

Light electric vehicles (LEVs)

Efficient and power dense solutions for complete LEV systems including battery chargers

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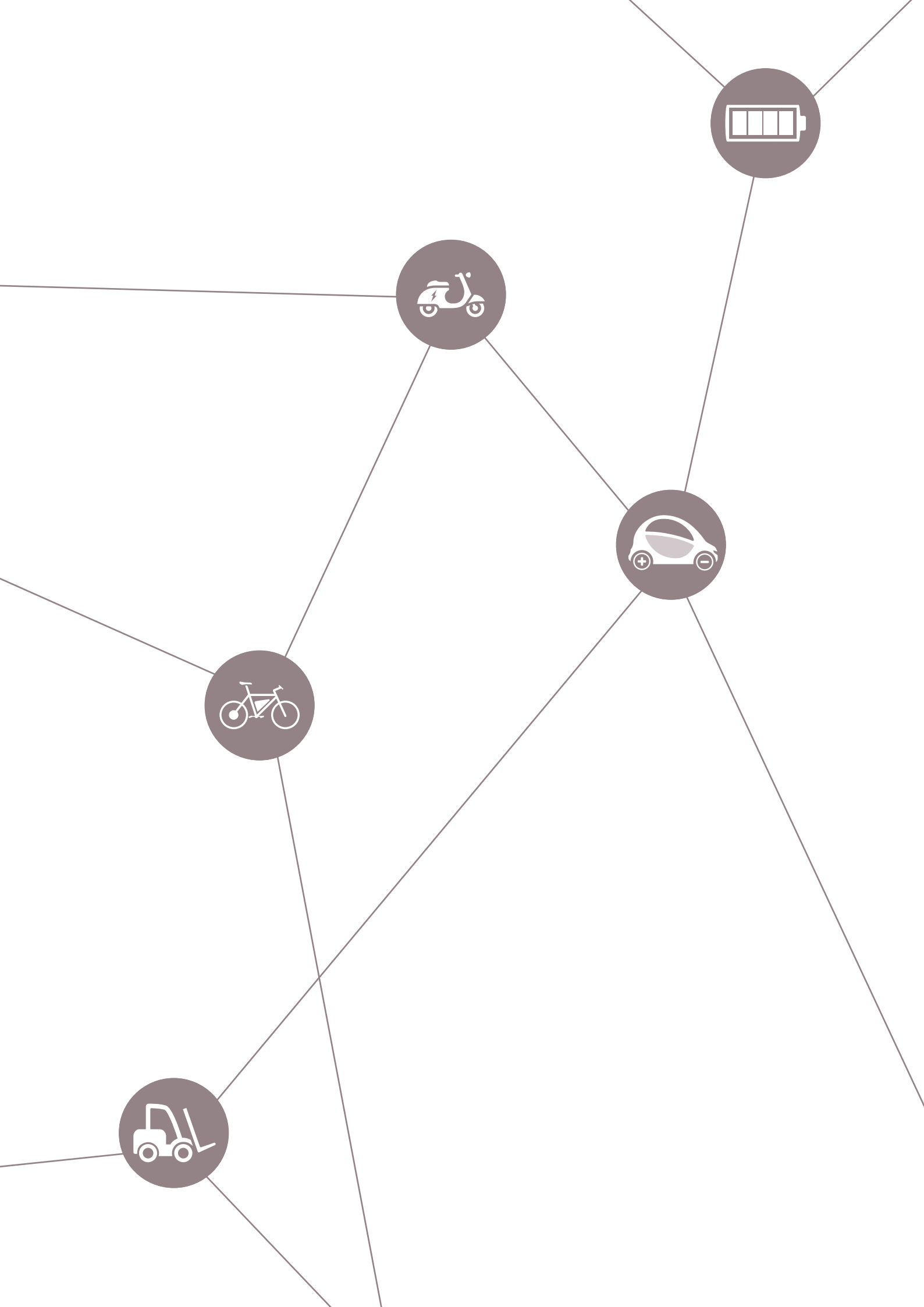

Contents

LEV industry overview 4

Infineon’s complete system solutions for LEVs 6

Low power LEVs 8

High power LEVs 12

Battery chargers for LEV 14

- Onboard battery chargers 14
- Off-board battery chargers 14

Development and evaluation 17

- Demonstration boards 17
- Development tool 18

LEV industry overview

Affordable and convenient mobility for a greener world

Light electric vehicles (LEVs) - another technology that is quietly flourishing and spreading around us without getting as much attention as it deserves, but yet with a world-changing potential for the emission-free solutions for the rising megacities. Increased urbanization, traffic congestions, poor air quality and lack of mobility options call for affordable and clean transportation alternatives. The new technologies applied to and the new materials built into today's LEVs enable greater power efficiency, smaller size, lighter weight, and lower cost solutions.

