High efficiency for
Automotive motor control

nexperia

Automotive trends and quality

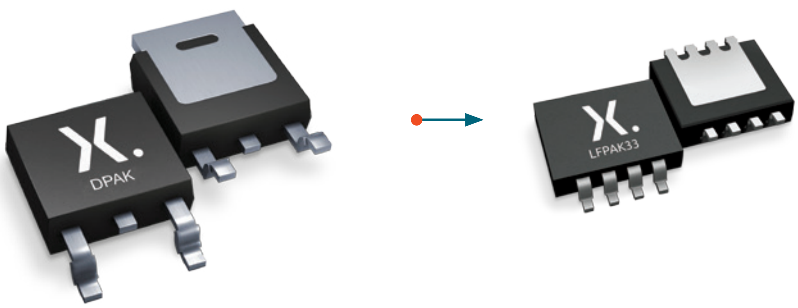
How EMC puts power density in the scope

The number of semiconductors used in cars has increased at almost double the rate of car production growth. The result: more complex ECUs with an increased number of electronic components and a direct impact on the electromagnetic compatibility (EMC) targets. While most semiconductor manufacturers just use shorter cables with smaller parasitic inductance, Nexperia's response to this problem is the development of packages with smaller footprints, increased thermal performance and increased power density.

Car electronic growth → Increased EMC → Shorter cables → High component density close to the engine

Silicon trends towards miniaturization

Every couple of years Nexperia releases a new power MOSFET silicon technology in order to offer higher productivity to our customers. This cycle of constant innovation brings down the R_{DSon} per square area figure of merit. Take the BUK7208-40B MOSFET, for example. This 8mn-channel MOSFET in a DPAK (10 mm x 6.5 mm) is becoming obsolete because today's 8mMOSFETs, such as the BUK7M8R0-40E LFPAK33 (3 mm x 3 mm), are available in much smaller packages. The cost of the newer, smaller MOSFETs is cheaper than the packaging for larger, outdated MOSFETs.



Beyond AEC-Q101

New automobiles increasingly require very sensitive applications such as braking, power steering, and engine management. Nexperia constantly anticipates car OEM quality constraints increases, and we improve quality procedures and processes on a daily basis. Today we offer a standard far beyond AECQ100/-Q101 because mission profiles more than double qualification cycle times. Our rigorous attention to detail and commitment to automotive quality have yielded a sub-ppm combined line, field, and 0 km failure rate for automotive industry customers. Our most demanding customers have rewarded Nexperia with several Quality Awards.

AEC-Q101 qualified

Go for quality

Design for excellence

Zero defect

3-Phase motors

3-Phase brushless DC (BLDC) motor and permanent magnet synchronous motor

Silicon trends toward miniaturization

- High controllability
- Low losses
- Better lifetime/reliability
- Low noise
- Easy to remove heat
- High ratio of total mass to output power

Semiconductor BOM: 6 MOSFET/motor

Application focus

- EPS
- Braking
- Windows lifter
- Sun roof
- Cooling fan
- Water pump
- Transmission
- HVAC

Market demands

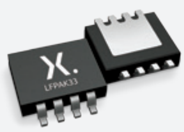
- BLDC motors are the preferred solution for high-power applications, because of having low losses and because it is structurally easy to remove any generated heat
- Powertrain applications face a high ambient temperature which makes the MOSFET operation challenging
- Window lifter and sunroof control are emerging applications for BLDC motors. Although brushed DC motors are typically used for body control applications, the low weight and the low noise operation of BLDC motors are key factors for future developments

Nexperia solution

- Package: LFPAK56, LFPAK56D and LFPAK33

LFPAK56
5 mm x 6 mm

LFPAK56D - Dual
5 mm x 6 mm



LFPAK33
3 mm x 3 mm

Brushed DC motors

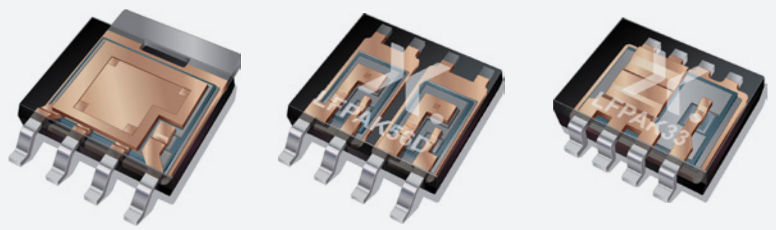
Motor benefits
- Low cost
- Simple control
- High starting torque

