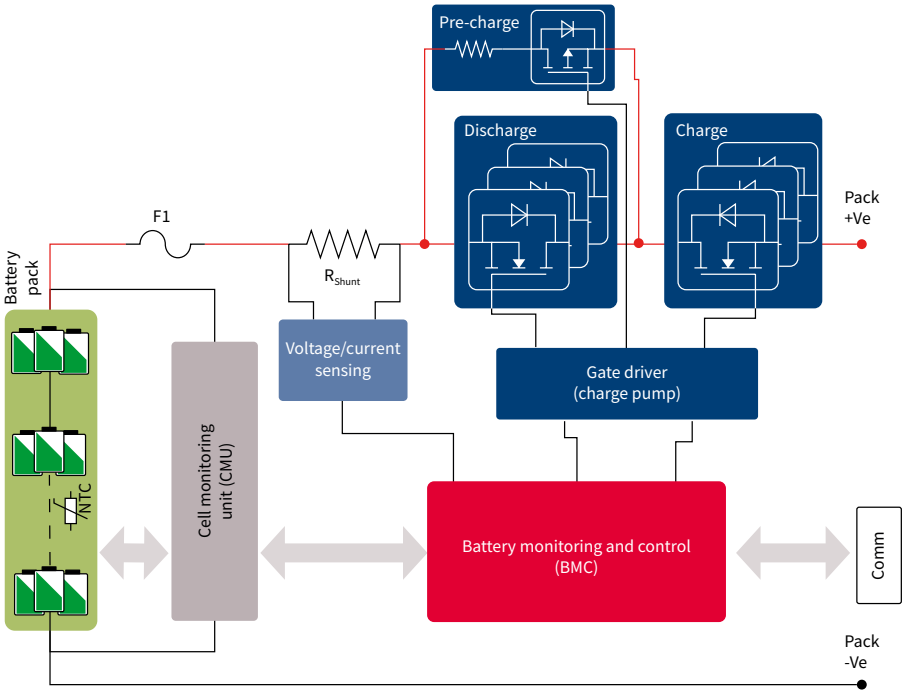
Battery protection

A battery needs to be protected against possible external faults that would put the system in danger. Protecting the battery from damage during the normal function of the system (charging and discharging process) is one of the main functionalities of a battery management system (BMS). Within Infineon's product portfolio you will find the right devices to disconnect the battery system in case a fault is detected, thereby protecting its value. They will also help to detect system faults like overcurrent/short circuits.



Product type	Battery voltage	BV(DSS)	Product	Part number	$R_{DS(on)}$
MOSFET	12-24 V	40 V 60 V	StrongIRFET™ 40 V	IRL40T209	1.1 mΩ
			StrongIRFET™ 60 V	IRF7748L1	2.2 mΩ
	40-60 V	100 V	OptiMOS™ 100 V	IPT015N10N5	1.5 mΩ
				IPB020N10N5	2.0 mΩ
				IPB017N10N5	1.7 mΩ
			OptiMOS™ LinearFET 100 V	IPB020N10N5LF	2.0 mΩ
	60-100 V	150 V	OptiMOS™ 150 V	IPT059N15N3	5.9 mΩ
				IPB048N15N5	4.8 mΩ
			OptiMOS™ LinearFET 150 V	IPB048N15N5LF	4.8 mΩ
	100-150 V	200 V	OptiMOS™ LinearFET 200 V	IPB110N20N3LF	11.0 mΩ
	150-400 V	600 V	600 V CoolMOS™ S7	IPT60R022S7	22.0 mΩ
Sensor	12-400 V	–	Current sensor	TLI4970	

Cell monitoring and balancing

An accurate and reliable battery monitoring solution is necessary to protect and maximize the performance of a lithium-ion battery. As such, the battery management system is in charge of monitoring each of the cells included in a battery pack and ensuring that they operate within the safe-operating range. Various parameters, such as cell voltage, state of charge (SoC), state of health (SoH), depth of discharge (DoD) and temperature have a decisive impact on the performance, safety, and lifetime of a battery pack. Additionally, the cell balancing function ensures that all cells operate under similar conditions, thus maximizing the battery capacity and longevity. Operating the battery outside of its specifications causes a drastic reduction in battery performance and risks damaging it. Thus leading to not only higher maintenance efforts but also a major cost factor.

www.infineon.com/energy-storage-systems

For more details on the product, click on the part number.

