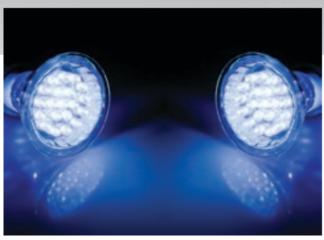
Automotive

LED lighting
An efficiency milestone in automotive



nexperia

Automotive trends and quality

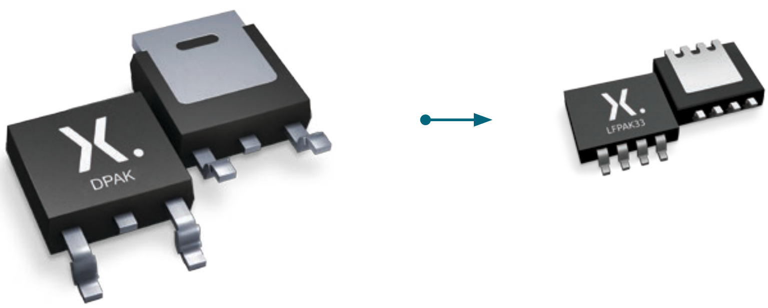
How EMC puts power density in the scope

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'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

In regular intervals, Nexperia releases a new power MOSFET silicon technology 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 8mΩ n-channel MOSFET in a DPAK (10 mm x 6.5 mm) is becoming obsolete because today's 8mΩ 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 The cost of the newer, smaller MOSFETs is cheaper than the packaging for larger, outdated MOSFETs.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 increases of Car OEM quality constraints. 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

LED lighting in the automotive space

Why LED makes the difference

LED lighting is a trending and fast-growing application in the automotive arena. Compared to standard light bulbs, LEDs were initially seen as a decorative upgrade targeting mostly high-end cars. Nowadays, they are also seen as a means of CO^2 reduction. Furthermore, the simple system integration, easy controllabilty, and the low rate of beam effect form the basic elements of beam forming, as well as animal and pedestrian detection systems within advanced drivers assistance systems (ADAS).

Automotive lighting: driven by segmentation

Automotive lighting applications can be divided into three categories: front LED, rear LED and interior LED lighting. Front LED lighting is the most power-hungry application and often has a high degree of complexity. We have seen a high number of innovations in this field. Engineers usually choose a multi-channel boost/back topology for providing flexibility for the LED drive. For the rear LED lighting application, we have medium power requirements and lower complexity than front LED lighting. Functional and aesthetic requirements drive interior LED lighting applications. Typically, these applications use little power and have basic controllability requirements.

Front LED lighting

- High power
- High voltage
- High controllability
- Dimming
- High frequency
- DC-DC conversion: multi boost/buck

Applications

- High beam
- Low beam
- Turn indicator
- Fog lights
- Day running light
- Spot lights