Semiconductor BOM:
Four (4) MOSFET/motor; when no direction selection is needed: 1 MOSFET/motor

Application focus
- Mirror control
- Windows lifter
- Soon roof
- Seat adjustment
- Valve shutters
- Door/truck lock
- HVAC

Market demands
- Brushed DC motors are the preferred solution for low-cost applications
- In high-end cars brushed motors often are used for controlling small loads
- In low-power applications relays are still used for speed control; because of reliability and efficiency targets semiconductor devices like power MOSFETs or bipolar transistors are used to replace relays
- Using discrete stand alone drivers often leads to cost down solutions without loosing on the performance aspect
- Standalone drivers are also used for EMC and switching lose optimization

Nexperia solution
- Package: LFPAK56, LFPAK56D and LFPAK33



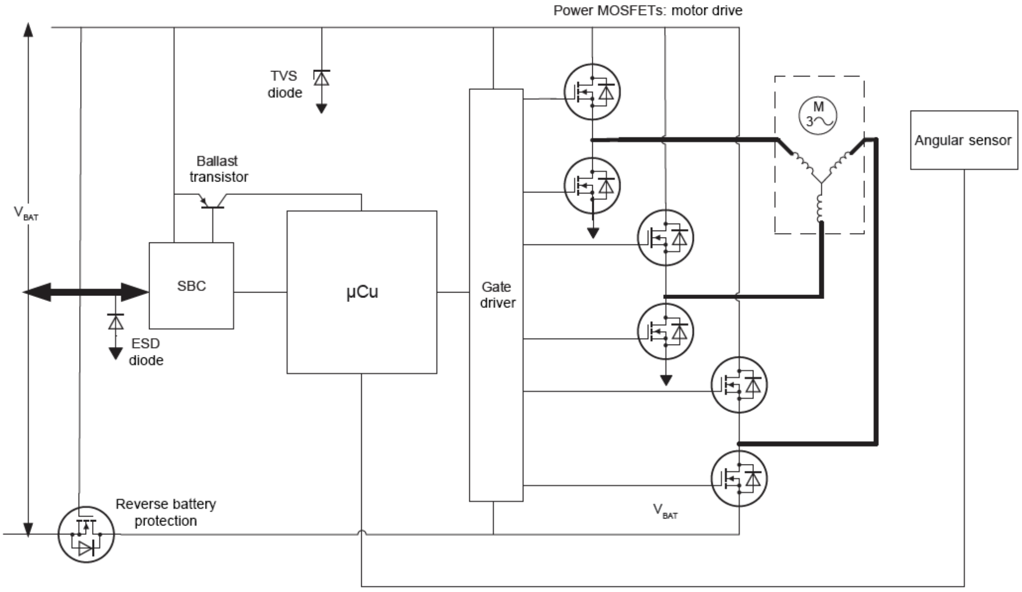
LFPAK56
5 mm x 6 mm

LFPAK56D - Dual
5 mm x 6 mm

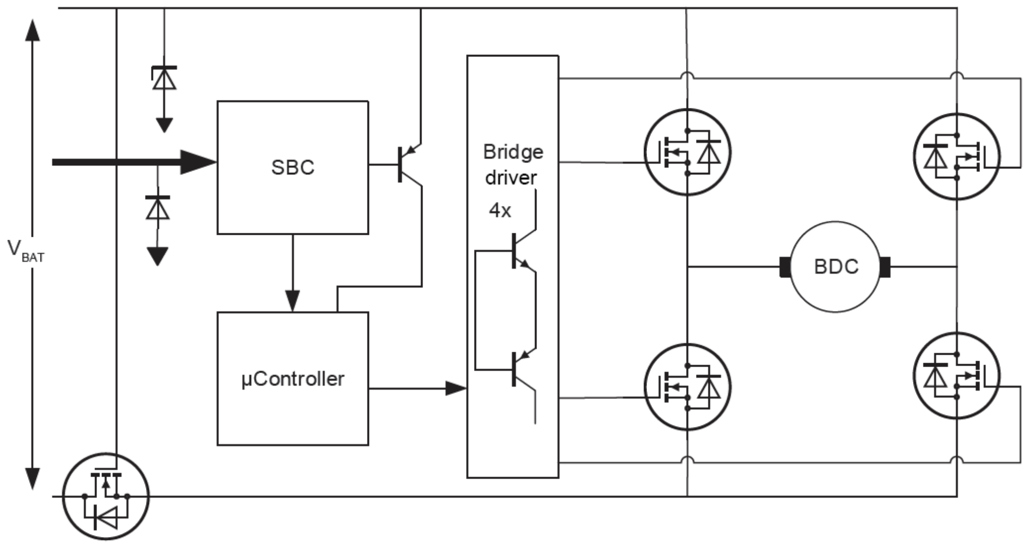
LFPAK33
3 mm x 3 mm

A typical BLDC motor is controlled from a circuit using six MOSFETs, while brushed DC motor control circuits using only four MOSFETs or just a single one in case of one directional operation. The MOSFETs need to be driven from a dedicated gate driver (often integrated in the μCU) because of typically having big gate capacitance. The μCU is responsible for the control of the application and the timing generation for switching the power MOSFETs. It can be powered directly from a system basis chip (SBC) or, if extra power is needed, from a standalone ballast transistor without overheating the SBC. A similar transistor can also be used for providing some extra power to the gate driver when high-speed operation is needed.

BLDC



Brushed DC



How to choose your power MOSFETs

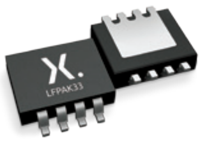
Power MOSFETs key parameters