LEV industry overview

An ever-increasing rate of conversion from internal combustion engines to full electrical drives has already been witnessed in some areas of the industry. In 2018, approximately 62 percent of the sold forklift units were electrical. When compared to gasoline or battery powered EVs, in some instances, LEVs cost less which makes them affordable and hence attractive to emerging markets, where a transition to electrified mobility is in progress (e.g. rickshaws into e-rickshaws, scooters into e-scooters). However, in some cases their price is still higher than that of gasoline powered versions, resulting in need for additional financial incentives to foster their widespread use. Nevertheless, at the moment, the LEV market in units is six to ten times larger than the one for plug-in EVs. The ultimate benefits of LEVs, driving their adoption in the market, are reduced operating costs and zero-emission levels. Following the current mobility trends, in the near future, LEVs are expected to be highly integrated with automated vehicle technology, i.e. sensors.

Due to an extremely simple configuration both their functioning and handling are easy to understand. They can be charged from the grid (e.g. power plugs in private homes) without necessarily requiring installation of a specific charging infrastructure. The intended users are those driving short distances at lower speed. Depending on the purpose of use there are variants with and without space for carry-on items. And most importantly, they fulfill the zero emissions mandate.

Major challenges and the impactful characteristics of the LEV industry

- Strong price erosion which makes it a cost driven segment
- Time-to-market pressure, especially in emerging markets where a lot of newcomers to the industry seek market penetration
- Small form factors
- Relaxed lifetime expectations
- Growing demand for easy-to-use system-level solutions (plug and play, turnkey) comprising the technology, software and hardware as well as services (e.g. software design) due to increasing system complexity

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Why LEVs

The advantage of LEVs

Reuse of the existing power grids and infrastructure

Simpler configuration for easy handling and maintenance

Low-priced, affordable mobility solutions

Enhanced mobility in city areas

Emission-free operation

Infineon's complete system solutions for LEVs

The right combination of components for compact, cost-effective LEV designs of today and tomorrow

With the pioneering spirit sustained by technical know-how, highest quality standards and preeminent manufacturing expertise throughout the entire supply chain, Infineon strives to be the benchmark in addressing a broad range of light electrical vehicles. Infineon's products and solutions cater for all design specifications and are tailored to customer needs, especially to the growing number of solution buyers looking for plug-and-play or turnkey options.

Infineon's LEV portfolio covers multiple functional blocks found in e-skateboards, e-scooters, pedal electric cycles (i.e. pedelecs), low speed electric cars, e-forklifts, electrical three-wheelers, e.g. e-rickshaws, and many other applications. Infineon is offering all the necessary components needed for motor control and inverters, battery chargers, battery management, air-conditioning systems, hydraulic control, sensing, as well as security and authentication. The power range of scalable motor control units stretches from a few kilowatts to over 20 kWs, while the offered product voltages range from 24 V up to 169 V.

Power management and consumption as well as voltage regulation are covered by an exceptional selection of power products such as high voltage CoolMOS™ SJ MOSFETs, low voltage OptiMOS™ and StrongIRFET™ power MOSFETs, SiC and GaN based products, XMC™ and AURIX™ microcontrollers, and EiceDRIVER™ gate driver ICs – amongst others.

The excellent reliability of best-in-class MOSFETs, e.g. OptiMOS™ and StrongIRFET™, results in longer product life spans, battery life and operating time. Further, reliable operation in harsh environments and avoidance of system downtime reduce chances for control failure. The parts are available in voltage classes ranging from 20 V to 300 V.

Infineon's components reduce overall system size and costs. They support smallest area and compact design as prerequisite for highest power density and BOM cost reduction due to lowest $R_{DS(on)}$. TO-Leadless (TOLL) package, as a replacement for D^2PAK 7-pin, facilitates 60 percent space reduction. Additionally, low voltage MOSFETs with SMD packaging improve productive capabilities by automatic production, thereby increasing reliability and saving assembly cost.

Infineon is a market leader in security solutions with a proven track record, the highest quality standards, and a safety certified development processes, building on an outstanding partner network for embedded security. Therefore, trustworthy hardware-based security and functional safety embedded in selected products are available to customers. The OPTIGA™ Trust family enables authentication of components connected to the system - e.g. battery pack recognition to avoid damages from using non-authorized third party batteries or chargers.

Infineon's multi-facetted development, testing and evaluation environment helps customers to easily prototype, what shortens their time to market and reduces their costs. On top of all that, they benefit from global system support.