Rear LED lighting

- Medium power
- High voltage
- High controllability
- DC-DC conversion: boost

Applications

- Stop indication
- Position indication
- Fog lights
- Turn indicator

Interior LED lighting

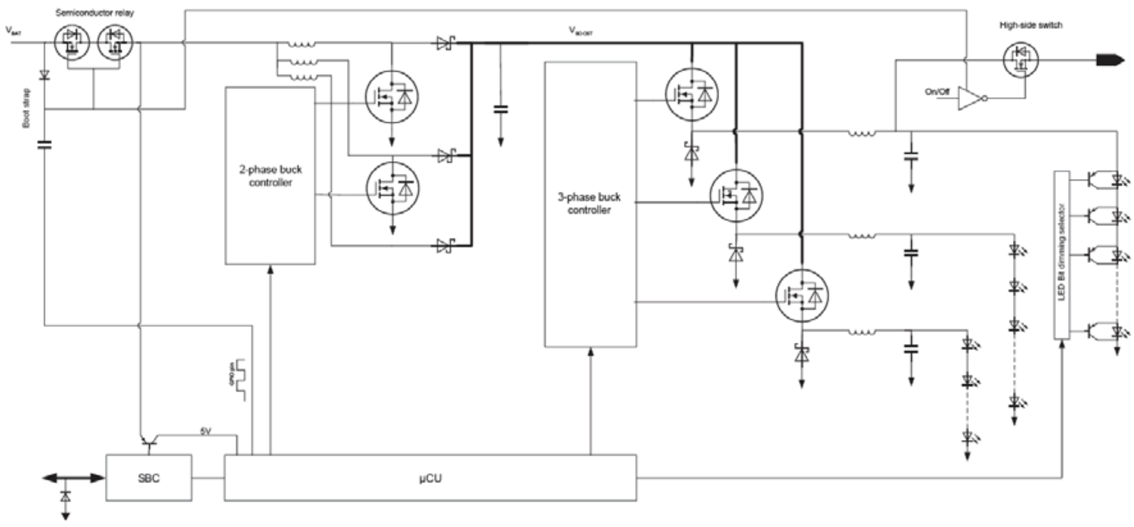
- Low power
- Low voltage
- Current controlled
- Dimming
- PWM

Applications

- Open door indication
- Reading light
- Cluster
- Gear shift indication
- Door module light
- Glove compartment light

Front LED lighting

3-channel boost-buck configuration



Schematic description

The system is switched on/off by a semiconductor relay, formed by two n-channel MOSFETs, connected back to back. Both n-channel MOSFETs and any output high-side switches are supplied by a higher voltage than the V_{BAT} provided by the bootstrap circuit. Operationally, the system is composed of two DC-DC converters: One boost and one buck, which can be either synchronous (using two (2) MOSFETs) or asynchronous, as shown in the above shematic. In this case, a MOSFET and a schottky diode are used for switching. The converters are controlled from a microcontroller which is powered by an LDO with a bipolar PNP transistor providing the output current.

The boost converter is mostly multiphase and is connected with two independent phases/outputs with increased power and less ripple. The buck converter transforms the boosted voltage down to a level adequate for the drive of each LED string. The light intensity is controlled by the two (2) controllers that can adjust the output voltage to a desired value. The output LEDs can be dimmed by using a combination of low-power bipolar transistors with a shift register.

Application insights

- High-brightness multi-LED driver solutions
- High efficiency
- Digitally controlled adaptive non-glare function
- Individually dimmable LED control
- Accurate LED current control
- Compact design
- High-efficiency driver design
- Low-cost total solution
- Low EMI solution using small-scale highly integrated package technology

Highlight parts

- 60 V to 80 V AEC-Q101 Power MOSFETs in LFPAK56
- Highly power-efficient schottky diodes
- Low R_{DSon} medium-power MOSFETs in 2 x 2 mm DFN
- Small-form-factor, low V_{CEsat} transistors in DFN

Subcircuits

LED dimming

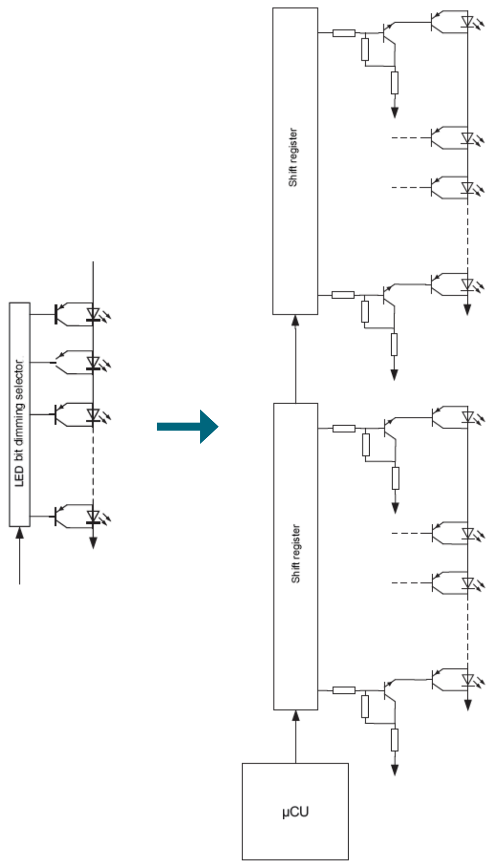
Dimming the LEDs of a front lighting application requires a circuit that can short-circuit each LED, and therefore bypass its current. This action can be completed by using a bipolar transistor parallel to each LED. A digital transistor activates the bipolar transistor (also know as the resistor-equipped transistor). They turn on and off via one or multiple shift registers.