Voltage Rating (Vds): depends on the battery voltage and any anticipated overshoots on the power. For 12 V_{BAT} applications typically 40 V MOSFETs are used; for 48 V_{BAT}, we recommend a Vds of 80 V or 100 V.

Package: depends mostly on mechanical factors like board level reliability, available space, thermal requirements, type f cooling and PCB type.

Current: depends on the DC operation of the package but also on the short circuit current requirements R_{DSon}; also depends on the power of the motor (P_{motor}) and the targeted thermal losses at the maximum ambient temperature. As a next selection step the designer needs to check if the generated thermal losses of the power MOSFETs can damage the system or not. If thermal losses is too high then the R_{DSon} needs to be reduced. In this case, R_{DSon} is designed in order to protect the system and not in order to meet the power loss targets.

LFPAK33



LFPAK56

LFPAK56D

D^2PAK

I^2PAK

Example

Application specs: P_{motor}=120 W motor, $T_{amb,max}$=90°C, a=90% application HVAC, V_{BAT}=12 V Calculations:

$I_{motor} = P_{motor}/V_{BAT}$=120 W/12 V=10 A

$P_{loss}=(1-a)*P_{motor}$ = 0.01*120 W=1.2 W

P_{max}, MOSFET= $P_{loss}/2 = i^2R$ ➔ R_{mos}=0.5* 1.2 W/10A^2 ➔

R_{max}= 6 mOhm (one half bridge has 2 MOSFETs)

Question: Can the PCB support this power?

- If yes, we are done
- If not: P_{max}, and MOSFET need to be estimated based on the PCB design

Quantitative info

If a MOSFET was an R_{th} of 1K/W then a dissipation of 1.2 W would result in a temperature difference between the junction of the MOSFET and the PCB of: ΔT_{j-mb}=1K/W* 1.2 W = 1.2 °K. This means that in case of a typical FR4 pcb with $_{Tj,pcb\ max}$=125 °C the MOSFET should be designed for $T_{j,max}$=126.2 °C . At this temperature the MOSFET should have an R_{DSon} of R_{max} and the selected package should be able to stand the nominal current *Imotor*.

