Battery formation: a crucial step in the battery production process

Agenda

1. Introduction
2. What is battery formation (BF)
3. Battery formation power systems
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Battery matters, now more than ever

We are more and more surrounded by battery powered devices and electrical **vehicles**.

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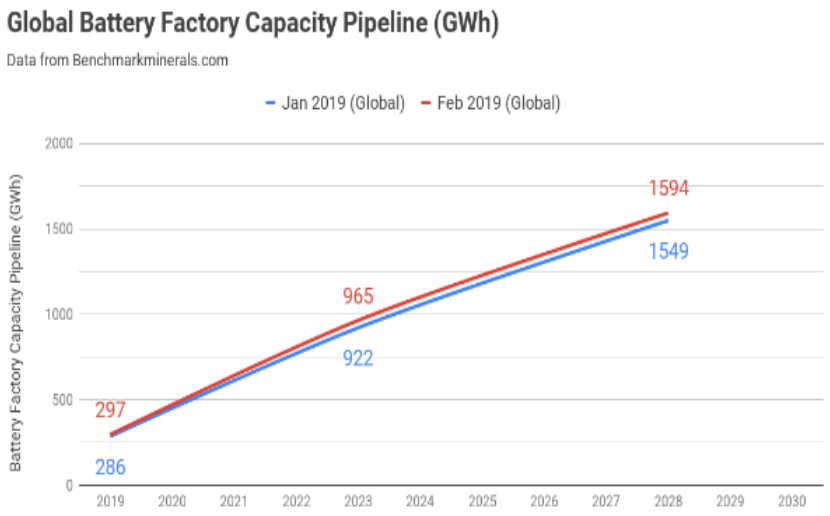
?

But what does it really take to make a battery? Moreover, what are the **requirements and challenges in the battery production process?**

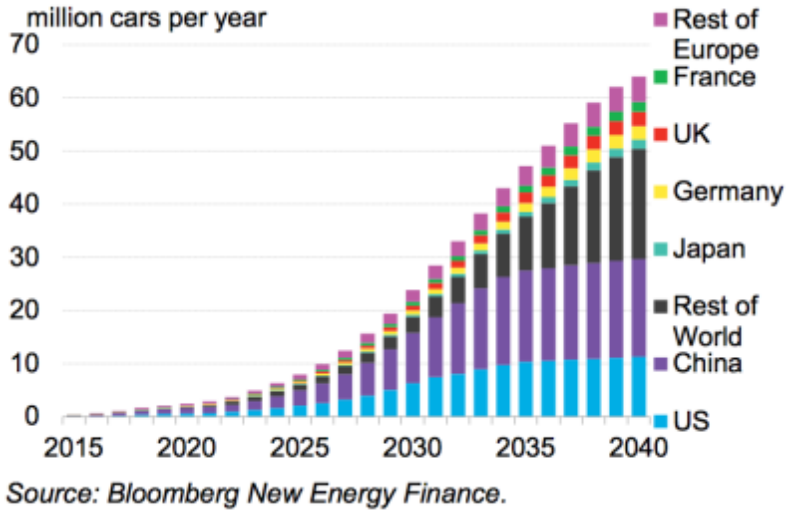
World powered by batteries

- **Increase in the number of battery power devices and electric vehicles (EVs)** in the following years will also propel the need for more batteries
- Today's production capacity of roughly 300 GWh is predicted to **increase to 1.6 TWh**