Bipolar NPN

DFN		V_{CEO}	I_C
PBSS5160PAPS	DFN2020D-6	60 V	2 x 1 A
PBSS5160QA	DFN1010D-3	60 V	1 x 1 A
PBSS5260QA	DFN1010D-3	60 V	1 x 2 A

Shift register

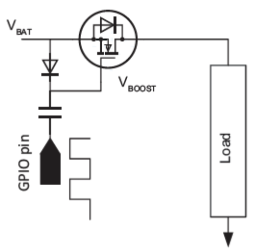
Product	Description	Packages
74HC(T)595-Q100	8-bit serial-in/parallel-out shift register with output storage register	SO, SSOP, TSSOP, DQFN



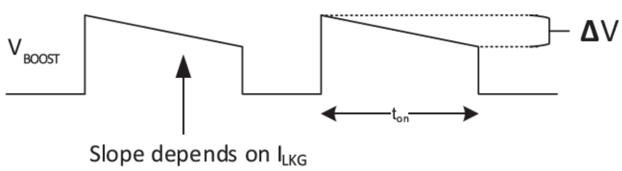
- Robust, AEC-Q100-compliant logic
- Side-solderable pads for 100% optical inspection
- Compact DFN-packaged, low-V_{CEsat} transistors
  - Single or dual package
  - Low V_{CEsat} optimizes efficiency
  - Low V_{CEsat} improves gain, thereby simplifying the drive circuit

Sizing the bootstrap capacitor

The bootstrap capacitor has to be able to supply the necessary charges (Qg) to turn on the power MOSFET and to anticipate the leakage current I_{LKG} that is causing the output ripple ΔV