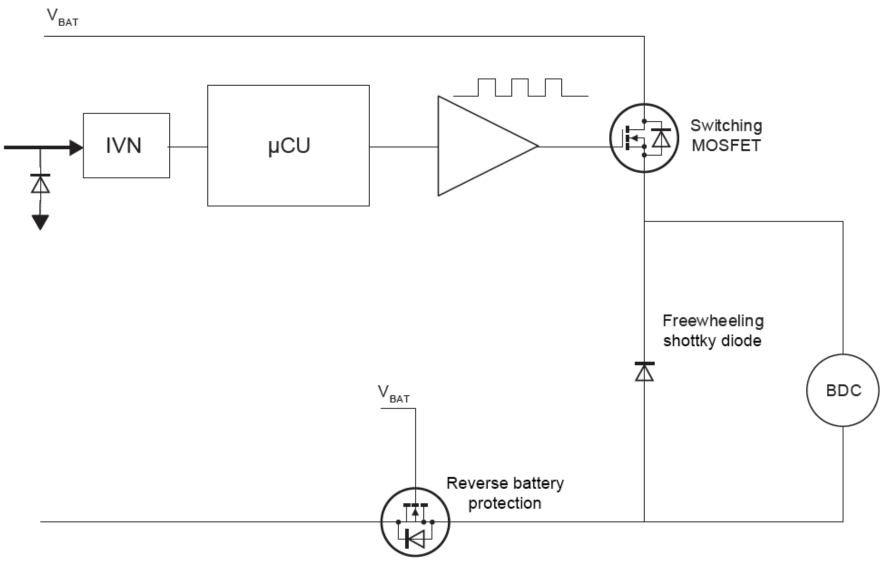
Brushed DC motor variants

In the motor-control domain depending on the application requirements and the motor type there can be alternative configurations and different ways to control the MOSFETs.

Application insight: HVAC with PWM

One directional BDC motor was widely used in HVAC application because it could be controlled just from one MOSFET in linear mode (current source configuration). Because of high-efficiency targets and demands on higher controllability, in new designs the MOSFET is being used in switching mode instead of linear mode (PWM).

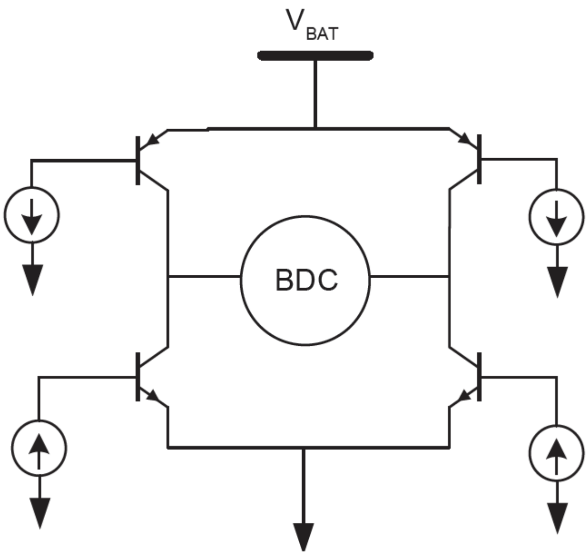
HVAC with PWM



Application insight

BDC can as well be driven from bipolar transistors. The disadvantage of bipolar transistors in motor-control is the power losses which tend to be minimal when a motor is operated just for a short time. In this case bipolar transistors can provide a low-cost alternative.