1 Increasing global demand for batteries



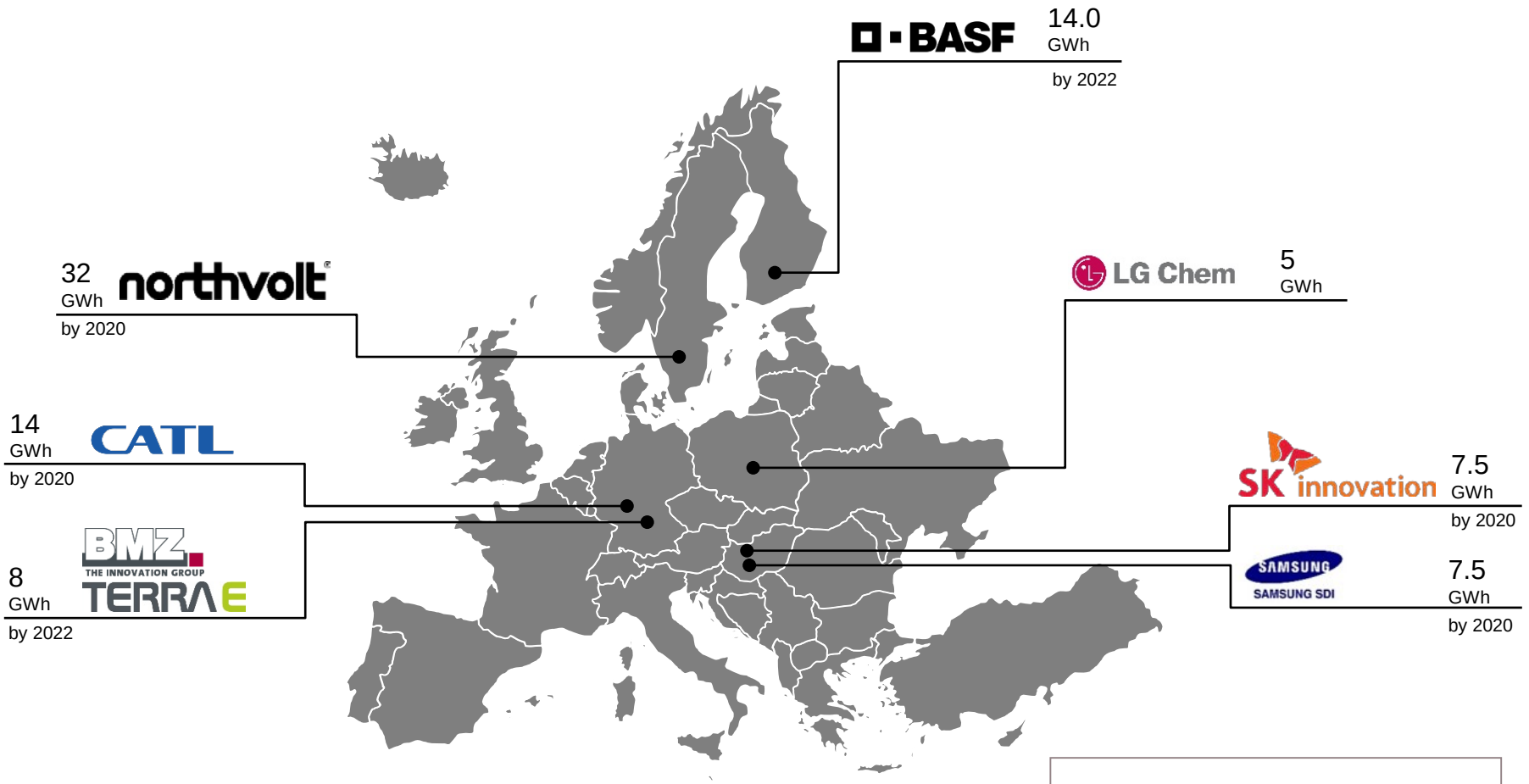
2 Rising number of EV



Source: Bloomberg New Energy Finance.

Current situation
Increasing production with key market in Asia

Future shift to Europe



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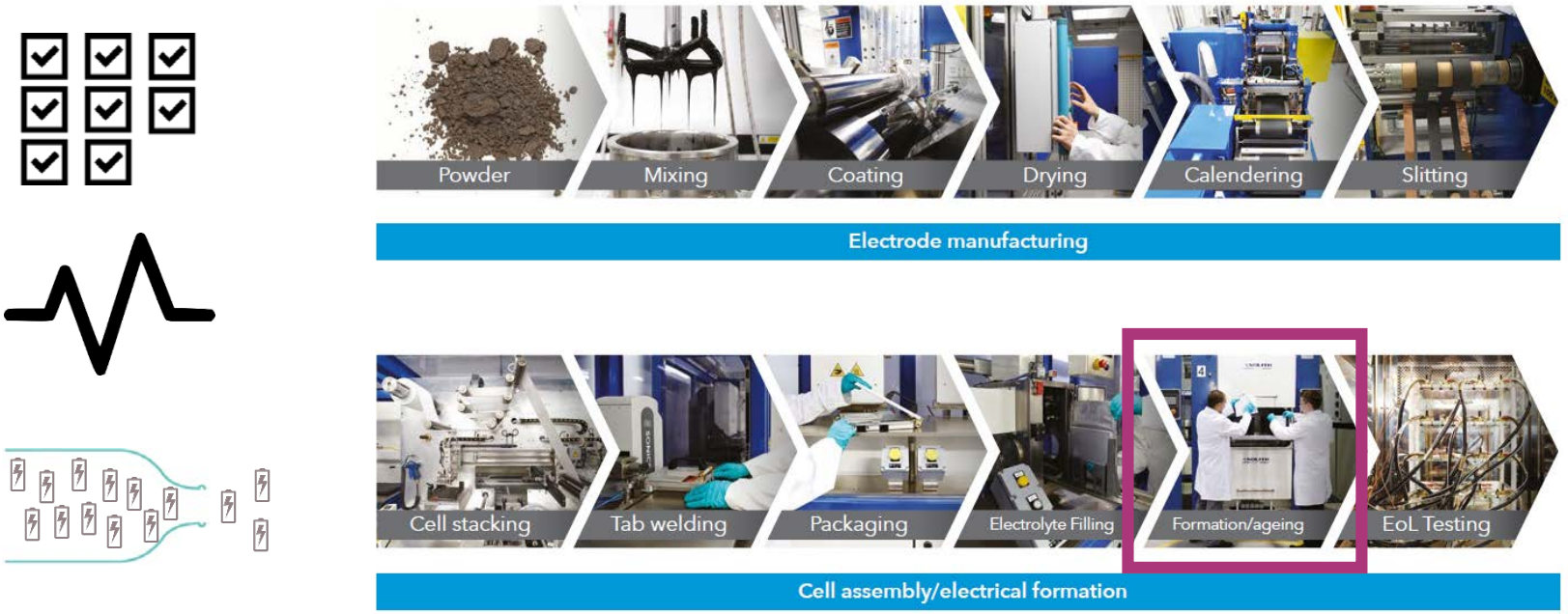
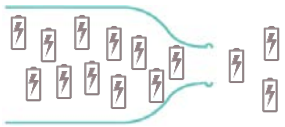
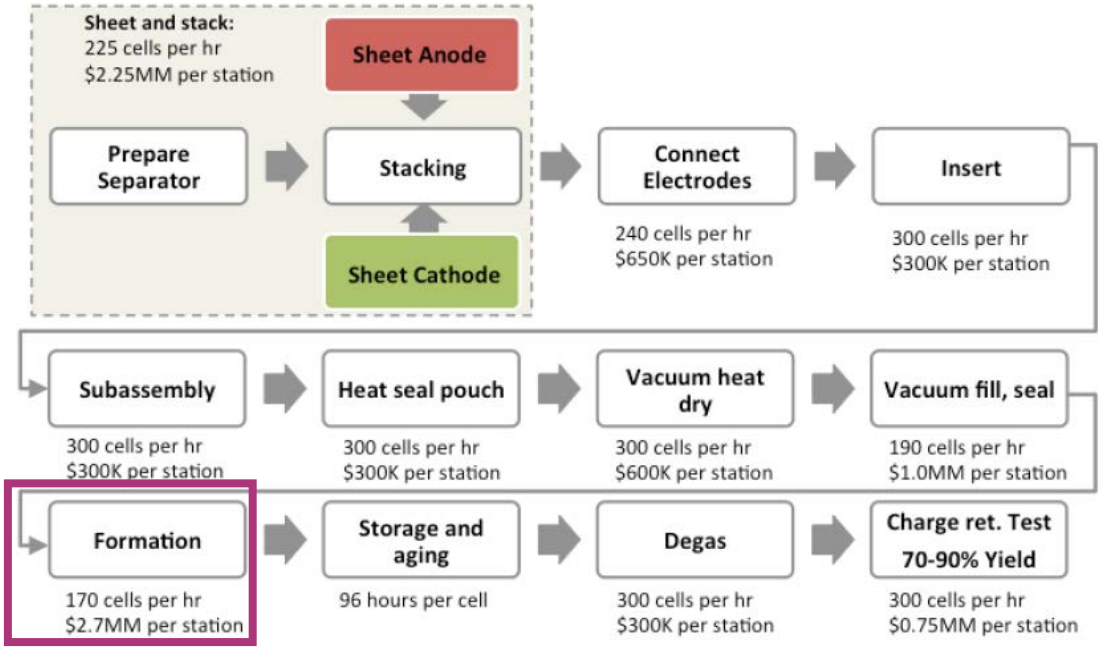
Battery formation – a critical step in the battery production process