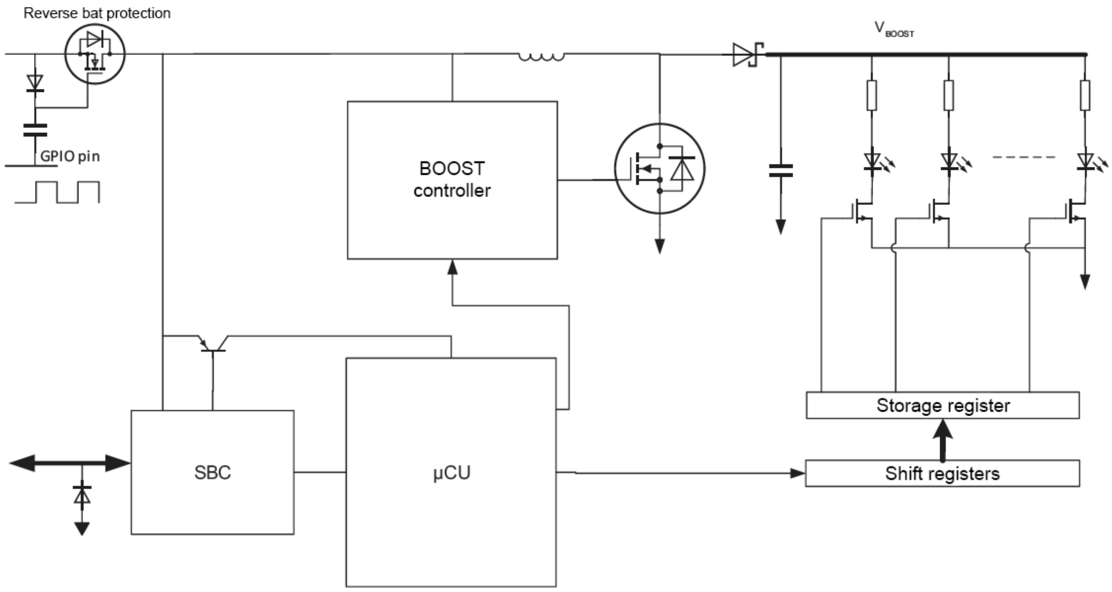


$C_{BOOST} \geq$



ΔV= ripple voltage
Qg: MOSFET gate's total charge
I_{LKG}: Total leakage current seen by the capacitor (because of the capacitor, diode, driver, etc.)

Rear LED lighting



Schematic description

Communication between the back-lighting ECU and the body control module occurs via an SBC, which is a LIN/CAN communication line via an ESD diode. The SBC implements the communication protocol and powers the microcontroller. To protect the SBC from overheating, use a PNP bipolar power supply output. The microcontroller regulates output boost level and controls switch on/off, as well as PWM output of LED strings.

The output LED strings are powered by a boost converter (asynchronous in the above schematic) with a well-defined output voltage that doesn't need to be changed/adapted. In case the LED strings need to have a different current, then a series resistor can be used. Alternatively, PWM control can control the LED light intensity. This action is accomplished with series MOSFETs (power MOSFETs if current is high or small-signal MOSFETs for low-power cases). MOSFETs are controlled directly from the microcontroller. In case the microcontroller doesn't have enough I/O pins available, then the power MOSFETs can be controlled by a shift register (I/O expansion).

Market demands

- V_{BAT} independent brightness output
- High efficiency
- Constant brightness output by means of accurate current control
- Compact design
- High-efficiency power conversion
- Low-cost total solution
- Low EMI and low susceptability using small-scale highly integrated package technology
- High-temperature-capable designs

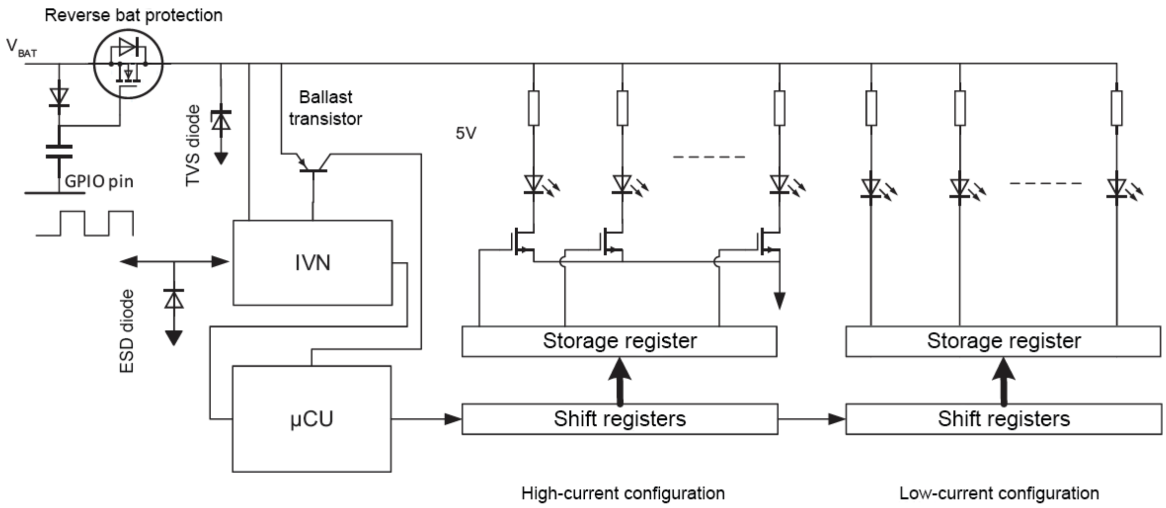
Application focus

- LFPAK56 power MOSFETs have best-in-class power density and current rating
- DFN with side-solderable leads packaged transistors and MOSFETs for 100% optical inspection
- Best-in-class system efficiency with Nexperia power schotty diodes
  - Low Vf
  - Ultra-low-leakage derivatives