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Why Infineon

Gain competitive advantage with Infineon

Low maintenance, complete solutions backed by broad portfolio of reliable components

Extended product life span, battery life and operating range

Security solutions including component authentication and functional safety embedded in selected products

Mastering all leading power technologies (Si, SiC, GaN)

Global application design support via a worldwide network of field application engineers and trusted distributors

Reduction of development cost and shortened time to market

Overall system size and BOM cost reduction

Low power LEVs

Power dense solutions at optimal system cost

The industry defines low power LEVs as electric vehicles with the power range from 1 kW to 10 kW and the voltage classes between 24 V and 72 V. Very popular in this category are two- and three-wheelers which are mainly used for short distance transport of passengers and/or goods, such as e-scooters (standing / self-balancing and folding types), e-bikes, e-rickshaws and other types of e-three-wheelers.

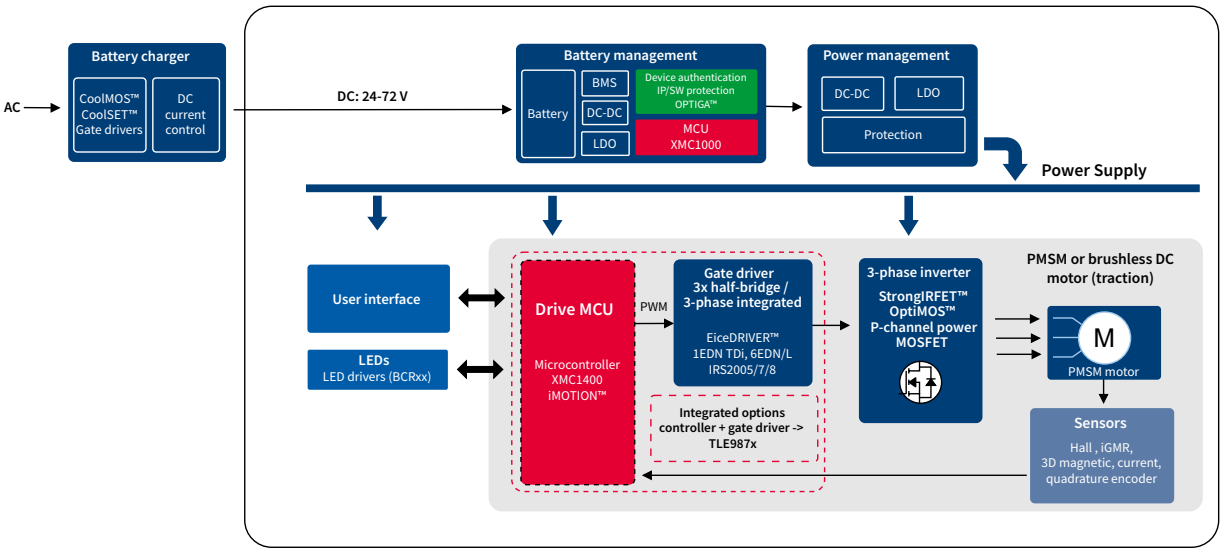
Current market trends and key drivers

In contrast to the relatively small volumes of EVs, tens of millions of electrified two-wheelers have already been sold worldwide. A fast transition to electric versions is observable especially in emerging Asian markets (e.g. India, Indonesia, Vietnam, etc.) with more than 200 million electrified two-wheelers already in use in China. In India, e-rickshaws are taking heavily polluted and congested cities by storm. These environmentally friendly vehicles are becoming increasingly popular in emerging markets' crowded metropolises for their reduced noise pollution levels and high degree of mobility combined with convenience at much lower initial and operational costs compared to typical EVs.

Top performance versus cost optimization

When it comes to high volume production, the range and speed of low power LEV applications are distinguishing factors. No matter if customers work on designs with either top performance targets or rather concentrate on cost optimization, Infineon is prepared to deliver the products they require. With best-in-class solutions for motor control, our customers may maximize levels of space and/or volume savings (e.g. essential for two-wheelers). StrongIRFET™ MOSFETs, to the contrary, are chosen for the development of cost optimized solutions whenever space and weight do not form limiting parameters (e.g. for three-wheelers).

System diagram: low power light electric vehicles (e.g. e-bike, e-scooter, e-rickshaw)



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Recommended products for low power LEVs

