Battery protection selection guide

The best-in-class protection solutions for lithium ion batteries

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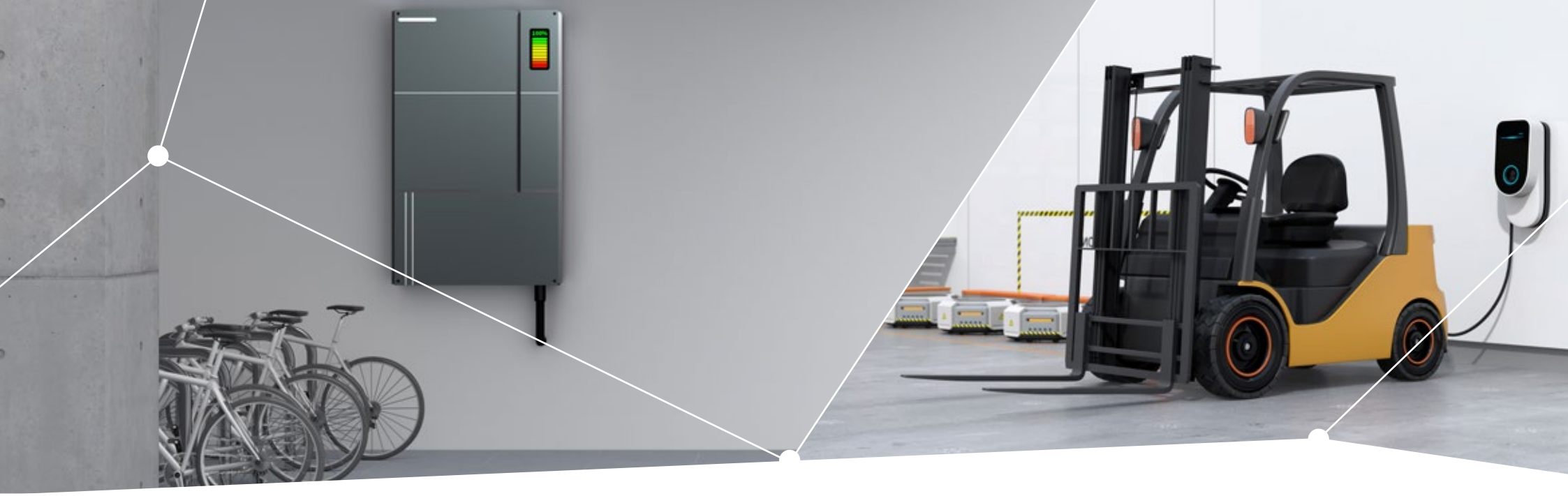


Battery protection

Lithium batteries are characterized by high energy and power density. Mishandling lithium batteries can lead to serious failures like thermal runaway, lithium plating, electrode decomposition, etc. Consequently, such batteries require special care in stressful conditions such as overcharge, undercharge, short circuits, overheat, etc.
For that, Infineon offers a wide range of battery protection solutions that, under stressful conditions, increase lifetime and efficiency of lithium batteries.

Battery protection			
Overcharge protection	Undercharge protection	Short circuit protection	Inrush current protection

