Automotive relay replacement
Reliability meets space savings

nexperia

Automotive Trends and Quality

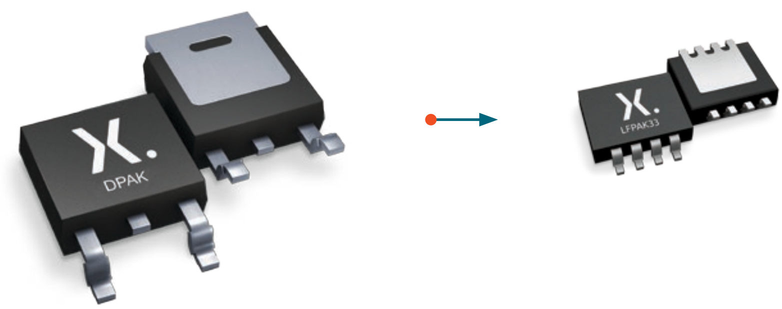
How EMC puts power density in the scope

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 use shorter cables with smaller parasitic inductance, Nexperia solves this problem by developing 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

In regular intervals, 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 8 mΩ n-channel MOSFET in a DPAK (10 mm x 6.5 mm) is becoming obsolete because today's 8 mΩ MOSFETs, 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 The cost of the newer, smaller MOSFETs is cheaper than the packaging for larger, outdated MOSFETs.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 AEC-Q100/-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

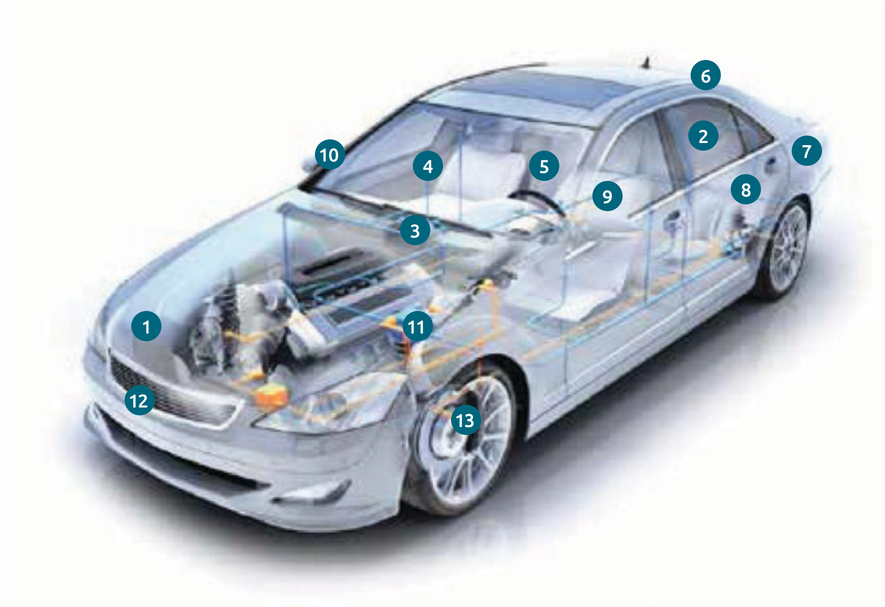
Design for excellence

Zero defect

Relays in automotive applications

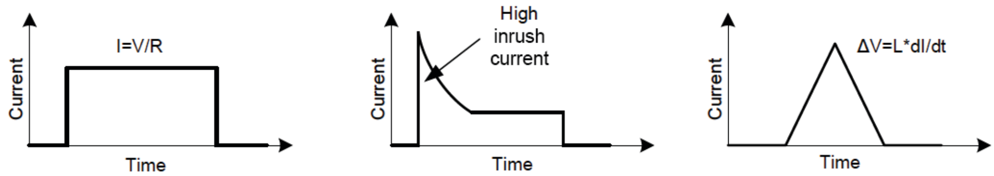
Historically, the automotive industry has seen relays as an easy solution for driving different ECUs. Relays have several advantages over semiconductor devices:

- Relays have almost zero resistance. Therefore, their power losses are at a minimum.
- Relays do not have critical operation regions; such as linear load, which is critical for capacitive loads, or avalanche, which is critical for inductive loads. Thus, relays are insensitive to load characteristics. This explains why there are more than 30 relays in an average car. Body control applications have low operating current and noncritical reliability or controllability parameters.