Functional block	Product category	Product family	Part number
Motor control	MOSFETs	HEXFET™ power MOSFET 60 V	IRFS3006TRL7PP
			IRFH7545TRPBF
		HEXFET™ power MOSFET 75 V	IRFB3607PBF
		HEXFET™ power MOSFET 200 V	IRFP4668PBF
		OptiMOS™ power MOSFET 60 V	IPT007N06N
			BSC039N06NS
		OptiMOS™ 5 power MOSFET 80 V	IPT029N08N5
			IPP052N08N5
		OptiMOS™ 5 power MOSFET 100 V	IPT015N10N5
			IPB017N10N5
		OptiMOS™ 3 power MOSFET 100 V	IPB042N10N3
		OptiMOS™ 5 power MOSFET 150 V	IPB048N15N5
	Gate driver ICs	EiceDRIVER™ Compact, 600 V half-bridge gate driver IC	2EDL05N06PF
		EiceDRIVER™ Compact, full bridge three-phase gate driver IC with thin-film-SOI-technology	6EDL04N02PR
		200 V half-bridge gate driver IC	IRS2008SPBF
		600 V three-phase gate driver IC for IGBTs and MOSFETs	IR2136STRPBF
		EiceDRIVER™ single-channel gate driver IC	1EDN7550
	Voltage regulator	Monolithic integrated voltage regulator	IFX21004TN
	Sensors	XENSIV™ integrated Hall effect switch	TLE4964-1M
		XENSIV™ 3D magnetic sensor	TLE493DW2B6Ax
	Motor control IC	iMOTION™ digital motor controller	IMC101T-F064
	Microcontrollers	3-Phase Bridge Driver IC with Integrated ARM® Cortex® M3	TLE9877QXW40
		XMC1400 series	XMC1404-F064X0200
Protection	MOSFET	OptiMOS™ 5 LinearFET 100 V	IPB017N10N5LF
	Security chip	OPTIGA™ Trust B	SLE95250

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

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E-bikes and e-scooters

Stars of urban mobility

The share of e-bikes of the total bicycle market has become substantial – and is expected to rise up to 30-40% in many countries. Instead of being specialty recreational devices as they were a couple of years ago, e-bikes are evolving into a standard means of transport, especially for work commuters.

Key drivers for increased e-bike and e-scooter sales

Low purchase and running cost
- Flexibility of transportation
- Lower cost of electricity compared to gasoline
- Li-ion battery costs decreasing

Convenience
- Reduced physical effort compared to a regular bicycle
- Can be charged at home (e.g. overnight)

Lithium-ion (Li-ion) batteries
- Weigh less than lead-acid batteries
- Have lower detrimental environmental impact
- Can be removed for charging

Pollution and over-crowded cities
- Successfull worldwide roll out of new shared mobility concepts

End-users' concerns as barriers of adoption

At the moment, there are two dissuasive concerns potential users have: lack of flexible charging and related to this, the limited range. Manufacturers are intensively working on solutions to overcome any existing barriers of adoption of two-wheelers. Different battery technologies, use of solar power, battery swapping stations plus the development of a supercharger network are only few examples under consideration – anything that provides more convenience to the end user.



Infineon's highlight solution for electrical two-wheelers

iMOTION™ - Digital motor control for e-bikes and e-scooters

One particular set of products suitable for low power two-wheelers such as e-bikes and folding e-scooters are Infineon's iMOTION™ motor control ICs. Integrated into these ICs are all the control and analog interface functions required for sensorless, field-oriented control (FOC) of PM motors using DC link or leg shunt current measurements. In addition, they feature Infineon's patented and field-proven motor control engine (MCE) that eliminates software coding from the motor control algorithm development process. Implementation of a variable speed drive is reduced to configuring the MCE for the respective motor. With powerful software tools such as **MCEWizard and MCEDesigner**, it is now possible to have the motor up and running in less than an hour. By comprising both the required hardware and software to perform sensorless control of a permanent magnet synchronous motor (PMSM), iMOTION™ ICs provide the highest energy efficient motor system with the lowest system cost for the named applications.

Play video | Download software | Learn more

Highlight products for e-bikes and e-scooters

Functional block	Product category	Product family	Part number
Motor control	MOSFETs	HEXFET™ power MOSFET 60 V	IRFH7545TRPBF
		HEXFET™ power MOSFET 75 V	IRFB3607PBF
		OptiMOS™ power MOSFET 60 V	BSC039N06NS
		OptiMOS™ 5 power MOSFET 100 V	IPT015N10N5
	Gate driver ICs	EiceDRIVER™ Compact, 600 V half-bridge gate driver IC	2EDL05N06PF
		EiceDRIVER™ Compact, full-bridge three-phase gate driver IC with thin-film-SOI-technology	6EDL04N02PR
	Motor control IC	iMOTION™ digital motor controller	IMC101T-F064
	Microcontroller	XMC1400 series	XMC1404-F064X0200
Protection	Security chip	OPTIGA™ Trust B	SLE95250

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

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High power LEVs

Longer operating range with highly efficient solutions at attractive system cost

High power LEVs cover electric vehicles with power range from 10 kW to over 30 kW and voltage class between 48 V and 144 V. The category mostly covers four-wheelers with space for carry-on items such as the ones used for material handling in industrial surroundings (off-highway EVs) or for passenger transportation with any sort of baggage. The most typical high power LEVs are light utility vehicles (LUVs), low speed electric vehicles (LSEVs / MicroEVs), e-motorbikes, and other for professional use such as e-forklifts, and golf carts.