- Essential stage **every battery needs to undergo** in the manufacturing process to become a functional unit
- **Activation of chemical material** by initially charging and discharging of newly assembled cell/pack over **high accuracy** in current and voltage (i.e. formation)
- The **formation cycle is a time consuming** process since each cell must be monitored separately, e.g. **bottleneck in production**
- **Capital and cost intensive** stage in battery production process

Battery formation (BF) – a critical step in the battery production process





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BF challenges and requirements

The BF process demands large amounts of energy and the system is running 24/7, resulting in three major requirements for battery formation applications, which are:

1	High power density
2	High system reliability
3	Energy recycling

As market leader in power semiconductors, Infineon is in a comfortable position to address these challenges and help customers to reach these goals.

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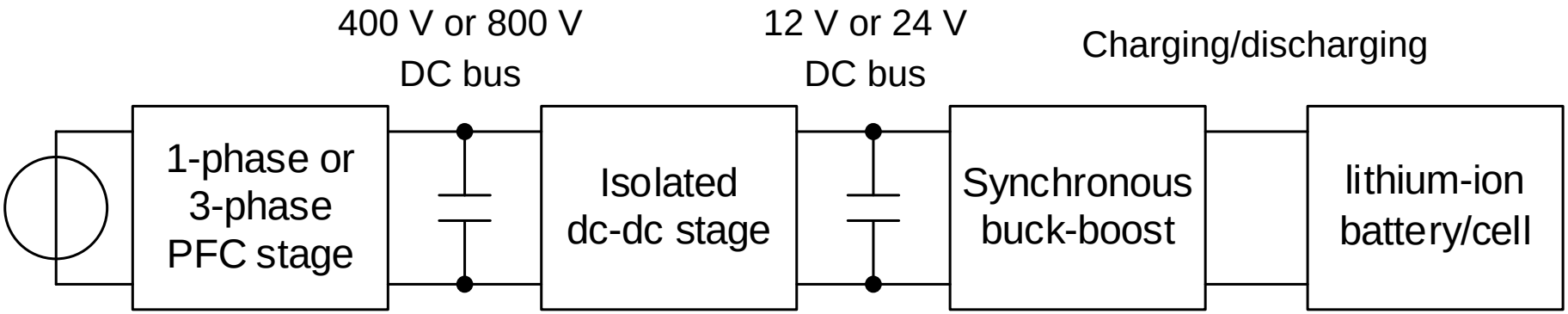
Block diagram of a formation power system