1. Ventilator coolant
2. Petrol pump
3. Wiper motor
4. Blower motor
5. Electric heat seating
6. Seat adjustment
7. Heated rear window
8. Brake light
9. Central locking system
10. Power windows
11. Power exterior mirrors
12. Starters
13. Horns
14. ABS
15. Power distribution
16. Blower fans
17. Car alarm
18. Hazard warning signal
19. Heated front screen
20. lamps front/rear/fog light
21. Interior lights
22. Main switch/supply relay
23. Seatbelt pretensioner
24. Sun roof
25. Turn signal
26. Valves
27. Global positioning systems
28. In-vehicle entertainment systems
29. Security devices
30. Driver assistance systems

	Resistive	Capacitive	Inductive	Simple motor control
Application	• Heating elements • LED drive	• Lamps (front and rear beam, fog lights, flasher) • ECU turn on	• Solenoids (valves) • Motors and pumps Power distribution	• Mirror control • Seat control • Door lock
Curent solution	• Single relay	• Single relay	• Single relay • Double relay	• Quadruple relay
Semiconductor solution	• Bipolar transistor • MOSFET • Smart MOSFET	• MOSFET • Smart MOSFET	• eSwitch • Mos • Trench+	• Bipolar (x4) • MOSFET(x4)
Application constraints	• Cost	• Cost • High inrush current, low steady- state current	• Cost • Avalanche energy	• Cost • Noise • Controllability



The good and the better:

Relays versus semiconductors

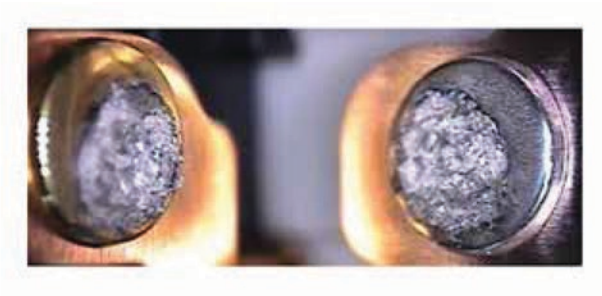
A relay is often perceived as the ideal device with perfect input/output isolation. Unfortunately, this is not the case. A mechanical contact always produces audible noise during switching and also mechanical vibrations that are a source of EMC. Fast degradation of performance leads to low reliability. Limited controllability makes them inappropriate for PWM operation and driving, as well as for BLDC motors, a key step for weight reduction. At the same time, the cost of semiconductor devices such as power MOSFETs and bipolar transistors is dropping rapidly and becoming more financially attractive than relays.

Mega trends

- Relay prices are constant or even increasing
- Semiconductor pricing is more competitive
- OEMs are looking for high reliability
- OEM want to have advanced control and added functionality
- BLDC motors are becoming more popular due to weight reduction and more efiicient operation

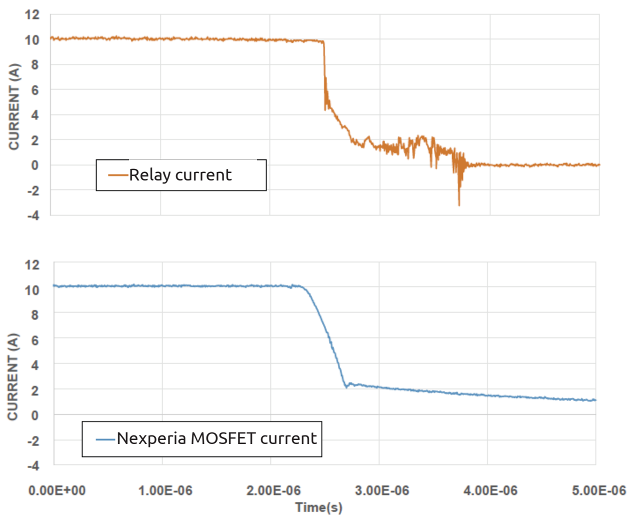
Relay disadvantages

- Fit rate is 15 times higher than that of semiconductor devices
- Big board space/big volume
- Low reliability/small lifetime
- Relay turns off slowly/low controllability/not intended for PWM operation
- Low current capability
- Low ambient temperature operation
- High audible noise
- Switching causes high emissions and bad EMC performance