Transceiver and sensing ICs

The TLE9012AQU is a multi-channel battery monitoring and balancing system IC designed for Li-Ion battery packs used in automotive, industrial and consumer applications. TLE9012AQU fulfills four main functions: cell voltage measurement, temperature measurement, cell balancing and isolated communication to main battery controller. Additionally, TLE9012AQU provides the necessary diagnosis tools to ensure proper function of the controlled battery and detect any faults. TLE9012AQU host many unique features such guaranteed accuracy over the batteries lifetime and integrated filtering and balancing components. Furthermore, it is a unique IC that supports both inductive and capacitive isolations. Thus reducing allowing an extra reduction in the total system size and cost.

The TLE9015QU is a general-purpose transceiver IC to be used in multi-cell battery systems to enable the communication between the main host microcontroller and the slaves in the battery. Besides other applications, the IC has been designed to fit ESS either having one or more cell modules in series.

Device	Product	Part number
Battery monitoring unit	isoUART/UART transceiver IC	TLE9015QU
Cell supervisory circuit	12 ch sensing IC	TLE9012AQU

TLE9015QU
9 x 9 x 1.2 mm

TLE9012AQU
9 x 9 x 1.2 mm

Small signal MOSFET

Some batteries require higher balancing currents, which can be achieved with external small signal MOSFETs. Infineon small signal MOSFETs cover a range of standard SOT packages, TSOP-6 and SC59. Additionally, Infineon's small signal MOSFETs are used for driving all types of small components such as indicator LEDs.

- 20 V – 250 V P-channel enhancement mode
- 20 V – 600 V N-channel enhancement mode
- -20 V/20 V and -30 V/30 V complementary (P + N channel) enhancement mode
- 60 V – 600 V N-channel depletion mode

Most products are qualified to AEC-Q100. The portfolio includes products in super logic level (SLL, 2.5 V rated) and ultra logic level (ULL, 1.8 V rated) that allow direct driving by a microcontroller without the need for a driver. However, it also includes products in logic level (4.5 V rated) and normal level (10 V rated).
Small signal MOSFETs offer full functionality by saving printed circuit board space.

Device	Product	Part number
Single P-channel MOSFET, SLL	SOT-23, -20 V, Super Logic Level	BSS215P
Single N-channel MOSFET, ULL	SOT-23, 20 V, Ultra Logic Level, ESD protected	BSS806NE
Dual N-channel MOSFET, ULL	SOT-363, 20 V, Ultra Logic Level	BSD840N

SOT23
2.9 x 2.4 x 1.0 mm

SOT363 / SOT323
2.0 x 2.1 x 0.9 mm

Find full portofolio of Infineons small signal MOSFETS:
www.infineon.com/smallsignal

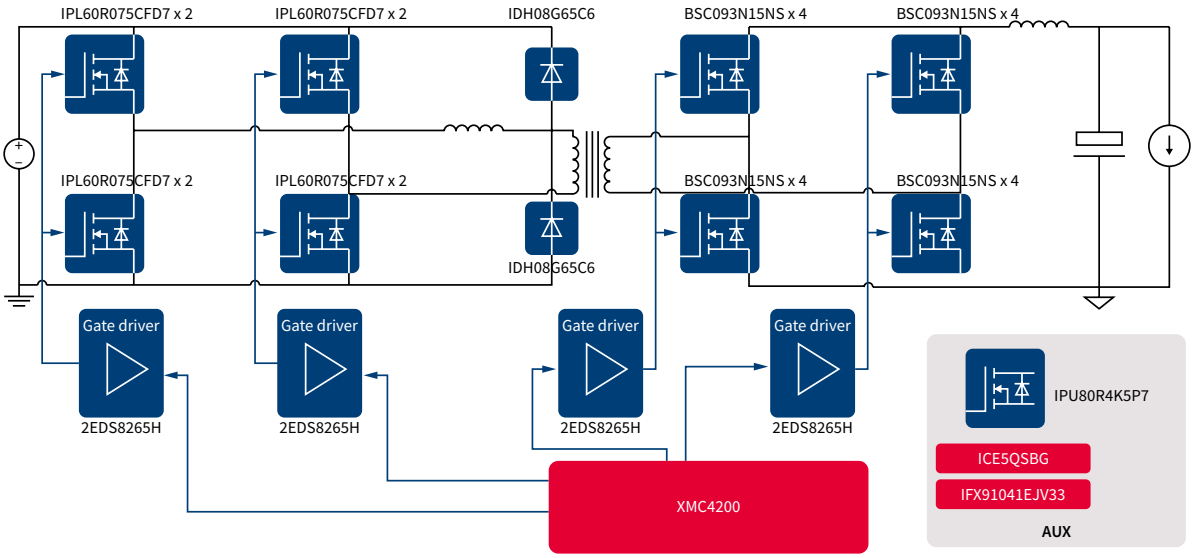
www.infineon.com/energy-storage-systems

BMS

For more details on the product, click on the part number.