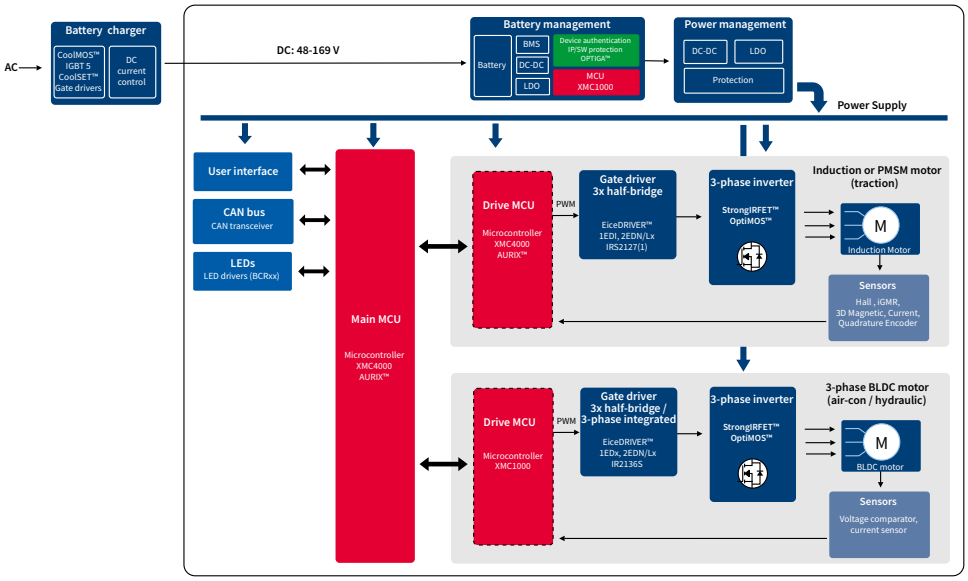
Current market trends and key drivers

The key value driver for LEVs, in addition to system cost, is efficiency, which is decisive for the time and distance one can drive them before recharging. In high power LEVs, an increased operating range is needed to prevent interruptions in the flow of materials and people. Until recently, there has been no standard regulation for LSEV manufacturers, what has lead to substandard safety performance. Additionally, the extensive usage of lead-acid batteries in LEV designs has negative environmental effects. Consequently, the Chinese government has taken up an initiative to introduce drastic measures limiting the proliferation of low quality LSEVs. Instead of using lead-acid batteries manufacturers are encouraged to focus on lithium-ion battery versions with extended operating range and improved battery power densities, along with mandatory safety tests.

Infineon's offering

Infineon's solutions respond exactly to these latest developments in the field. They enable LSEV manufacturers to upgrade their product portfolio and benefit from the shortened time to market. More precisely, they extend the battery lifetime of e-forklifts, LSEVs and e-motorbikes while providing robust performance at competitive costs. Via a modular approach, a wide range of application voltages and power levels can be covered. The customer is offered a vast assortment of products for almost the entire LEV-system including motor control units, hydraulic units, and air-conditioning units, depending on the specific application.

System diagram: high power low speed electric vehicle (LSEV)



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Recommended products for high power LEVs

Functional block	Product category	Product family	Part number
Motor control	MOSFETs	600 V CoolMOS™ CFD7 power MOSFET	IPW60R018CFD7
		HEXFET™ power MOSFET 100 V	IRFB4110
		OptiMOS™ Fast Diode (FD) power MOSFET 220 V	IPB156N22NFD
		OptiMOS™ 3 power MOSFET 80 V	IPB019N08N3 G
		OptiMOS™ 3 power MOSFET 200 V	IPB107N20N3 G
		OptiMOS™ 5 power MOSFET 80 V	IPT012N08N5
		OptiMOS™ 5 power MOSFET 100 V	IPT015N10N5
			IPB027N10N5
			IPP051N15N5
		OptiMOS™ 5 power MOSFET 150 V	IPB044N15N5
		StrongIRFET™ power MOSFET 200 V	IRF200S234
	Gate driver ICs	EiceDRIVER™ 1200 V Coreless Transformer IC	1EDI20N12AF
		EiceDRIVER™ Compact	2EDL23N06PJ
	IGBT Discretes	600 V DuoPack IGBT (TRENCHSTOP™ Performance) with RAPID 1 fast anti-parallel diode	IKW30N60DTP
		600 V DuoPack IGBT with RAPID 1 fast anti-parallel diode	IKW50N60DTP
	Voltage regulators	Monolithically integrated w/ dual output: 5 V and 15 V	IFX21004TN V51
		OPTIREG™ Tracker	TLS115D0EJ
	Sensor	XENSIV™ integrated Hall effect switch	TLE4964-1M
	Microcontrollers	XC2000 family	SAK-XC2365B-40F80LR AB
		XMC4300	XMC4300-F100K256
Air-conditioning	MOSFETs	HEXFET™ power MOSFET 200 V	IRFP4668PBF
		StrongIRFET™ power MOSFET 200 V	IRF200P222
	Gate driver IC	600 V three phase gate driver IC for IGBTs and MOSFETs	IR2136STRPBF
Protection	MOSFET	OptiMOS™ 5 LinearFET 150 V	IPB048N15N5LF
	Security chip	OPTIGA™ Trust B	SLE95250