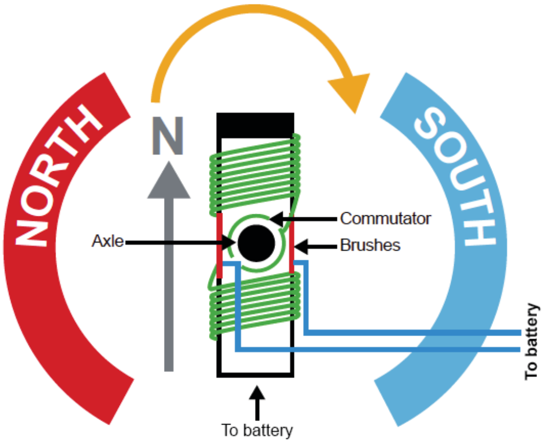
	Relay	Bipolar	MOSFET
FIT rate	--	+++	+++
ESD performance	+++	++	+
Component cost	++	+	0
On-resistance	+	0	+
Control nature	Current	Current	Voltage
Control efficiency	-	-	++
PWM capability	-	+	++
EMC	-	++	+
Audible noise	-	++	++
Operate at ambient temperature >125 °C	-	++	++
Board space/volume	-	++	++
Diagnosis possible	-	+	+
Assembly cost	-	+	+
Electrical isolation	++	-	-
Avalanche handling	++	0	0
Current handling	-	0	++

Recommended current derating to expand lifespan of relay	
Type of load	% of rated value
Resistive	75
Inductive	35
Motor	20
Capacitive	75



Relays in motor control

Brushed DC motors are the current solution for relay-motor-controlled applications.



Typical applications

- Power mirror
- Door latch
- Wipers
- Window lifters
- Sunroofs

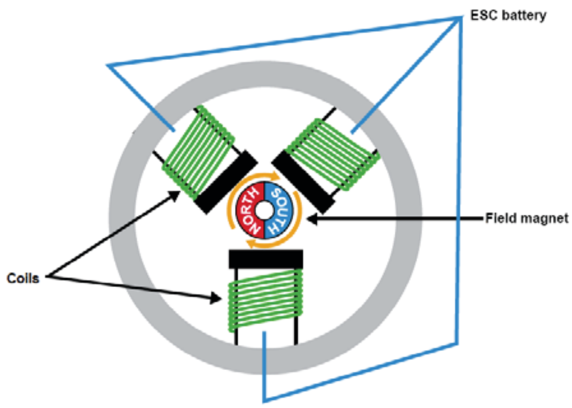
Main specs

- Simple turn on/off
- Operation of a few seconds

Current solutions

- Brushed MOSFETs

BLDC motors are the future of motor control. Their much lower weight is the main driving factor here.

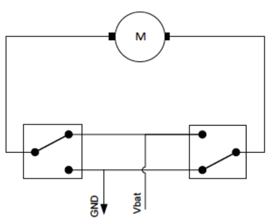
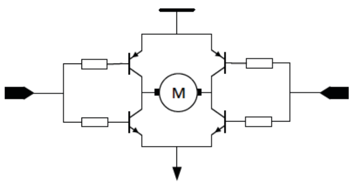
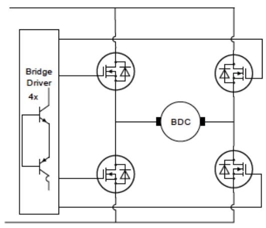


Disadvantages

- Brushed motors are much bigger and heavier
- Relays are a significant noice source
- Relays need big PCB space
- Advanced control only electronically

Future trends

- Short-term: Use of the same brushed motor but with four (4)power MOSFETs or (4) bipolars
- Long-term: use BLDC motors with six (6) power MOSFETs

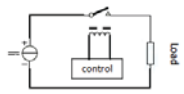
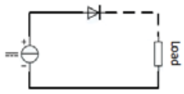
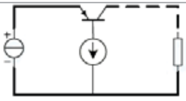
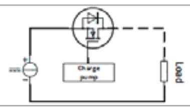
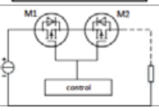
	Relay	Bipolar solution	MOSFET solution
			