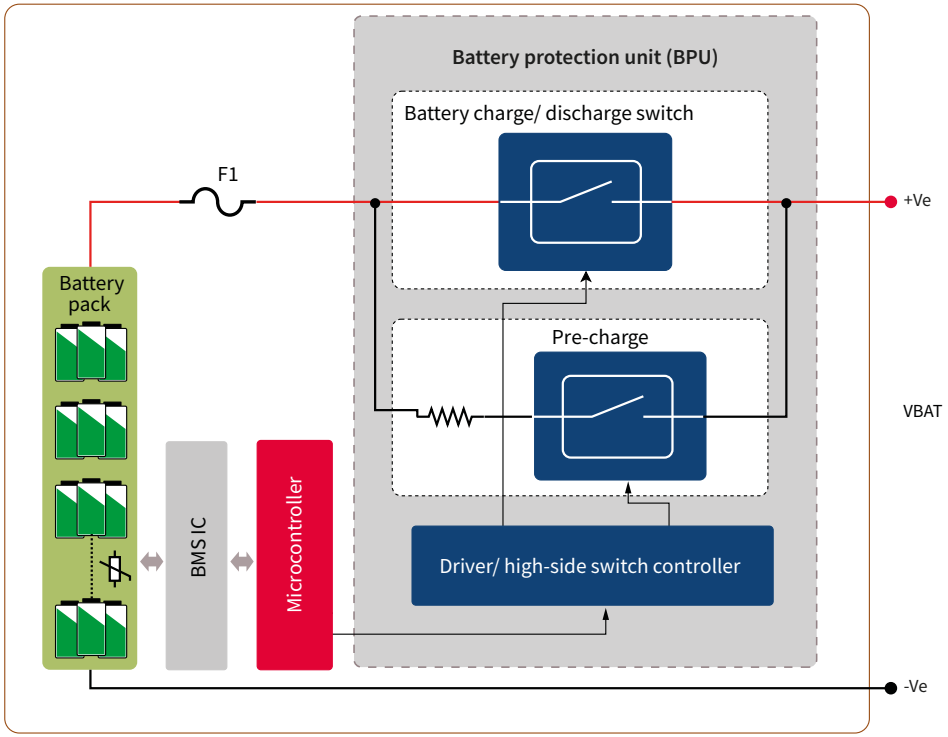
High side protection	Low side protection	Switching speed	Parallel FETs	Heat management

Key benefits

- Higher performance with lower $R_{DS(on)}$
- Wider safe operating area (SOA)
- Cheaper solutions with more compact bill of material and more effective parallelization solutions
- Short circuit protection with higher peak current rates
- Turn-on and turn-off solutions tailored to applications needs
- Up to 600 V MOSFET protection solutions (including single- and multi-module)

Battery protection unit

The battery protection circuit disconnects the battery from the load when a critical condition is observed, such as short circuit, undercharge, overcharge or overheating. Additionally, the battery protection circuit manages current rushing into and out of the battery, such as during pre-charge or hotswap turn on.



Key features and benefits

Wider SOA	Lower $V_{GS,th}$ spread	Fewer MOSFETs in parallel	Lower $R_{DS(on)}$
› Better inrush current management › More rugged during short circuit conditions	› More rugged and reliable solutions › Faster and more stable short circuit response › More robust parallelization	› Higher system reliability › Lower system cost › Smaller PCB footprint	› Lower thermal losses › Higher efficiency › Smaller PCB footprint