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

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LEV battery chargers

Powering applications from 200 W to more than 5 kW

Depending on their power requirements, LEV batteries can be charged either directly from the grid using a dedicated onboard charger or by an off-board charger. As the number of LEVs is expected to grow further, the efficiency of battery chargers becomes particularly important. Taking into account that the vast majority of LEVs sold each year are deployed in developing countries with weak local power grids, every percentage point of efficiency increase translates into significant energy savings.

Onboard vs off-board battery chargers

Onboard chargers

AC onboard chargers are more suitable if:

- more flexibility in charging is needed without the need to install any special infrastructure nor to carry additional charging equipment (i.e. low speed EVs (quadricycles), golf carts, small electric forklifts)
- more complex battery management systems are used, e.g. for Li-ion batteries (i.e. high power e-scooters)

The performance of onboard charger is evaluated by its power-conversion efficiency and power quality, i.e. total harmonic distortion and power factor. As for all items installed in the vehicle, size, weight, and lifetime are critical parameters. Conventional onboard chargers usually have a two-stage structure consisting of a power factor correction (PFC) stage and a DC–DC power-conversion stage. This specific structure brings along major drawbacks such as low efficiency and circuit complexity, and a bulky intermediate DC link capacitor. Due to high current flowing through the intermediate DC link capacitor significant power loss is caused, what considerably reduces the capacitor lifetime, eventually leading to capacitor failure. As an alternative to the two-stage structure, single-stage approaches are being investigated with the aim to eliminate the PFC stage and reduce the DC link capacitance.

Off-board chargers

Off-board chargers are more suitable if:

- the LEV can be easily located or moved close to the charger (i.e. e-bikes, folding e-scooters)
- the LEV battery does not require a complex battery management system, e.g. low cost sealed lead-acid (SLA) batteries (i.e. low cost e-scooters, electrical wheelchairs)
- whenever charging requires very high power, because of limitations of weight/volume on the vehicle itself, as is the case for electrical forklifts



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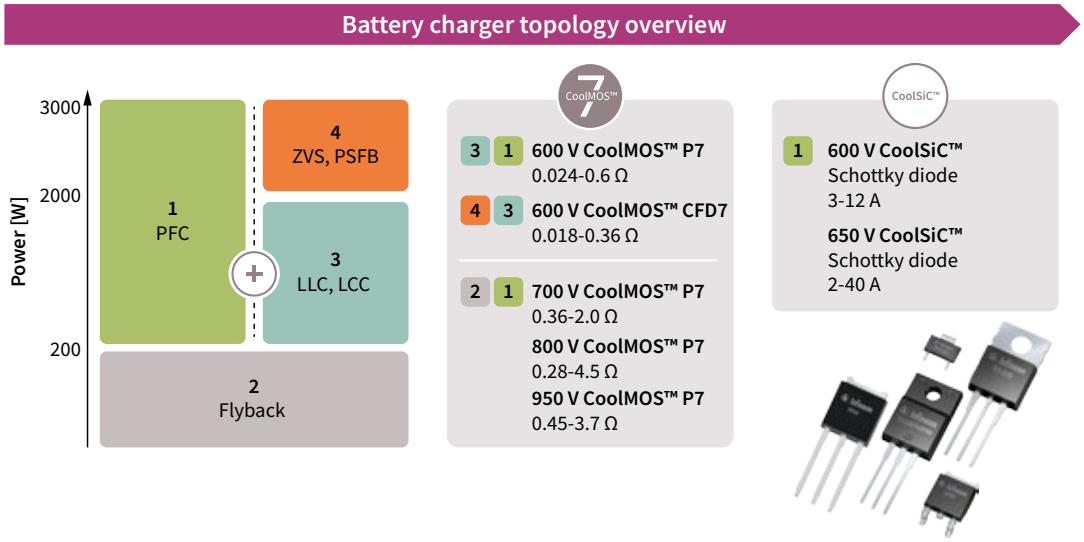
Infineon's LEV battery charger solutions

Infineon's LEV onboard and off-board battery charger solutions comprising power MOSFETs, gate driver ICs, PWM/flyback-based controllers, integrated power stage ICs and microcontrollers are optimized to fit any system. In order to accommodate as many customer requirements as possible, different topologies are available and efforts are made to meet a variety of cost/performance optimization targets. Customers benefit from small form factors, best-in-class performance ratio (attractive pricing with competitive long term price down roadmap), easy-to-use technologies, as well as powerful and reliable components.