Highlight parts

- 60 V to 80 V AEC-Q101 power MOSFETs in LFPAK56
- High-efficiency power schottky diodes
- Low R_{DSon} medium power MOSFETs in 2 x 2 mm DFN

Interior lighting



Schematic description

The proposed architectures for interior lighting look very similar to the architecture for back LED lighting. One big difference is the absence of a DC-DC (boost) converter. The DC-DC boost converter is not included because usually a less available power for interior lighting is needed. Therefore, the battery voltage (12 V) can directly control the LEDs. There is one possible side effect: In case of cranking—without the DC-DC converter and a stable voltage— the passengers can experience light brightness variation. One way to overcome this problem is to use the microcontroller to monitor the battery voltage and control the duty cycle of the LEDs through PWM.

In regard to functionality: In case LED current is too high, LEDs have to be switched on/off via MOSFET. Alternatively, in case the current isn't that high, then the current can be synched directly by a shift register or by the microcontroller if there are enough I/O pins. In the above schematic, the reverse battery protection is implemented from an n-channel MOSFET connected directly to the battery side. In order to fully enhance the MOSFET, we are using a bootstrap circuit made from a simple diode and a capacitor and controlled from a switching I/O pin of the microcontroller.

Market demands

- Single-, dual- and multi-channel LED drivers
- Constant-current LED drivers
- Compact design
- Serial interface reducing the number of interface lines
- Cost-efficient system solution
- Low EMI and EMC by using our leadless packages

Logic solutions

- Logic high-power NPIC family
- NCR4xx constant-current
- LED drivers
- Packages with side-solderable leads for 100% optical inspection
- A full range of LED driver solutions, from single discrete ones to fully integrated and cascadable

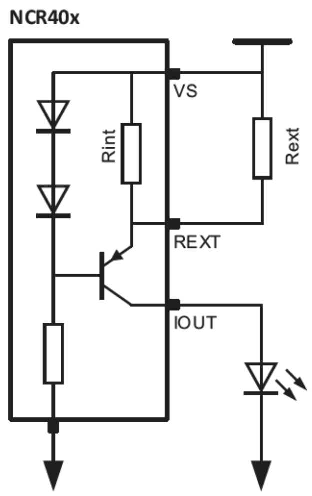
Highlight parts

- Logic NPIC family LED drivers
- High-efficiency power schottky diodes
- Low R_{DSon} medium power MOSFETs in 2 x 2 mm DFN
- Small form factor, Low V_{CEsat} transistors in DFN

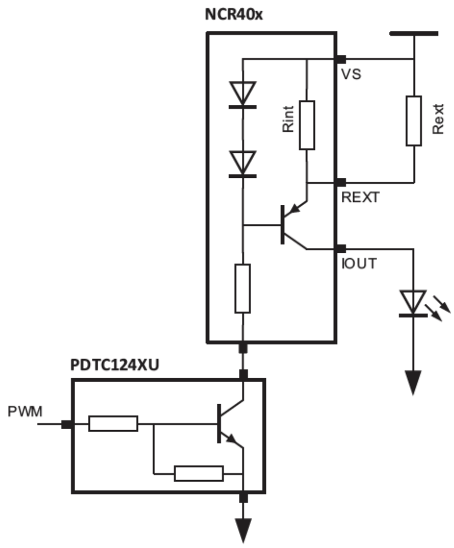
Interior lighting

Constant-current LED driver

Simple stand-alone LEDs are typically placed inside the passenger cabin of a car for aesthetic value, but also for functionality. Preferably, a constant current source should drive those LEDs in order to ensure a constant brightness. Nexperia NCR40x constant-current drivers provide an adjustable output current of 20–65 mA and also can provide PWM functionality when driven from a switch (typically a resistor-equipped transistor/digital transistor).