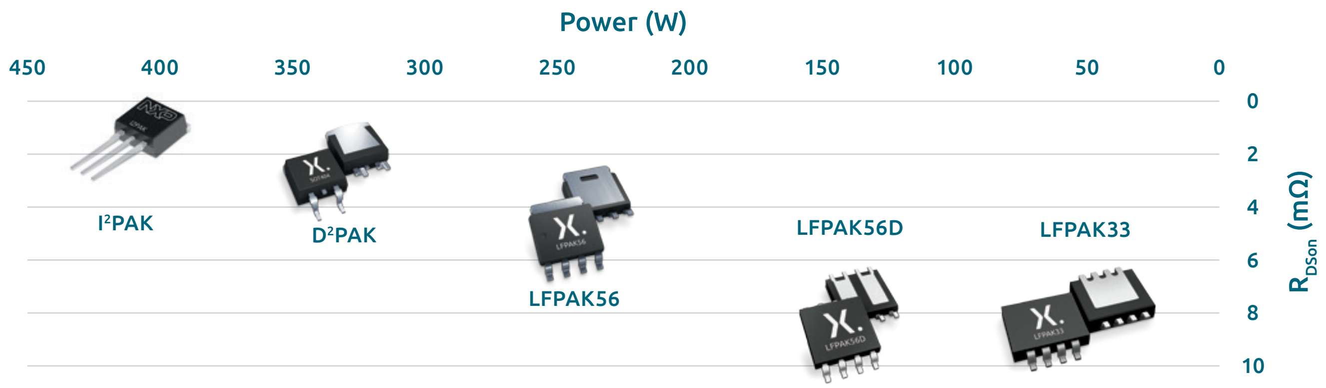
Mirror control door/truck latch control



Part proposals
40 V power MOSFETs

Power MOSFETs selection needs to be adjusted to the needs of the application and the amount of power level.
For low-power applications, preferred solutions are power MOSFETs in LFPAK33 and in dual LFPAK56D.
For medium power, LFPAK56, and for high-power, D²PAK or I²PAK.

Power levels define package selection



400 W

N-Channel MOSFET	Package	R_{DSon}	I	R_{th}
BUK761R6-40E	D²PAK	1.6 mΩ	120 A	0.43 K/W
BUK7E1R9-40E	I²PAK	1.9 mΩ	120 A	0.46 K/W
BUK762R0-40E	D²PAK	2 mΩ	120 A	0.51 K/W
BUK7E2R3-40E	I²PAK	2.3 mΩ	120 A	0.51 K/W

250 W

N-Channel MOSFET	Package	R_{DSon}	I	R_{th}
BUK762R6-40E	D²PAK	2.6 mΩ	100 A	0.57 K/W
BUK9Y3R0-40E	LFPAK56	6.3 mΩ	100 A	0.77 K/W
BUK7Y3R5-40E	LFPAK56	7.6 mΩ	100 A	0.9 K/W
BUK7Y4R4-40E	LFPAK56	8 mΩ	100 A	1.02 K/W

150 W

N-Channel MOSFET	Package	R_{DSon}	I	R_{th}
BUK7K6R2-40E	LFPAK56D	5.8 mΩ	100 A	2.21 K/W
BUK7M6R3-40E	LFPAK33	6.3 mΩ	50 A	1.89 K/W
BUK7Y7R6-40E	LFPAK56	7.6 mΩ	100 A	1.58 K/W
BUK7M8R0-40E	LFPAK33	8 mΩ	100 A	2 K/W

50 W

N-Channel MOSFET	Package	R_{DSon}	I	R_{th}
BUK7K8R7-40E	LFPAK56D	8.7 mΩ	100 A	2.84 K/W
BUK7M10-40E	LFPAK33	10 mΩ	50 A	2.43 K/W
BUK7M12-40E	LFPAK33	12 mΩ	100 A	2.75 K/W
BUK7Y12-40E	LFPAK56D	12 mΩ	100 A	2.31 K/W

Part proposals
Bipolar transistors and schottky rectifier

Nexperia is a provider of high-power bipolar transistor for motor-control or LDO applications/ballast transistor. Furthermore, the application can be complemented by power schottky diodes. All the above built in high-power-density clip-bonded packages.

Bipolar transistors $T_{j\,MAX}$ 175°C

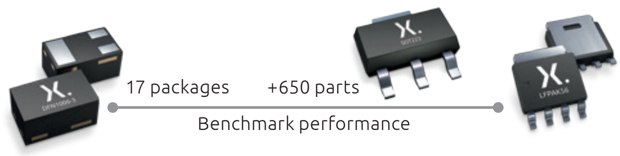
Motor-control	I_F	Configuration	Package
PHPT60406NY	6 A	NPN	LFPAK56
PHPT60406PY	6 A	PNP	LFPAK56
PHPT60406NY	10 A	NPN	LFPAK56
PHPT60406PY	10 A	PNP	LFPAK56
PHPT610030NK	3 A	NPN/NPN	LFPAK56D
PHPT610030PK	3 A	NPN/NPN	LFPAK56D
PHPT610030NPK	3 A	NPN/PNP	LFPAK56D

Ballast transistor for SBCs or µCUs	V_{CEO}	I_F	Configuration
PHPT60603NY	60 V	3 A	NPN
PHPT60603PY	60 V	3 A	PNP