EVAL_3K3W_BIDI_PSFB

Parameter	Specification
Input voltage	350 V_{DC} ~ 415 V_{DC}
Output voltage	40 V_{DC} ~ 60 V_{DC}
Output power	3300 W
Efficiency	98% peak
Topology	› Bi-directional mode › Novel integrated magnetics concept › Novel SMD cooling concept
HV devices	IPL60R075CFD7 (75 mΩ, 600 V)
LV devices	16x BSC093N15NS5 (9.3 mΩ, 150 V)
Driver	2x 2EDS8265H (4 A/8 A source/sink) 2x 2EDF7275F (4 A/8 A source/sink)
Schottky diode	2x IDH08G65C6 (650 V) 4x BAT165 (40 V)
Controller	XMC4200-F64K256 BA
AUX	ICE5QSBG CoolSET™ IPU80R4K5P7 (4.5 Ω, 800 V)



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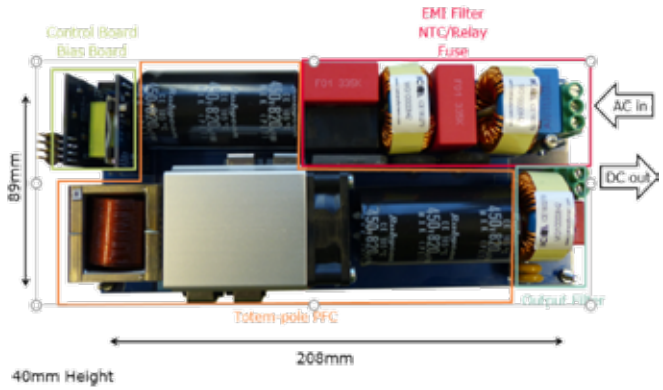
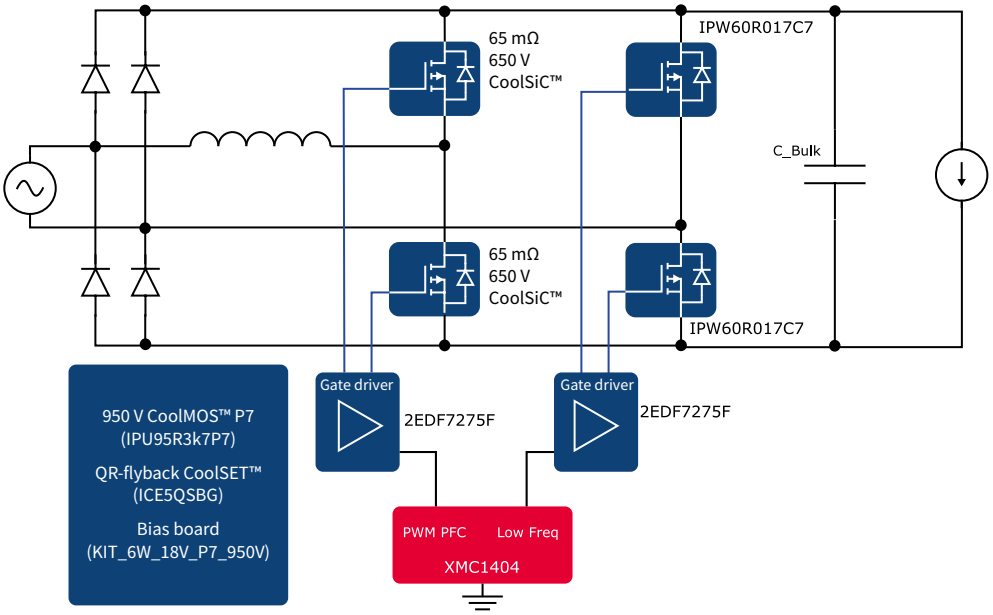
For more details on the product, click on the part number.

EVAL_3K3W_TP_PFC_SIC



Parameter	Specification
Input voltage	176 V_{AC} - 265 V_{AC}
Output voltage	400 V_{DC}
Output power	3300 W
PF	>0.95 from 20% load
Target efficiency	99% at 50% load
Power density	~72 W/inch^3
HV devices	2x IMZA65R048M1H CoolSiC™ 2x IPW60R017C7 CoolMOS™
Driver	2x 2EDF7275F EiceDRIVER™
Controller	XMC1404-F064X0200
QR-flyback	ICE5QSBG IPU95R3K7P7 CoolMOS™



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We partner
We innovate
We perform

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We make life easier, safer and greener.

Part of your life. Part of tomorrow.

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- India ..... 000 800 4402 951 (English)
- USA ..... 1-866 951 9519 (English/German)
- Other countries ..... 00* 800 951 951 951 (English/German)
- Direct access ..... +49 89 234-0 (interconnection fee, German/English)

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