a) Standard functionality



b) PWM dimming

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

Key features & benefits

- High current accuracy at supply voltage variation
- Reduces component count and board space while simplifying PCB design
- Single die design results in low temperature dependence
- Low voltage overhead of 1.4 V
- High thermal power capability
- Stabilized output current adjustable up to 65 mA when external resistor used

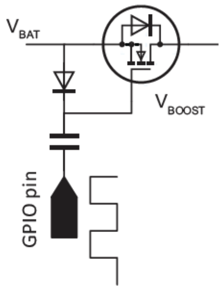
Adaptive front lighting

Part selection

RBP

Reverse battery protection and semiconductor relay					
Part	V_{DS}	$R_{DS(on)}$	I_d	R_{th}	Package
BUK9Y3R5-40E	40 V	3.5 mΩ	100	0.9 K/W	LFPAK56
BUK9Y4R4-40E	40 V	4.4 mΩ	100	1.02 K/W	LFPAK56
BUK9Y7R6-40E	40 V	7.6 mΩ	79	1.58 K/W	LFPAK56
BUK9M6R6-30E	30 V	6.6 mΩ	70	2 K/W	LFPAK33

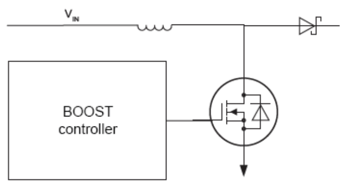
Tip: Using two MOSFETs in parallel instead of just one can give commercial benefits, but can also provide a robust thermal environment by distributing the heat on the PCB.



Boost converter

Power MOSFET					
Part	V_{DS}	$R_{DS(on)}$	I_d	R_{th}	Package
BUK9Y25-80E	80 V	25 mΩ	37 A	1.58 K/W	LFPAK56
BUK9M23-80E	80 V	23 mΩ	37 A	1.89 K/W	LFPAK33
BUK9M35-80E	80 V	35 mΩ	28 A	2.43 K/W	LFPAK33
BUK9Y41-80E	80 V	41 mΩ	25 A	2.31 K/W	LFPAK56

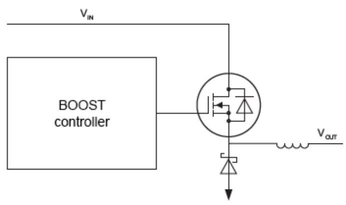
Schottky diodes					
Part	V_R	L_F	Vf	$I_R$max@$V_R$max	Package
BUK9Y25-80E	60 V	5 A	560 mV	0.04 mA	CFP15
BUK9M23-80E	100 V	8 A	850 mV	0.001 mA	CFP15
BUK9M35-80E	60 V	10 A	560 mV	0.07 mA	CFP15
BUK9Y41-80E	100 V	10 A	850 mV	0.001 mA	CFP15



Buck converter

Power MOSFET/Small-signal MOSFET					
Part	V_{DS}	$R_{DS(on)}$	I_d	R_{th}	Package
PMPB215ENEA	80 V	230 mΩ	2.8 A	8 K/W	DFN2020MD-6
PMPB95ENEA	80 V	105 mΩ	4.1 A	8 K/W	DFN2020MD-6
BUK9M35-80E	80 V	35 mΩ	28 A	2.43 K/W	LFPAK33
BUK9M85-60E	60 V	85 mΩ	14 A	4.8 K/W	LFPAK33

Schottky diodes					
Part	V_R	L_F	Vf	$I_R$max@$V_R$max	Package
PMEG6010ER	60 V	1 A	530 mV	0.06 mA	SOD123W
PMEG6010ELR	60 V	1 A	660 mV	0.0003 mA	SOD123W
PMEG6020AELP	60 V	2 A	680 mV	0.0007 mA	SOD128
PMEG6020AELR	60 V	2 A	680 mV	0.0007 mA	SOD123W
PMEG10020AELR	100 V	2A	770 mV	0.0003 mA	SOD123W