Infineon's battery charger topology overview



Highlight technologies

OPTIGA™ Trust – authentication at its best

Another particular aspect of interest for chargers is their close connection with the type of battery stacks that they are supposed to charge. Practically, any LEV manufacturer selects different variants of batteries that best fit its own, very specific applications. The battery chargers must hence be designed with the proper charging algorithms for the corresponding battery stacks chosen by the LEV manufacturer. Connecting a wrong charger type to a battery runs the risk of damaging the batteries, what voids the manufacturer's warranty. Infineon's OPTIGA™ Trust security solution is easy to use and implement, and will ensure that only the right type of charger is used in connection with a certain type of battery, reducing the risk of hazardous damage or fire.

Play video

CoolMOS™ - cutting-edge power MOSFET technology

The CoolMOS™ P7 offers the ideal balance between high efficiency and ease of use in both standard and industrial grade packaging. Customers may choose from 71 parts in 9 different packages with an impressive $R_{DS(on)}$ granularity ranging from 24 mΩ to 600 mΩ.

The CoolMOS™ CFD7 fulfills customer needs by providing efficiency improvements of up to 1.45 % compared to previous CoolMOS™ families and most similar industry offerings. Its attractive price convinces with a competitive long term price-down roadmap.

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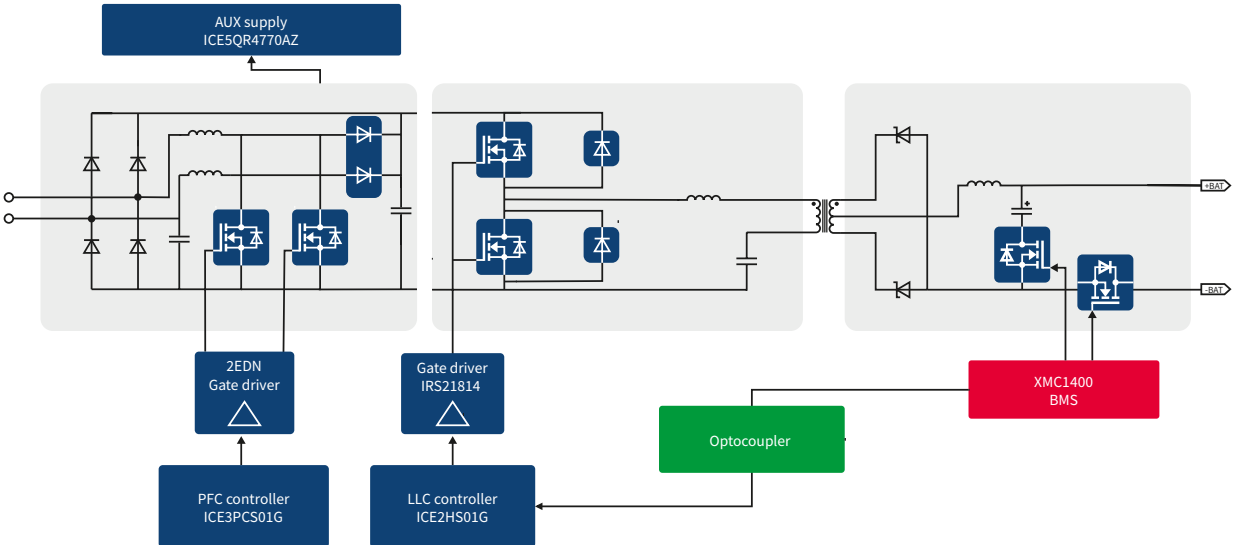
System diagram: 2 kW battery charger for light electric vehicles