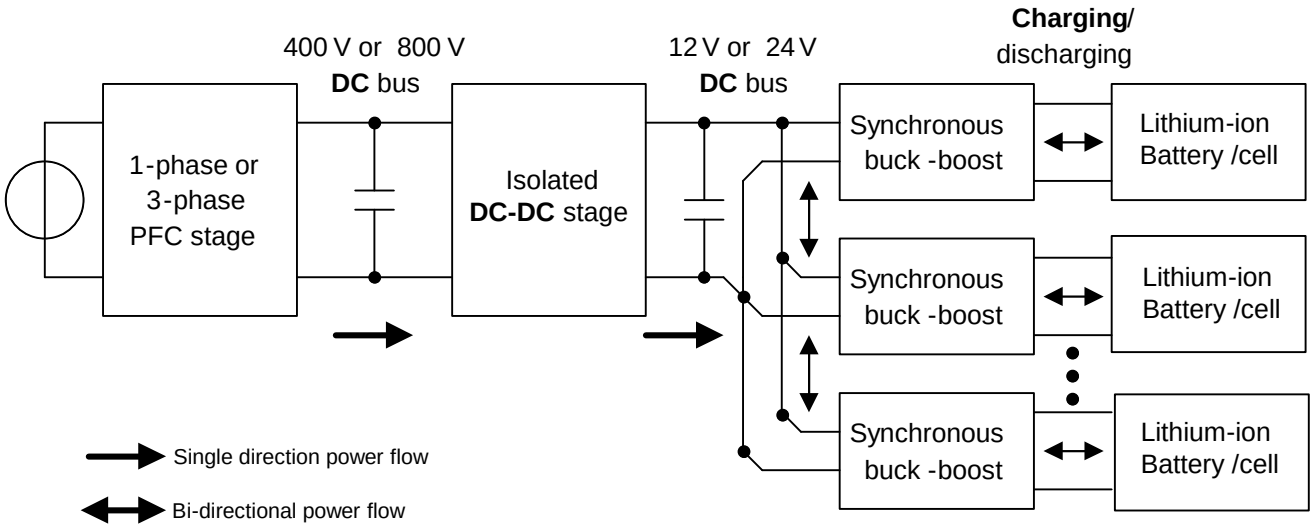


Stage	Description
PFC	PFC stage as an interface to the AC grid, single-phase and three-phase input voltage, unidirectional or bidirectional power transfer depends on system design
DC-DC	Provides galvanic isolation and step down 400 V (single-phase) to middle voltage, i.e., 100 V, 48 V, 24 V, or 12 V, based on tested battery voltage. Feature contains unidirectional or bidirectional power transfer.
Syn. Buck-boost	Key stage for battery function testing, provides 10 A, 20 A, 30 A or even 60 A sink and source capability. Required very precise battery voltage and battery current measurement. Bidirectional power transfer is must.
Battery/cell	Usually is Li-ion type battery. The battery cell voltage is 3.7-4.2 V or battery pack (12-48 V). Sometimes, the battery pack voltage can go up to 96 V.

Battery formation systems

Most common power stages used in battery formation equipment

Unidirectional system | Semi bidirectional system | Bidirectional system

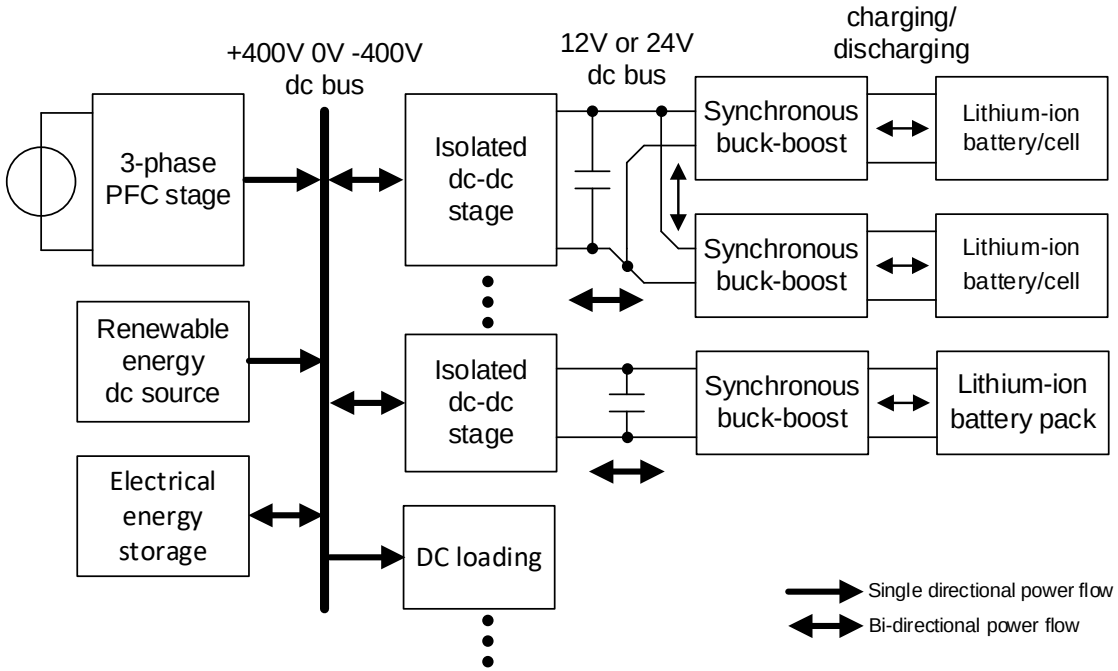


- PFC stage and isolated DC-DC stage are unidirectional power flow
- SR buck-boost converter is bidirectional power flow
- Discharge energy send to other SR buck-boost converter for charging
  - the discharge energy may not be completely recycle