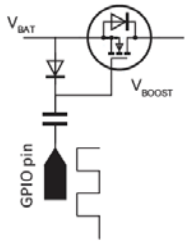


Rear LED lighting

Parts proposals

RBP

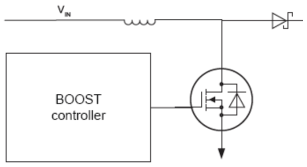
Reverse battery protection and semiconductor relay: Power MOSFETs and small-signal MOSFETs					
Part	V_{DS}	$R_{DS(on)}$	I_d	R_{th}	Package
BUK9M17-30E	30 V	17 mΩ	39 A	3.4 K/W	LFPAK33
BUK9M52-40E	40 V	52 mΩ	19 A	4.8 K/W	LFPAK33
PMV25ENEA	30 V	24 mΩ	5.5 A	2 K/W	SOT23
PMDPB56XNEA	30 V	72 mΩ	3.1 A	15 K/W	DFN2020D-6



Boost converter

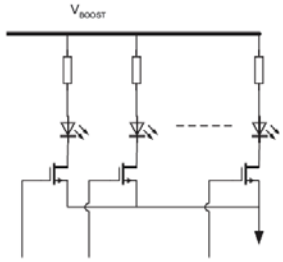
Power MOSFET					
Part	V_{DS}	$R_{DS(on)}$	I_d	R_{th}	Package
BUK9Y15-60E	60 V	15 mΩ	53 A	1.58 K/W	LFPAK56
BUK9Y25-60E	60 V	25 mΩ	34 A	2.31 K/W	LFPAK56
BUK9M42-60E	60 V	42 mΩ	23 A	3.4 K/W	LFPAK33
BUK7M53-60E	60 V	53 mΩ	19 A	4.17 K/W	LFPAK33

Schottky diodes					
Part	V_R	I_F	Vf	$I_R$max@$V_R$max	Package
PMEG060V050EPD	60 V	5 A	560 mV	0.04 mA	CFP15
PMEG060V100EPD	60 V	10 A	560 mV	0.001 mA	CFP15
PMEG100V100ELPD	100 V	10 A	850 mV	0.07 mA	CFP15
PMEG6030ELP	60 V	3 A	850 mV	0.001 mA	SOD128
PMEG6045ETP	60 V	4.5 A	-	-	SOD128



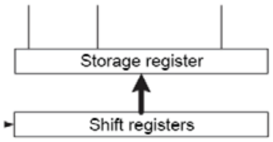
Current switch

Power MOSFET and small-signal discretes					
Part	V_{DS}	$R_{DS(on)}$	I_d	R_{th}	Package
BUK9M42-60E	60 V	42 mΩ	23 A	3.4 K/W	LFPAK33
BUK9M53-60E	60 V	53 mΩ	19 A	4.17 K/W	LFPAK33
PMPB55ENEA	60 V	56 mΩ	4 A	8 K/W	DFN2020MD-6
PMV55ENEA	60 V	60 mΩ	3.1 A	15 K/W	SOT23



Shift register

8-bit parts	Output storage register	SO	SSOP	TSSOP	DQFN
BUK9M42-60E		X	X	X	X
BUK7M53-60E	X	X	X	X	
PMPB55ENEA	X	X	X	X	X
PMV55ENEA		X	X	X	X
PMPB55ENEA	X	X	X	X	



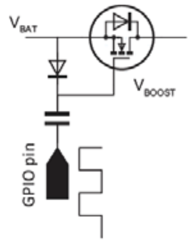
Shift register key features and benefits

- Easy-to-use shift-register-based LED drivers
- 3.3 V and 5 V interface voltage (available versions)
- 8- bit and 12-bit versions; can be cascaded
- Cost-effective integrated LED driver solution
- Reduced number of components/BOM lines
- Excellent quality in production (<110 ppb)
- NPIC family designed for LED driving