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Product portfolio

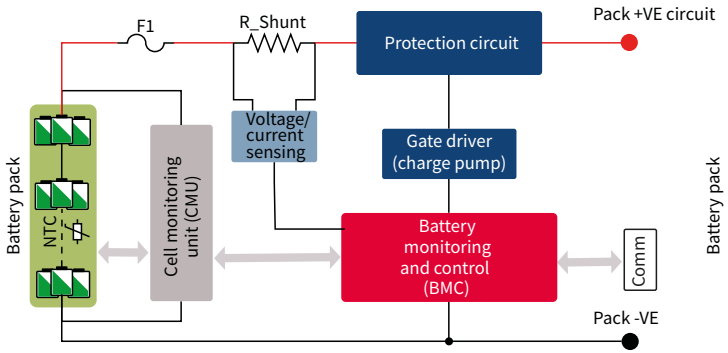
Battery voltage	MOSFET voltage class	Package	Technology	$R_{(DS)on}$	R_{thJC}	Part number
12 V	25 V	SuperSO8	OptiMOS™	≤ 0.45 mΩ	≤ 0.8 °C/W	BSC004NE2LS5
		PQFN 3.3x3.3 SD	OptiMOS™	≤ 0.65 mΩ	≤ 1.4 °C/W	IQE006NE2LM5
		DirectFET	StrongIRFET™	≤ 0.8 mΩ	≤ 1.4 °C/W	BSB008NE2LX
		PQFN 3.3x3.3	OptiMOS™	≤ 0.9 mΩ	≤ 1.8 °C/W	BSZ009NE2LS5
	20 V	SuperSO8	StrongIRFET™	≤ 0.95 mΩ	≤ 0.8 °C/W	IRFH6200
		DirectFET		≤ 2.7 mΩ	≤ 1.4 °C/W	IRF6620
		TO220		≤ 1.5 mΩ	≤ 0.5 °C/W	IRF1324
18 V	30 V	TOLL	OptiMOS™	≤ 0.4 mΩ	≤ 0.5 °C/W	IPT004N03L
		SuperSO8		≤ 0.55 mΩ	≤ 0.8 °C/W	BSC005N03LS5
		PQFN 3.3x3.3		≤ 1.5 mΩ	≤ 1.8 °C/W	BSZ0500NSI
		DirectFET	StrongIRFET™	≤ 1.7 mΩ	≤ 1.4 °C/W	IRF6726M
		D2PAK		≤ 1.95 mΩ	≤ 0.64 °C/W	IRLS3813
		TO220		≤ 1.95 mΩ	≤ 0.64 °C/W	IRLB3813
	34 V	SuperSO8	OptiMOS™	≤ 7.9 mΩ	≤ 4.1 °C/W	BSC079N03LSC G
24 V	40 V	DirectFET	StrongIRFET™	≤ 0.45 mΩ	≤ 0.44 °C/W	IRL7472L1
		sTOLL	OptiMOS™	≤ 0.6 mΩ	≤ 0.6 °C/W	IST006N04NM6
		D2PAK7P	StrongIRFET™	≤ 0.65 mΩ	≤ 0.36 °C/W	IRL40SC228
		SuperSO8	OptiMOS™	≤ 0.7 mΩ	≤ 0.8 °C/W	BSC007N04LS6
		TOLL	StrongIRFET™	≤ 0.72 mΩ	≤ 0.3 °C/W	IRL40T209
		D2PAK		≤ 1.2 mΩ	≤ 0.4 °C/W	IRFS7430
		TO220		≤ 1.25 mΩ	≤ 0.4 °C/W	IRL40B209
		PQFN 3.3x3.3	OptiMOS™	≤ 1.8 mΩ	≤ 1.8 °C/W	BSZ018N04LS6
24-36 V	55 V	D2PAK7P	StrongIRFET™	≤ 2.6 mΩ	≤ 0.5 °C/W	IRF3805S-7P
36 V		D2PAK		≤ 3.3 mΩ	≤ 0.5 °C/W	IRF3805S
		TO220		≤ 3.3 mΩ	≤ 0.45 °C/W	IRF3805
	60 V	TOLL	OptiMOS™	≤ 0.75 mΩ	≤ 0.4 °C/W	IPT007N06N
		D2PAK7P	StrongIRFET™	≤ 1.3 mΩ	≤ 0.36 °C/W	IRF60SC241
		SuperSO8	OptiMOS™	≤ 1.45 mΩ	≤ 0.8 °C/W	BSC014N06NS
		DirectFET	StrongIRFET™	≤ 1.5 mΩ	≤ 0.44 °C/W	IRF7749L1
		TO220		≤ 1.9 mΩ	≤ 0.4 °C/W	IRL60B216
		D2PAK		≤ 1.95 mΩ	≤ 0.4 °C/W	IRL60S216
		PQFN 3.3x3.3	OptiMOS™	≤ 3.7 mΩ	≤ 1.8 °C/W	BSZ037N06LS5