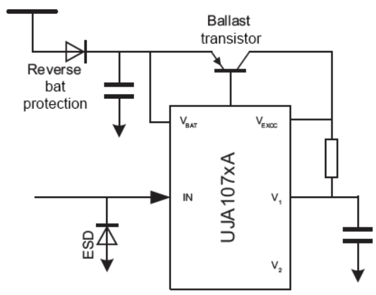
Schottky diodes

Part type	V_R	I_F	Package
PMEG4050EP	40 V	5 A	CFP5
PMEG060V100EPD	60 V	10 A	CFP15
PMEG060V050EPD	60 V	5 A	CFP15
PMEG10030ELP	100 V	3 A	CFP5
PMEG10020AELP	100 V	2 A	CFP5

Current portfolio of medium-power/power and high-voltage low V_{cesat} bipolar transistors



- Application focus: LDO/Ballast
- Power increase
- Heat distribution
- PCB optimization

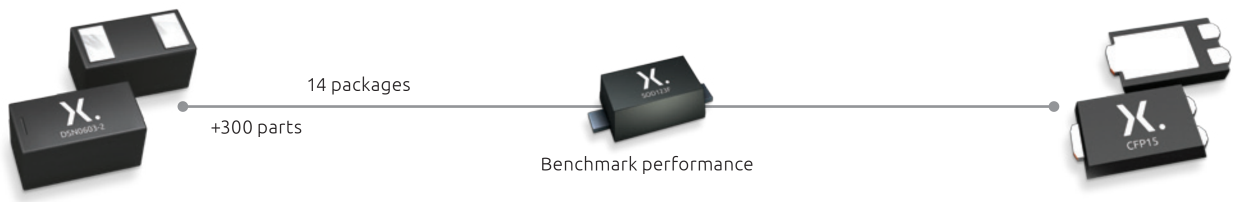


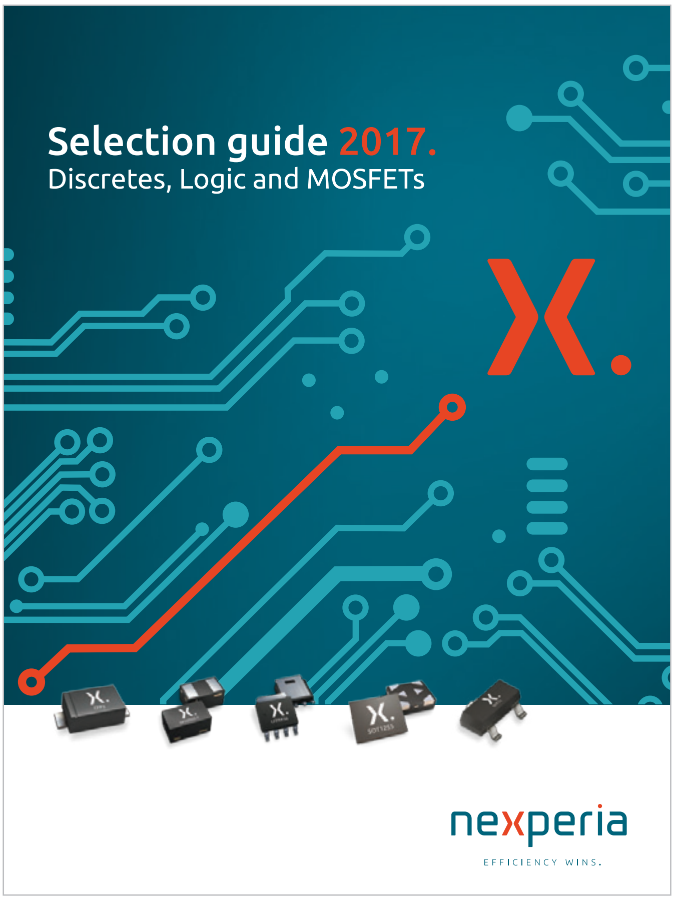
Clip bonded packages

- High-efficiency, high-power density
- Low Vf power schottky technology
- Ultra-low leakage capable
- High-temperature operation (175°C)
- Flat/Thin power package (CFP15)

Part type	Bipolar transistor in LFPAK56	Bipolar transistors in LFPAK56D - Dual	Schottky diodes in CFP15
Small-signal discretes			

