Residential energy storage systems (ESS) and multi-modular topology for 2\textsuperscript{nd} life batteries
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 of behind-the-meter.

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 & temperature conditions enabling smaller size and weight → lower $ 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.

Full CoolSiC™ portofolio, consisting 1200 V and 650 V can be found on www.infineon.com/coolsic

![Energy storage systems diagram](image-url)
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 bidirectional 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.

Value of SiC in ESS

**Challenges and requirements**

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

**Benefits and value add**

- 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
- Losses reduction and increase efficiency at high operating temperatures, i.e. less losses and better thermals (smaller heatsink)

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**Enabling 2nd life of batteries**

Expensive testing, analysis, and matching of batteries diminishes the economic advantages of the 2nd life approach. Economical approach of reusing ranged out batteries and no need of battery maching.

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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)

<table>
<thead>
<tr>
<th>Product type</th>
<th>Battery module voltage</th>
<th>Product</th>
<th>Part number*</th>
<th>( R_{\text{DS(on)}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOSFET</td>
<td>48 V</td>
<td>OptiMOS™ 5 80 V</td>
<td>IPT012N08N5</td>
<td>0.7 mΩ</td>
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<tr>
<td></td>
<td>60 V</td>
<td>OptiMOS™ 5 100 V</td>
<td>IPT015N10N5</td>
<td>1.5 mΩ</td>
</tr>
<tr>
<td></td>
<td>&gt; 60 V</td>
<td>OptiMOS™ 5 150 V</td>
<td>IPB048N15N5</td>
<td>4.8 mΩ</td>
</tr>
<tr>
<td>Driver IC</td>
<td></td>
<td>EiceDRIVER™</td>
<td>2EDF7275F</td>
<td>–</td>
</tr>
</tbody>
</table>

*more products available at www.infineon.com/optimos

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Battery management system

Infineon’s integrated circuits and designs help you layout your battery management system. Careful design considerations on charging and discharging processes on battery protection and cell monitoring will support you throughout your design. Our solutions and design resources for a battery management system, help in overcoming design challenges and ensure your success in developing more efficient, longer-lasting and more reliable battery-powered applications.

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

› Battery protection
› Battery monitoring

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Battery protection

Detecting a variety of fault conditions and protecting the battery from damage during the charging and discharging process is the main functionality of a battery management system (BMS). Operating a battery outside of its specifications causes damages to the battery cells and leads to a failure of the battery. This is not only causing maintenance efforts, it is also a major cost factor. That explains why batteries must be closely monitored during charging and discharging.

Battery monitoring

In order to protect it, a battery must be monitored accordingly. The battery management system is in charge of monitoring each of the cells included in a battery pack and ensuring that they are operated within the safe-operating range. Various parameters, such as cell voltage, state of charge (SOC), state of health (SOH), and also the temperature have a decisive impact on the performance, safety, and lifetime of batteries. Battery configuration equals putting battery cells in series. The so called cell balancing ensures an even balancing between those cells.

Battery monitoring addresses

› State of charge (SOC)
› State of health (SOH)
› Cell temperature
› Cell balancing status

In order to offer its customers a complete system solution, Infineon's engineers are working on products paying specifically into battery monitoring. A general-purpose transceiver IC for multi-cell battery systems as well as a multi-channel battery monitoring and balancing system IC are currently in the pipeline. Don't miss out on these! Send an e-mail to the responsible Application Marketing Manager at Infineon if you are interested in receiving updates.

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### Parameter Specification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage</td>
<td>350 V_{DC} ~ 415 V_{DC}</td>
</tr>
<tr>
<td>Output voltage</td>
<td>40 V_{DC} ~ 60 V_{DC}</td>
</tr>
<tr>
<td>Output power</td>
<td>3300 W</td>
</tr>
<tr>
<td>Efficiency</td>
<td>98% peak</td>
</tr>
<tr>
<td>Topology</td>
<td>- Bidirectional mode</td>
</tr>
<tr>
<td></td>
<td>- Novel integrated magnetics concept</td>
</tr>
<tr>
<td></td>
<td>- Novel SMD cooling concept</td>
</tr>
<tr>
<td>HV devices</td>
<td>IPL60R075CFD7 (75 mΩ, 600 V)</td>
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<tr>
<td>LV devices</td>
<td>16x BSC093N15NS5 (9.3 mΩ, 150 V)</td>
</tr>
<tr>
<td>Driver</td>
<td>2x 2EDS8265H (4 A/8 A source/sink)</td>
</tr>
<tr>
<td></td>
<td>2x 2EDF275F (4 A/8 A source/sink)</td>
</tr>
<tr>
<td>Schottky diode</td>
<td>2x IDH08G65C6 (650 V)</td>
</tr>
<tr>
<td></td>
<td>4x BAT165 (40 V)</td>
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<tr>
<td>Controller</td>
<td>XMC4200-F64K256AB</td>
</tr>
<tr>
<td>AUX</td>
<td>ICESQSAG CoolSET™</td>
</tr>
<tr>
<td></td>
<td>IPU80R4K5P7 (4.5 Ω, 800 V)</td>
</tr>
</tbody>
</table>

![Diagram of the EVAL_3K3W_BIDI_PSFB](image-url)
Parameter Specification

- **Input voltage**: 176 VAC - 265 VAC
- **Output voltage**: 400 VDC
- **Output power**: 3300 W
- **PF**: >0.95 from 20% load
- **Target efficiency**: 99% at 50% load
- **Power density**: ~72 W/inch³
- **HV devices**: 2x IMZA65R048M1 CoolSiC™
  2x IPW60R17C7 CoolMOS™
- **Driver**: 2x 2EDF7275F EiceDRIVER™
- **Controller**: XMC1404-F064X0200
- **QR-flyback**: ICE5Q5AG
  IPU95R3K7P7 CoolMOS™

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We are the link between the real and the digital world.

Our values
We commit
We partner
We innovate
We perform

Our mission
We make life easier, safer and greener.

Part of your life. Part of tomorrow.
Service hotline

Infineon offers its toll-free 0800/4001 service hotline as one central number, available 24/7 in English, Mandarin and German.

› Germany .................... 0800 951 951 951 (German/English)
› China, mainland .......... 4001 200 951 (Mandarin/English)
› 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)

* Please note: Some countries may require you to dial a code other than "00" to access this international number.
Please visit www.infineon.com/service for your country!