Battery voltage	MOSFET voltage class	Package	Technology	$R_{(DS)on}$	R_{thJC}	Part number
48 V	80 V	TOLL	OptiMOS™	≤ 1.2 mΩ	≤ 0.4 °C/W	IPT012N08N5
		TO220		≤ 2 mΩ	≤ 0.4 °C/W	IPP020N08N5
		SuperSO8		≤ 2.5 mΩ	≤ 0.8 °C/W	BSC025N08LS5
		DirectFET	StrongIRFET™	≤ 4.4 mΩ	≤ 1 °C/W	BSB044N08NN3 G
		PQFN 3.3x3.3	OptiMOS™	≤ 7 mΩ	≤ 1.8 °C/W	BSZ070N08LS5
	100 V	TOLL	OptiMOS™	≤ 1.5 mΩ	≤ 0.4 °C/W	IPT015N10N5
		D2PAK	OptiMOS™ Linear FET	≤ 1.7 mΩ	≤ 0.4 °C/W	IPB017N10N5LF
		TO220	OptiMOS™	≤ 2.3 mΩ	≤ 0.4 °C/W	IPP023N10N5
		SuperSO8		≤ 3.4 mΩ	≤ 0.8 °C/W	BSC034N10LS5
		DirectFET	StrongIRFET™	≤ 3.5 mΩ	≤ 1.2 °C/W	IRF7769L1
		D2PAK7P		≤ 3.9 mΩ	≤ 0.4 °C/W	IRLS4030-7P
		D2PAK		≤ 4.2 mΩ	≤ 0.34 °C/W	IRF100S201
		PQFN 3.3x3.3	OptiMOS™	≤ 9.6 mΩ	≤ 1.8 °C/W	BSZ096N10LS5
72 V	120 V	TO220	OptiMOS™	≤ 4.1 mΩ	≤ 0.5 °C/W	IPP041N12N3 G
		SuperSO8		≤ 7.7 mΩ	≤ 0.9 °C/W	BSC077N12NS3 G
		PQFN 3.3x3.3		≤ 24 mΩ	≤ 1.9 °C/W	BSZ240N12NS3 G
	135 V	D2PAK7P	StrongIRFET™	≤ 5.9 mΩ	≤ 0.3 °C/W	IRF135SA204
		D2PAK		≤ 8.4 mΩ	≤ 0.34 °C/W	IRF135S203
		TO220		≤ 8.4 mΩ	≤ 0.34 °C/W	IRF135B203
	150 V	D2PAK	OptiMOS™ Linear FET	≤ 4.8 mΩ	≤ 0.4 °C/W	IPB048N15N5LF
		TO220	OptiMOS™	≤ 5.1 mΩ	≤ 0.5 °C/W	IPP051N15N5
		TOLL		≤ 5.9 mΩ	≤ 0.4 °C/W	IPT059N15N3
		SuperSO8		≤ 7.4 mΩ	≤ 0.7 °C/W	BSC074N15NS5
		DirectFET	StrongIRFET™	≤ 11 mΩ	≤ 1.2 °C/W	IRF7779L2
		D2PAK7P		≤ 11.8 mΩ	≤ 0.4 °C/W	IRFS4115-7P
		D2PAK		≤ 12.1 mΩ	≤ 0.4 °C/W	IRFS4115
		PQFN 3.3x3.3	OptiMOS™	≤ 52 mΩ	≤ 2.2 °C/W	BSZ520N15NS3 G
96 V	200 V	TO220	OptiMOS™	≤ 11 mΩ	≤ 0.5 °C/W	IPP110N20N3 G
		D2PAK	OptiMOS™ Linear FET	≤ 11 mΩ	≤ 0.5 °C/W	IPB110N20N3LF
		TOLL	OptiMOS™	≤ 11.1 mΩ	≤ 0.4 °C/W	IPT111N20NFD
		D2PAK	StrongIRFET™	≤ 16.9 mΩ	≤ 0.36 °C/W	IRF200S234
		SuperSO8	OptiMOS™	≤ 32 mΩ	≤ 1 °C/W	BSC320N20NS3 G
		DirectFET	StrongIRFET™	≤ 59.9 mΩ	≤ 1.4 °C/W	IRF6641
		PQFN 3.3x3.3	OptiMOS™	≤ 90 mΩ	≤ 2.5 °C/W	BSZ900N20NS3 G
150 V	250 V	TO220	OptiMOS™	≤ 20 mΩ	≤ 0.5 °C/W	IPP200N25N3 G
		TOLL		≤ 21 mΩ	≤ 0.4 °C/W	IPT210N25NFD
		D2PAK	StrongIRFET™	≤ 48 mΩ	≤ 0.45 °C/W	IRFS4229
		SuperSO8	OptiMOS™	≤ 60 mΩ	≤ 1 °C/W	BSC600N25NS3 G
		PQFN 3.3x3.3		≤ 165 mΩ	≤ 2 °C/W	BSZ16DN25NS3 G
	300 V	TO220		≤ 41 mΩ	≤ 0.5 °C/W	IPP410N30N
		SuperSO8		≤ 130 mΩ	≤ 1 °C/W	BSC13DN30NSFD
300 V	600 V	TO220	CoolMOS™ S7	≤ 22 mΩ	≤ 0.32 °C/W	IPP60R022S7
		TOLL		≤ 22 mΩ	≤ 0.32 °C/W	IPT60R022S7