Battery formation systems

Most common power stages used in battery formation equipment

Unidirectional system | **Semi bidirectional system** | Bidirectional system

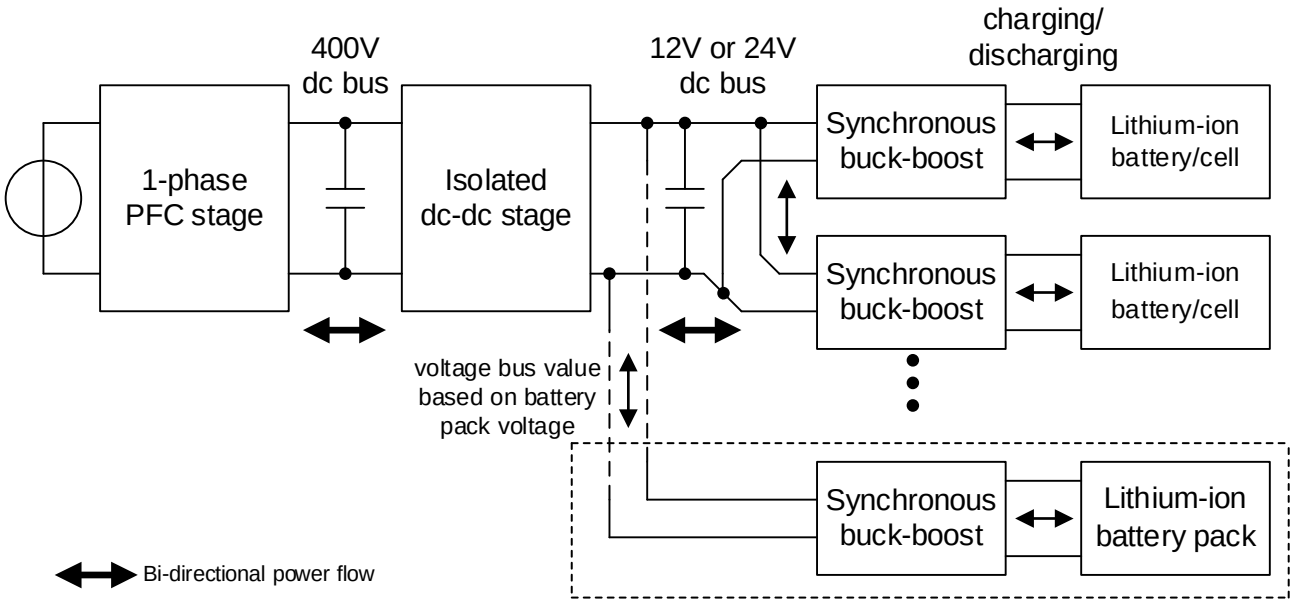


- PFC stage is unidirectional, isolated DC-DC stage, and SR buck-boost stages are bidirectional
- System power ~10 kW-30 kW, connecting several few kilowatts bidirectional isolated DC-DC stages
- HV bus is an interface for energy recycling

Battery formation systems

Most common power stages used in battery formation equipment

Unidirectional system | **Semi bidirectional system** | **Bidirectional system**



- PFC stage, isolated DC-DC stage, and SR buck-boost stages are bidirectional power flow
- Charging and discharging power levels are few kilowatts
- SR buck-boost converters charge and discharge at the same time to maximize recycling energy efficiency
- The system also possible to test high power battery pack

Infineon's solutions to Battery formation

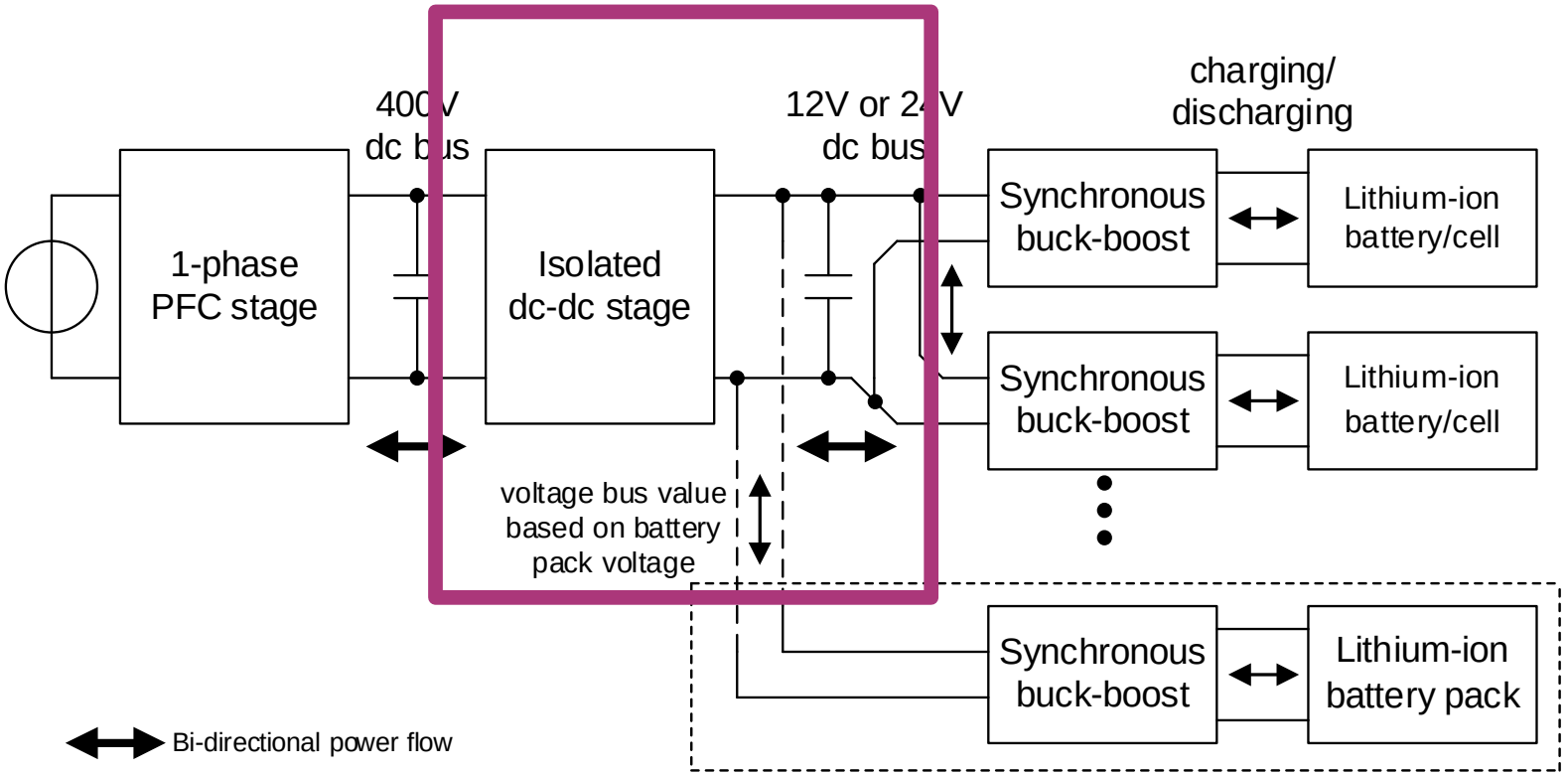
AC/DC Stage: Bi-directonal converter			
Power	**Stage**	**CoolMOSTM & IGBT**	**Driver**
2 KW	PFC	IPW60R090CFD7 TrenchtopTM H5	2EDFx 2EDSx 2EDNx 1EDIx
4KW		IPW60R040CFD7 TrenchtopTM H5	
2 KW	Isolated DC/DC_Primary Side	IPW60R105CFD7	
4KW		IPW60R090CFD7	
Auxiliary power supply		CoolSET TM 5 - ICE5QR4780AZ	
Microcontroller		XMC 4000 family	