Highlight products for LEV battery chargers

Functional block	Product category	Product family	Part number
Charger	MOSFETs	600 V CoolMOS™ CFD7 SJ MOSFET	IPW60R070CFD7
		600 V CoolMOS™ P7 SJ MOSFET	IPW60R037P7
			IPW60R060P7
			IPW60R080P7
			IPAW60R280P7S
		700 V CoolMOS™ P7 SJ MOSFET	IPA70R450P7S
		800 V CoolMOS™ P7 SJ MOSFET	IPA80R360P7
		950 V CoolMOS™ P7 SJ MOSFET	IPA95R450P7
	Gate driver ICs	EiceDRIVER™ Compact, 600 V half-bridge gate driver IC	2EDL05N06PF
		Fast dual-channel 5 A EiceDRIVER™ gate driver IC	2EDN7524F
		Fast single-channel, low-side, non-isolated EiceDRIVER™ gate driver IC	1EDN8550
	IGBT discretes	650 V / 40 A, high speed switching TRENCHSTOP™ 5	IKB40N65ES5
			IKB40N65EF5
	AC-DC PWM-PFC controller	LLC resonant mode controller	ICE2HS01G
		PFC-CCM (continuous conduction mode) IC	ICE3PCS01G
	AC-DC integrated power stage	Fixed frequency CoolSET™ G5	ICE5GR4780AG
	Schottky diode	CoolSiC™ Schottky diode 650 V G6	IDH16G65C6
	Microcontrollers	XMC1300	XMC1301-Q040F0032 AB
		XMC1400	XMC1403-Q064X0200 AA
		XMC4300	XMC4300-F100K256

For more details on the products, click on its part number.

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Development and evaluation

Perfect-fit solutions for prototyping and thorough testing

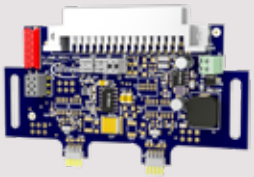
Test and then invest. Shorten your time to market and reduce the development costs. Infineon's offer of evaluation and demonstration boards along with reference designs offers the right environment for fast and easy prototyping. With available simulations, technical documentation, and global system support, Infineon is your reliable partner in every step of your LEV design project.

Low voltage drives scalable power demonstration board for motor drive prototyping

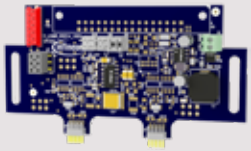
The motor drive prototyping kit consists of a set of modules which combined together reduce design development and test efforts for low speed electric vehicles, e-scooters, electrical three-wheelers, electric golf carts, e-forklifts.



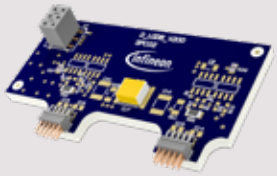
KIT_LGPWR_BOM003
Power half-bridge board featuring OptiMOS™ power MOSFETs*
OPN: KITLGPWRBOM003TOBO1



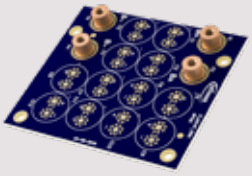
KIT_LGMB_BOM003
Master mother board featuring EiceDRIVER™ (2EDL23N06PJ) gate driver IC
OPN: KITLGMBBOM003TOBO1



KIT_LGMB_BOM503
Mother board featuring EiceDRIVER™ (2EDL23N06PJ) gate driver IC for 2nd and 3rd phase
OPN: KITLGMBBOM503TOBO1



KIT_LGDB_BOM003
Daughter board, interconnecting the gate driver and the power boards
OPN: KITLGDBBOM003TOBO1



KIT_LGCAP_BOM005
Capacitor board, PCB interconnecting the 12 capacitors for the DC bus
OPN: KITLGCAPBOM005TOBO1

*See **web page** for MOSFET variations

Piqued your interest? Click below for more.

Check out 3D model | **Download white paper** | **Download user manual** | **Play video** | **Learn more**

2 kW Battery Charger Evaluation Board

The 2 kW industrial battery charger offers a charging solution for LSEV applications that operates on any single-phase 90 V_{AC} to 265 V_{AC} grid worldwide with a 94.7 percent peak efficiency. The charger has two charging profiles implemented: one for Li-ion batteries and the other for lead-acid batteries. The demonstration board uses a dual-boost PFC + half-bridge LLC power supply solution.



EVAL_2KW_48V_CHAR_P7

› 48 V lead-acid/Li-ion battery charger
› 2 kW high efficient natural convection cooled evaluation board based on CoolMOS™ P7

OPN: EVAL2KW48VCHARP7TOBO1*

Features

› Wide range input operation 90 V_{AC} – 265 V_{AC}
› Capable of charging lead-acid and Li-ion batteries
› Battery capacity selection (40 Ah – 250 Ah)
› Build your own board and customize with Infineon's components and design files

*Components and design files available on request

Check out 3D Model | Download application note | Play video | Learn more

DAVE™ - professional development platform for XMC™ microcontrollers

DAVE™ and complementary tools support the entire development process from evaluation to production (E2P).

DAVE™ software package

› Current version - DAVE™ v4.4.2
› Available: DAVE™ IDE, XMC™ Lib (Low Level Driver), DAVE™ APPs and examples for reuse in one of the major ARM® compiler/IDEs such as Altium, Atollic, ARM/KEIL, IAR Systems, Rowley

Go to tool

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A world leader in semiconductor solutions



Our vision

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.

Where to buy

Infineon distribution partners and sales offices:
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