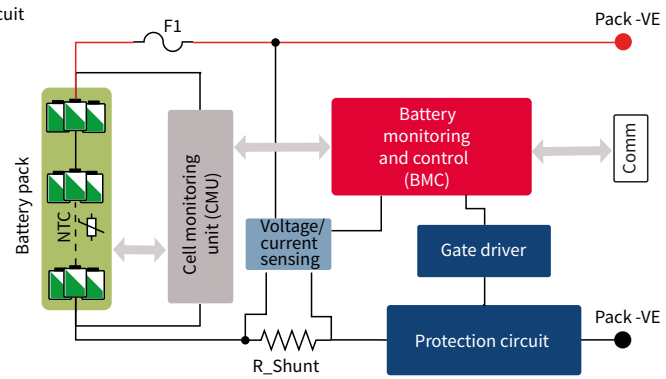
Battery disconnect protection

Battery protection topologies

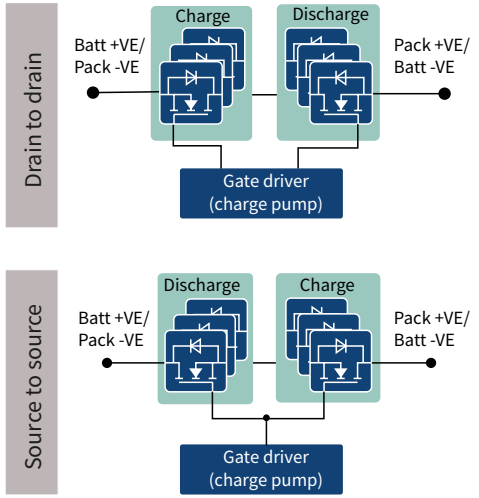
High side



Low side

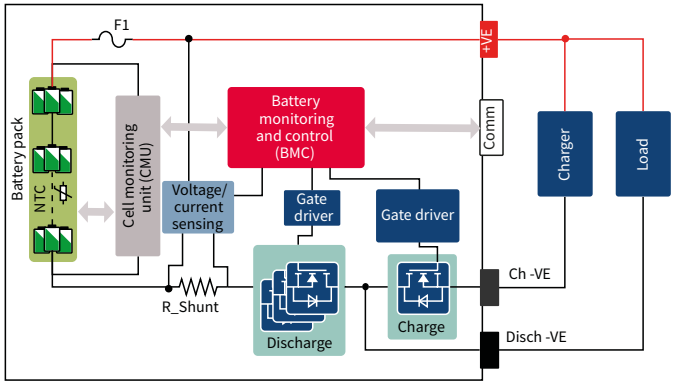


Protection circuit

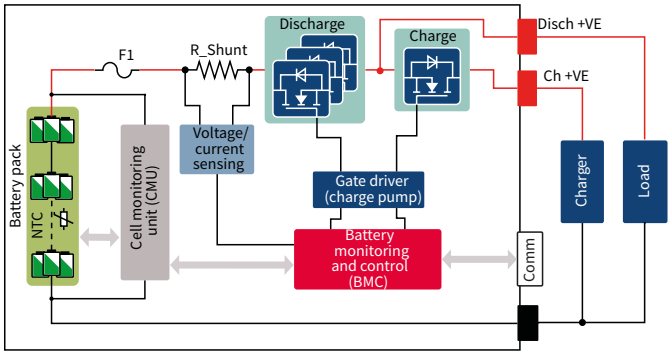


Separate charge and discharge port

Low side



High side



- Charge MOSFET is the MOSFET which controls the flow of charging current (i.e. current from the source or charger) into the battery.
- Discharge MOSFET is the MOSFET which controls the flow of discharging current (i.e. current from the battery) into the load.

Please note:
Shown are examples. Irrespective to the protection implementation on high or low side, either source-to-source or drain-to-drain configurations are possible.

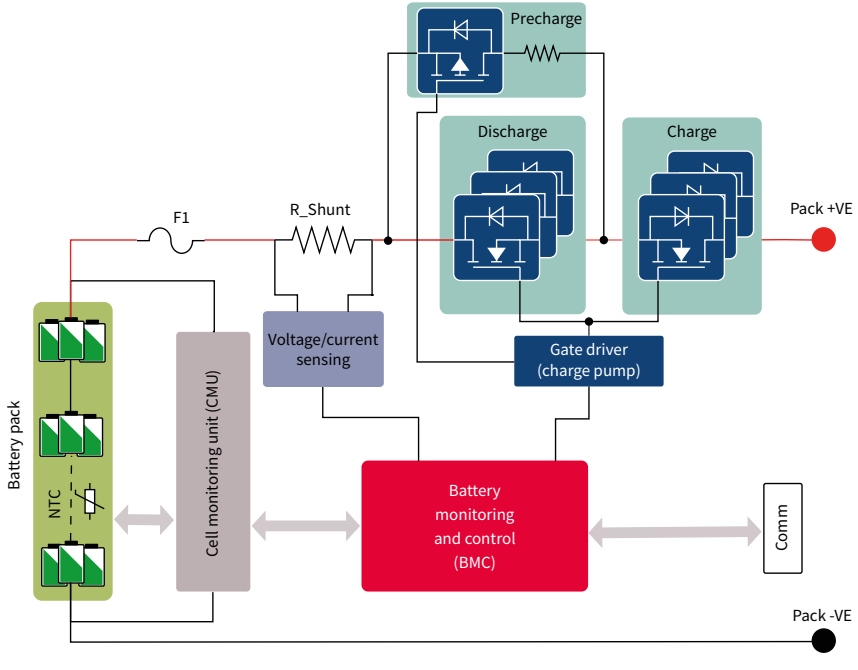
Load inrush current protection

Inrush currents arise during the turn on, mainly when the battery is first connected to the load. The inrush currents can get high enough to either destroy the protection circuit or to blow off the protection fuse. A load pre-charge circuit would limit the inrush current during the turn on phase and protect both the battery and the load. The pre-charge circuit is required whenever any of the following conditions occur:

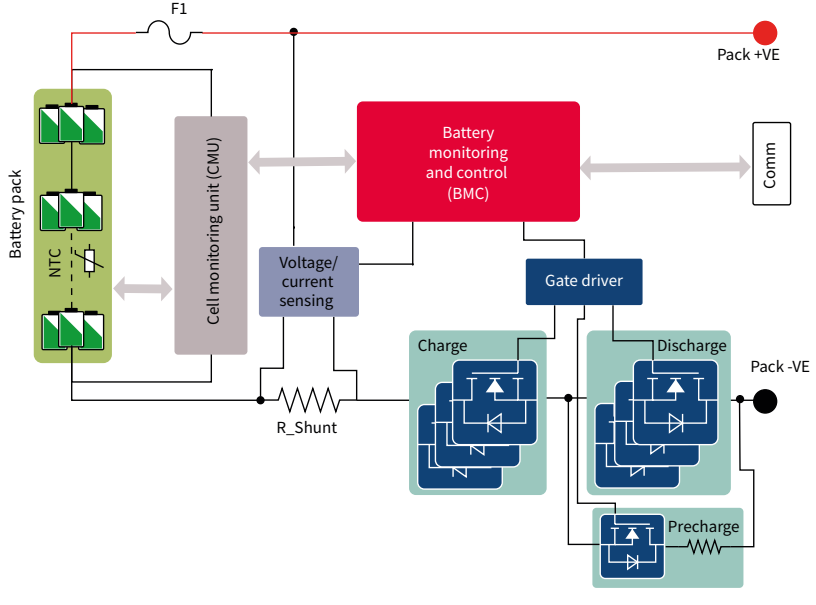
- The load has high input capacitance, which will be damaged by the inrush current
- The main fuse will blow off if the turn on current exceeded the fuses limit
- The contactors, if present, will be damaged by the inrush current
- The battery cells are not rated for the inrush current
- The MOSFETs are not rated for the inrush current

Inrush current / load pre-charge circuit configuration

Using P-MOSFET



Using N-MOSFET



Precharge MOSFET Package	PQFN 2x2	S308	SS08	SOT223	DPAK	
Dimension	2 mm x 2 mm	3 mm x 3 mm	5 mm x 6 mm	6.5 mm x 6.5 mm	6.5 mm x 6.5 mm	
Current	<5 A	<10 A	<20 A	>2 A	<2 A	<10 A
Type	N-Ch	N-Ch	N-Ch	N-Ch	P-Ch	N-Ch

Please note:
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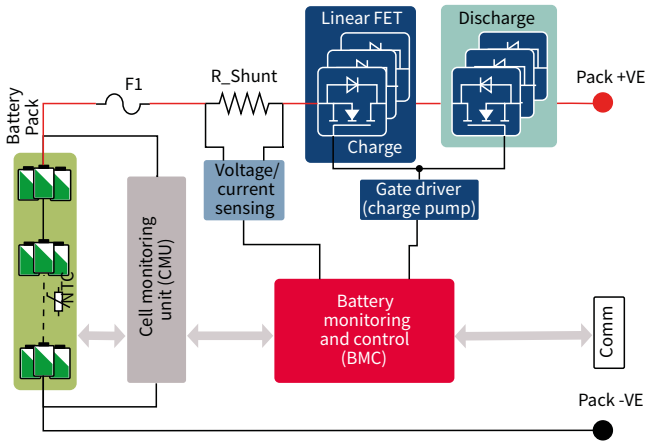
Battery pre-charge protection

Battery pre-charge protection with Linear FET

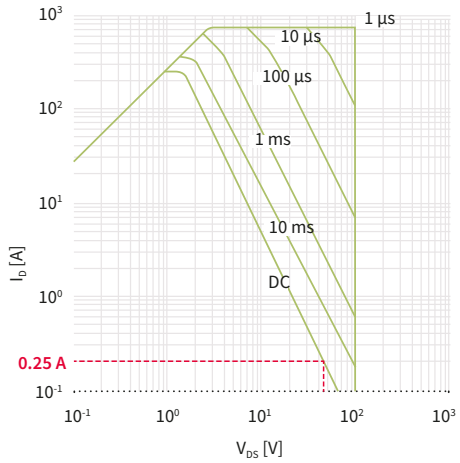


Li-ion batteries have three primary charging stages. During the first stage a pre-charge current is applied if the battery is deeply discharged (usually below 2.8 to 3 V). This stage prevents overheating of a deeply discharged battery. The pre-charge current is usually set to 10 percent of the fast-charge current. Once the battery voltage is greater than 2.8-3.0 V, the second stage of charging can be performed using the fast-charge current.