Isolated DC-DC Secondary side*					
Vout	**MOSFET Breakdown Voltage**	**SMD package OptiMOSTM 6 & OptiMOSTM 5**			
		D2PAK	**SS08**	**TOLL**	**D2PAK-7**
12 V	**40 V**	IPB015N04L G(1.5mΩ)	BSC007N04LS6(0.7 mΩ)	IRL40T209(0.7mΩ)**	IPB011N04L(1.1mΩ)
24V	**60V**	IPB019N06L3 G (1.9 mΩ)	BSC012N06NS(1.2 mΩ)	IPT007N06N(0.75mΩ)	IPB014N06N(1.4mΩ)
48 V	**100 V**	IPB020N10N5 (2.0 mΩ)	BSC027N10NS5 (2.7mΩ)	IPT015N10N5(1.5mΩ)	IPB017N10N5(1.7mΩ)
96 V	**150 V**	IPB048N15N5(4.8mΩ)	BSC093N15NS5 (9.3mΩ)	IPT059N15N3(5.9mΩ)	IPB044N15N5(4.4mΩ)
	200 V	IPB107N20N3 (10.7mΩ)	BSC220N20NSFD(22mΩ)	IPT111N20NFD(11.1mΩ)	
Drivers		1EDN7550B 2EDF7275X			
Microcontroller		XMC 4000 family			

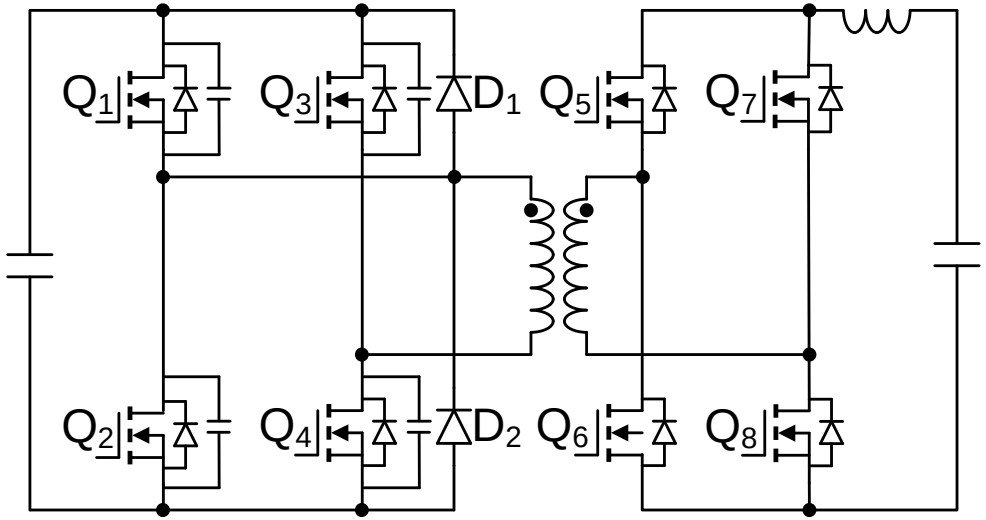
Non Isolated Bidirectional DC/DC stage*							
Vin	MOSFET Breakdown Voltage	SMD package OptiMOSTM 6 & OptiMOSTM 5				Through the hole package OptiMOStm & StronIRFET	
		D2PAK	**SS08**	**TOLL**	**D2PAK-7**	**TO220**	**TO247**
12 V	30 V	IRLS3813PbF (1.95mΩ)	BSC011N03LS(1.1 mΩ)	IPT004N03L(0.4mΩ)	IPB009N03L(0.95mΩ)	IRLB3813(1.95mΩ)	IRFP3703 (2.8mΩ)
24 V	40V	IPB015N04L G (1.5mΩ)	BSC007N04LS6(0.7 mΩ)	IRL40T209(0.7mΩ)**	IPB011N04L(1.1mΩ)	IRLB3034 (2.0mΩ)	IRFP7430PBF(1.3mΩ)
	60V	IPB019N06L3 G (1.9 mΩ)	BSC012N06NS(1.2 mΩ)	IPT007N06N(0.75mΩ)	IPB014N06N(1.4mΩ)	IPP020N06N(2.0mΩ)	IRFP7530(2.0mΩ)
48 V	100V	IPB020N10N5 (2.0 mΩ)	BSC027N10NS5 (2.7mΩ) BSC093N15NS5 (150V, 9.3mΩ)	IPT015N10N5(1.5mΩ)	IPB017N10N5(1.7mΩ)	IPP023N10N5(2.3 mΩ)	IRF100P219(1.7 mΩ)
96 V	200V	IPB107N20N3 (10.7mΩ)	BSC220N20NSFD(22mΩ)	IPT111N20NFD(11.1mΩ)		IPP110N20N3(11 mΩ)	IRF200P222(6.6 mΩ)
Driver		1EDN7550B 2EDF7275X					