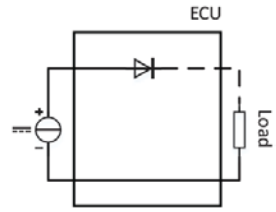
Interior LED lighting

Parts proposals

Reverse battery protection



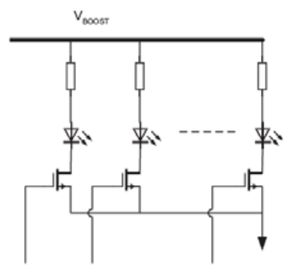
Small-signal MOSFETs					
Part	V_{DS}	$R_{DS\,(on)}$	I_d	R_{th}	Package
PMV25ENEA	30 V	24 mΩ	5.5 A	2 K/W	SOT23
PMV50ENEA	30 V	43 mΩ	3.9 A	32 K/W	SOT23
PMDPB56XNEA	30 V	72 mΩ	3.1 A	15 K/W	DFN2020D-6
PMV100ENEA	30 V	72 mΩ	3 A	28 K/W	SOT23



Schottky diodes					
Part	V_R	L_F	Vf	$I_R$max@$V_R$max	Package
PMEG2010ER	20 V	1 A	340 mV	1 mA	CFP3
PMEG3020ER	30 V	2 A	420 mV	1.5 mA	CFP3
PMEG3030EP	30 V	3 A	360 mV	5 mA	CFP3
PMEG3050EP	30 V	5 A	360 mV	8 mA	CFP3
PMEG045V100EPD	45 V	10 A	490 mV	0.6 mA	CFP3

Tip: Schottky diodes are a low-cost reverse battery protection alternative for low-power applications.

Current switch



Small-signal discretes					
Part	V_{DS}	$R_{DS\,(on)}$	I_d	R_{th}	Package
PMV65ENEA	40 V	75 mΩ	2.7 A	20 K/W	SOT23
PMV130ENEA	40 V	120 mΩ	2.1 A	25 K/W	SOT23
PMV120ENEA	60 V	123 mΩ	2.1 A	20 K/W	SOT23

Shift register

8-bit parts	Output storage register	SO	SSOP	TSSOP	DQFN
74HC(T)164		X	X	X	X
74HC(T)594	X	X	X	X	
74HC(T)595	X	X	X	X	X
74LV164		X	X	X	X
74LV595	X	X	X	X	

Ballast transistor

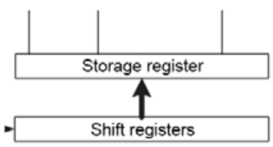
Part	V_{CEO}	I_F	Configuration	Package
PHPT60603NY	60 V	3 A	NPN	LFPAK56
PHPT60603PY	60 V	3 A	PNP	LFPAK56
PHPT61002NYC	100 V	2 A	NPN	LFPAK56
PHPT61002NYC	100 V	2 A	PNP	LFPAK56

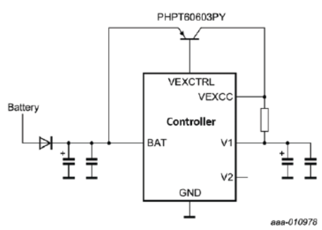
Shift register key features and benefits

- Easy-to-use shift-register-based LED drivers
- 3.3 V and 5 V interface voltage (available versions)
- 8- bit and 12-bit versions; can be cascaded
- Cost-effective integrated LED driver solution
- Reduced number of components/BOM lines
- Excellent quality in production (<110 ppb)
- NPIC family designed for LED driving

Key benefits

- LFPAK56 AEC-Q101 power MOSFETS
- Low Vf power schottky technology
- Ultra-low leakage capable
- High-temperature operation (175 °C)
- Flat/thin power package (CFP15)
- Low R_{DSon}, high efficiency, high power density





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