Design effort	Medium	Small	High
Control	Low controllability	Medium controllability	High controllability
Driving	Needs current drive		Low power
Power losses	N/A	V_{ce}*I_C can be significant, but not important if the motor is on sporadically and only for a few seconds	Low power
When to use		Low-cost solution Short operation Low-power application	High controllability Long operation High-loss target

Relay as high-side switch

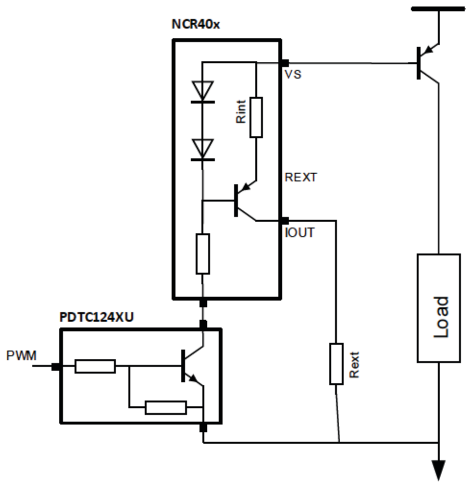
Application focus: motor control

Functionality
- High-side switch
- Power distribution
- Reverse battery protection

Semiconductor alternatives
- Single power MOSFET
- Single bipolar
- Semiconductor relay

		Voltage drop	Power dissipation	Control	Reverse battery protection	ECU turn ON/OFF
Relays		Very low	Very small	Current	✔	✔
Diodes		High	High	N/A	✔	
Bipolar		High	High	Current	✔	✔
MOSFET		Low	Low	Change pump	✔	
Semiconductor relay		Low	Low	Charge pump and turn on/off	✔	✔

Point of attention
When driving heaters or other resistive loads, a relay replacement with a semiconductor device is a straight-forward approach. For capacitive loads or inductive loads, special attention is needed for protecting the semiconductor against a linear mode or avalanche operation, respectively. In those cases the use of protection devices is often mandatory.



Tip
A bipolar PNP transistor driven by constant current sources can replace a high-side relay drive. The intrinsic characteristics of bipolar transistors make them a good solution for both high-side switch and reverse battery protection. Adding a digital transistor to the circuit can provide additional PWM functionality. A similar configuration can be used with an NPN transistor for low-side drive.

Part proposals

150 W

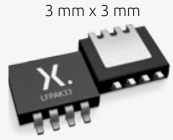
N-Channel MOSFET	Package	R_{DSon}	I	R_{th}
BUK7K6R2-40E	LFPAK56D	5.8 mΩ	100 A	2.21 K/W
BUK7M6R3-40E	LFPAK33	6.3 mΩ	50 A	1.89 K/W
BUK7Y7R6-40E	LFPAK56	7.6 mΩ	100 A	1.58 K/W
BUK7M8R0-40E	LFPAK33	8 mΩ	100 A	2 K/W

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	LFPAK56	12 mΩ	100 A	2.31 K/W

10 W

PNP bipolar transistors	Package	$R_{ce,sat@}$	Ic	V_{ce}
PHPT60603PY	LFPAK56	120 mΩ	-3 A	-60 V
PHPT60406PY	LFPAK56	78 mΩ	-6 A	-40 V
PHPT60410PY	LFPAK56	55 mΩ	-10 A	-40 V
PHPT60415PY	LFPAK56	57 mΩ	-15 A	-40 V

Small-signal discretes	Bipolar transistor in LFPAK56 	Bipolar transistors in LFPAK56D - Dual 	Schottky diodes in CFP15 
Power MOSFETs	LFPAK56 5 mm x 6 mm 	LFPAK56D - Dual 5 mm x 6 mm 	LFPAK33 3 mm x 3 mm 

Constant-current driver

Nexperia Type	PSSI2021SAY	NCR405U	NCR402U	NCR401U
Supply voltage V_S	75 V	40 V	40 V	40 V
Output current I_{Out}	50 mA	65 mA	65 mA	65 mA
LED drive current I_{out} @VS = 10 V	15 uA	50 mA	20 mA	10 mA
R_{int}	48 kΩ	17 Ω	44 Ω	91 Ω
Package	SOT353 	SOT457 	SOT457 	SOT457 
Package dimension	2.0 x 2.1 x 0.95	2.9 x 2.5 x 1.1	2.9 x 2.5 x 1.1	2.9 x 2.5 x 1.1

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