* Best in class products for given package
** StrongIRFET

Bidirectional system: isolated HV DC/DC stage



Isolated bidirectional DC-DC demonstration board

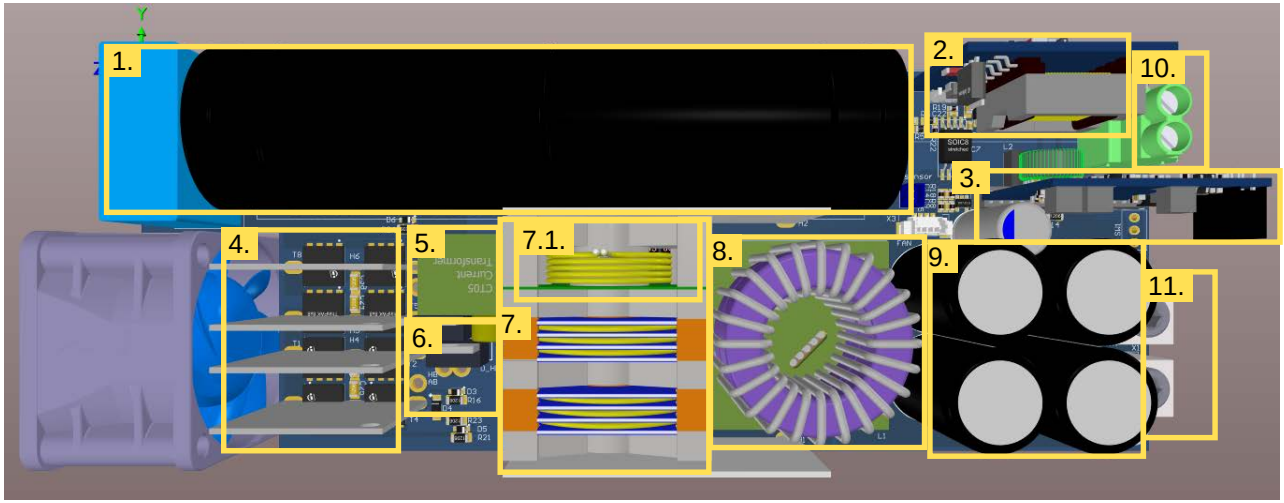


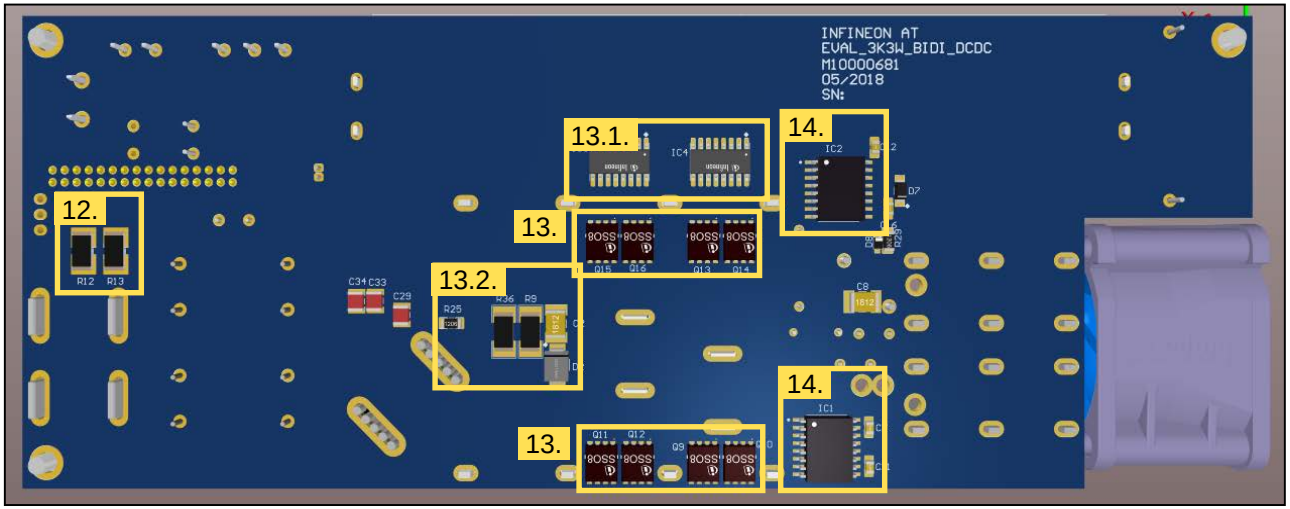
Specification:

- V_{in}: 360-420 V_{dc} (400 V nom.)
- V_{out}: 40-60 V (54.5 V nom.)
- P_{out}: 3300 W
- Topology: ZVS PSFB
- Power density: 96 W/in³ (without fan)
- Peak efficiency: 98.07% at charging mode (with bias supply)
- Peak efficiency: 97.57% at discharging mode (with bias supply)