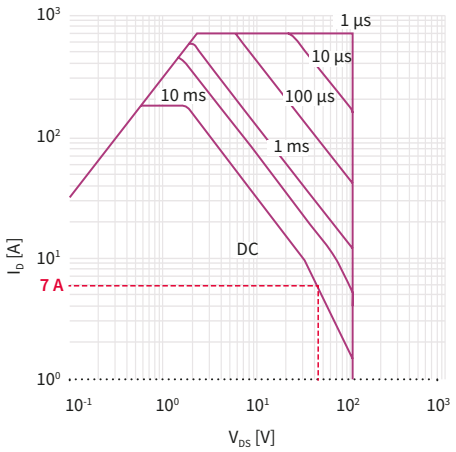
OptiMOS™ LinearFET has an extra wide SOA limiting the pre-charge current during the first stage. Thus adding additional protection to the battery in case the charger fails.

SOA of comparison 100 V

OptiMOS™

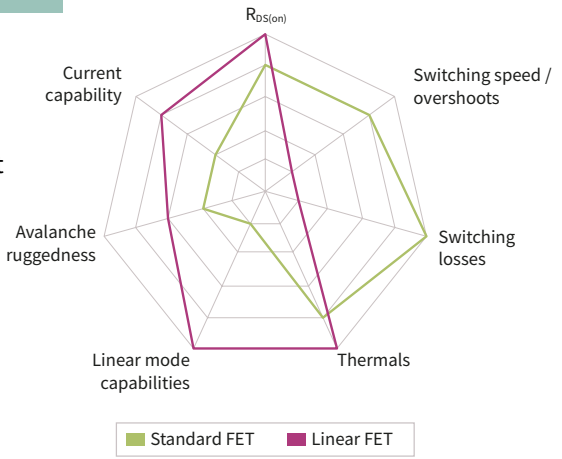


OptiMOS™ Linear FET



With Linear FET

- Combination of low $R_{DS(on)}$ and wide safe operating area (SOA)
- Higher continuous and pulse current
- Rugged linear mode operation
- Higher avalanche ruggedness
- Pre-charge circuit not required
- Compact solution with smaller PCB footprint



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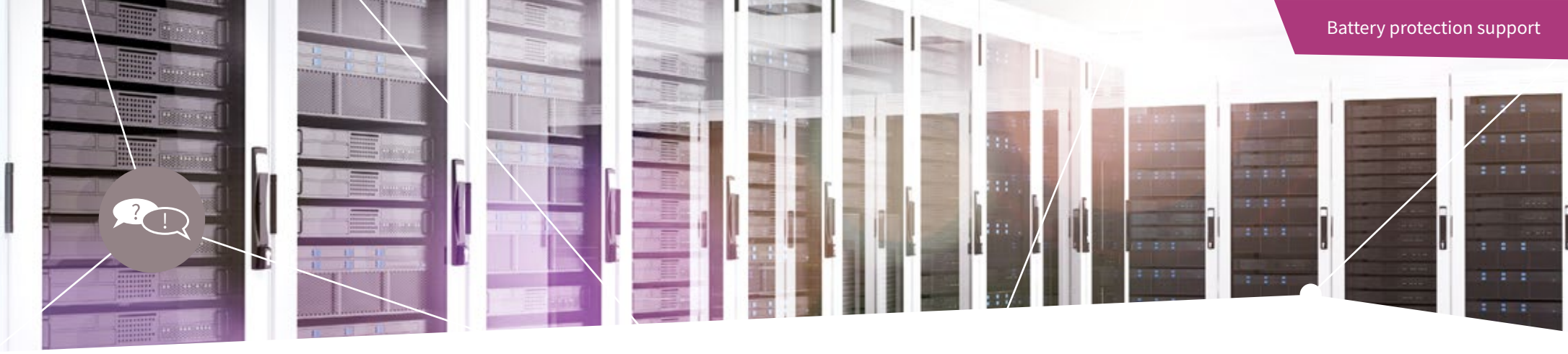

Battery protection support

Support by Infineon

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