Current portfolio of medium power and power schottky rectifiers




Selection guide 2017.
Discretes, Logic and MOSFETs
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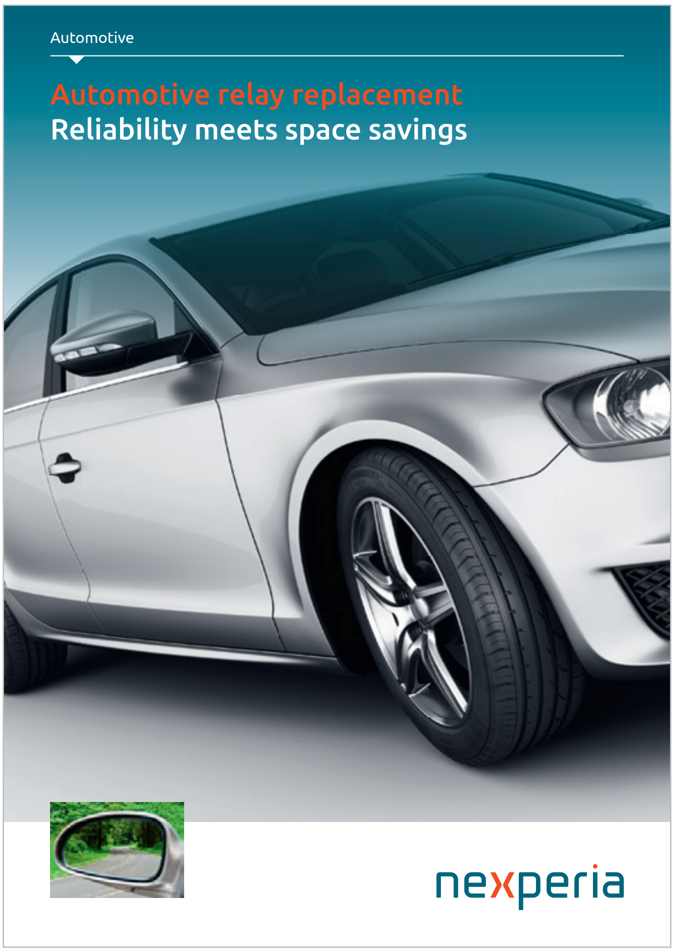
EFFICIENCY WINS.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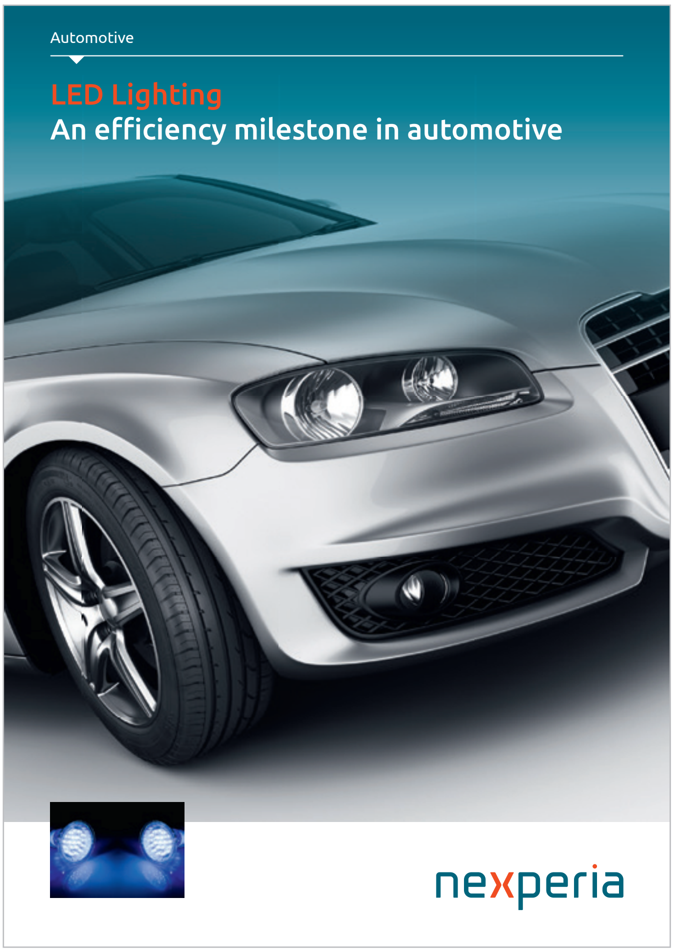
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