HV & LV bus voltage	Designator	Part number
HV bus 400 V	Q_1-Q_4	IPL60R075CFD7 two pieces in parallel
	D_1-D_2	IDH08G65C6
	Driver IC Q_1-Q_4	2EDS8265H
LV bus 12 V	Q_5-Q_8	BSC007N04LS6 four pieces in parallel
LV bus 24 V	Q_5-Q_8	BSC025N08LS5 four pieces in parallel
LV bus 48 V	Q_5-Q_8	BSC093N15NS5 four pieces in parallel
	Driver IC Q_5-Q_8	2EDF7275F
	AUX controller	ICE5QSAG
	AUX flyback MOSFET	IPU80R4K5P7

Board distribution





Functional blocks

1. HV bulk
2. Bias supply
3. Control card
4. HV bridge
5. C. sence
6. C. diodes
7. Maintransformer

7.1. LR

8. Output choke
9. Output capasitor
10. Input connector
11. Output connector
12. Output shunt
13. Synchronous rectification

13.1. Functional isolated driver (SR)

13.2. Snubber (SR)

14. Reinforced isolated drivers (bridge)

*SR - Synchronous rectification

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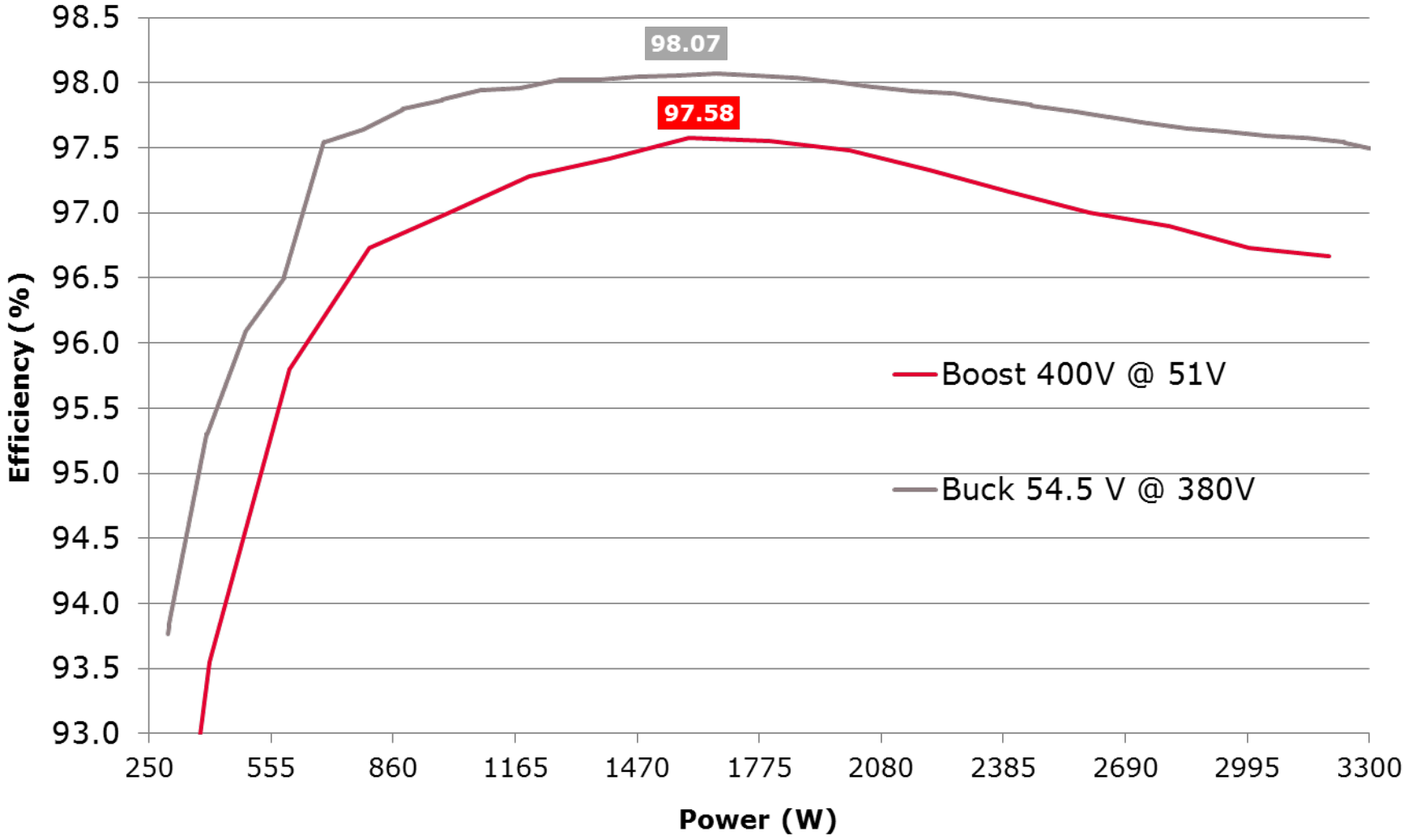
Efficiency
Bias and fan included



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Summary

- The next years will see an increasing demand for batteries, especially for EVs
- Today, bottleneck in battery production is the battery formation process, which is:
  - time consuming
  - cost intensive
  - high power demanding

- Infineon offers a full system power solution that enables you to:
  1. Increase power density
  2. Improve efficiency
  3. Lower system cost and energy recycling

- 3.3 KW DC-DC demonstration board available – request one now!
- Visit: www.infineon.com/batteryformation

Summary

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Remember:
Every battery needs formation

Part of your life. Part of tomorrow.