

Body Power / H. Hopfgartner

LED Driving Concepts and Infineon® Basic LED Drivers

Application Note

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Basic LED Driver

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1 Abstract

Note: The following information is given as a hint for the implementation of the device only and shall not be regarded as a description or warranty of a certain functionality, condition or quality of the device.

Note: All application diagrams shown in this application note are very simplified examples of application circuits. The function must be verified in the real application.

This application note is intended to provide detailed application hints regarding the usage and design in of the Infineon® Basic LED Drivers. The selection of external components is shown within this application note. Furthermore, different principles of LED driving concepts are explained.

2 Introduction

The Infineon® Basic LED Drivers is a family of single- and three-channel current sources. The typical output current range is from 20 mA up to 2500 mA, which can be adjusted in most cases. Furthermore, some device also offer diagnosis features.

This document shows how to define the external circuitry for the required output current and gives hints for diagnosis function.

3 How to Control LEDs

Light emitting diodes (LED) are semiconductor pn-junctions. When the LED is forward biased, electrons are able to recombine with holes within the device, releasing energy in the form of photons. The LED's forward current, which has to be limited, defines the brightness of the LED.

The current limiting and setting can be done with different methods:

- A resistor to limit the forward current
- A linear current source to set a defined and stable current
- A DCDC converter in constant current mode

In automotive applications LED-modules for exterior lighting are usually controlled via a switch on the central body control module (BCM) as it is shown in Figure 1, Figure 2 and Figure 3. The reason is to protect the wire from the BCM to the LED-module against short circuits. The LED-control ICs are mounted very close to the LEDs to ensure:

- A protection of the LEDs, if the wire from the BCM to the LED-module is shorted to the supply voltage
- To react on high temperature conditions in the LED-module (active current reduction to protect LEDs)

The following three chapters explain the different methods of LED control. Benefits and disadvantages are identified.

3.1 Resistor for LED Current Limitation

A resistor can act only as a current limiter, but not as a current control circuit for the LED. The picture below shows the simplified circuit schematic with a resistor solution:

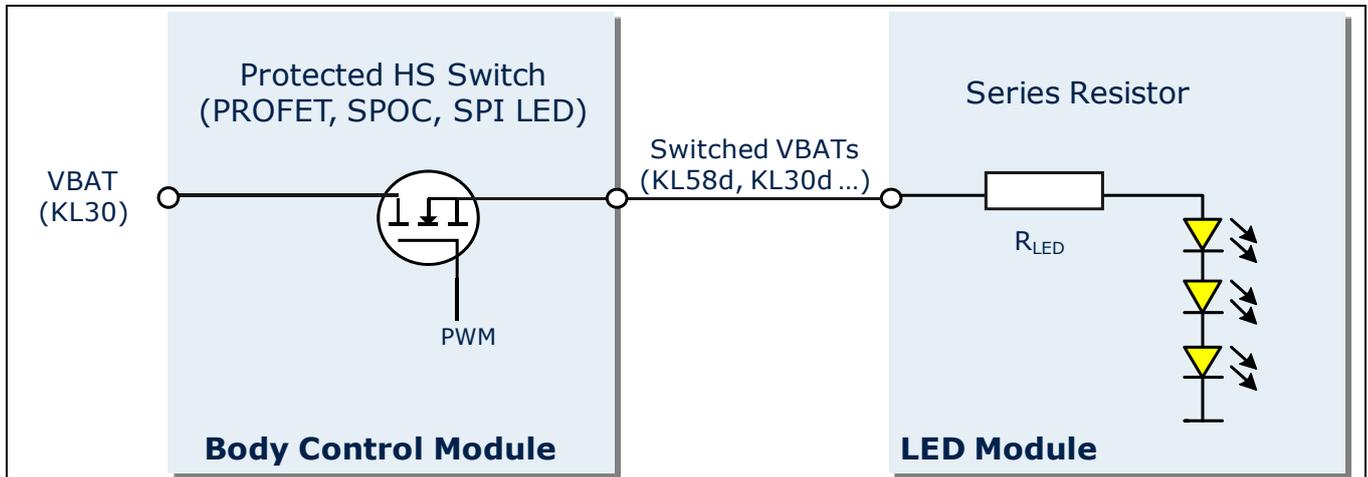


Figure 1 LED driving schematic

The resistor has to be defined for the worst case supply voltage e.g. $V_{BATs(max)} = 18\text{ V}$.

E.g. An LED for a typical rear light application is operated usually at a typical current of $I_{LED} = 50\text{ mA}$ with a typical forward voltage of $V_F = 2.2\text{ V}$

Therefore, the resistor R_{LED} can be calculated for the example above (3 LEDs $\rightarrow n = 3$):

$$(1) \quad R_{LED} = \frac{V_{BATs(max)} - n \cdot V_F}{I_{LED}} = \frac{18\text{V} - 3 \cdot 2.2\text{V}}{50\text{mA}} = 228\Omega$$

The resistor R_{LED} has to withstand a power loss of:

$$(2) \quad P_{R_{LED}} = (V_{BATs(max)} - n \cdot V_F) \cdot I_{LED} = (18\text{V} - 3 \cdot 2.2\text{V}) \cdot 50\text{mA} = 0.6\text{W}$$

So, a power resistor is required.

In case of lower supply voltages or voltage drops (e.g. start stop) the LED current is reduced, which leads to significant reduced brightness! If the supply voltage drops down to e.g. $V_{BATs(min)} = 9\text{ V}$:

$$(3) \quad I_{LED} = \frac{V_{BATs(min)} - n \cdot V_F}{R_{LED}} = \frac{9\text{V} - 3 \cdot 2.2\text{V}}{228\Omega} = 11\text{mA}$$

Pros

- Simplest solution

Cons

- High power loss across the R_{LED}
- Resistor needs to be defined for maximum supply voltage conditions. For typical supply voltage conditions the LED current is much lower, which leads to a visible decrease of brightness e.g. during start stop operation
- LED nominal current range cannot be used for nominal operation conditions, because current has to be fixed for maximum supply voltage
- No intrinsic overvoltage protection (during supply voltage spikes the LEDs are stressed significantly, because of exceeding the LEDs maximum ratings) \rightarrow degradation of LEDs

- No simple temperature protection of the LEDs possible → degradation of LEDs
- Reduced LED lifetime Any diagnosis functions needs to be realized by additional circuits
- Only limited LED chain length, dependent on the LED forward voltage V_F and minimum supply voltage

3.2 Linear Current Source for Constant Current Supply of LEDs

A linear current source provides a constant output current to the LED over the entire supply voltage range. In addition to the benefits of the constant LED current diagnosis functions are provided by most linear current sources. The figure below shows a simplified LED module using a constant current source.

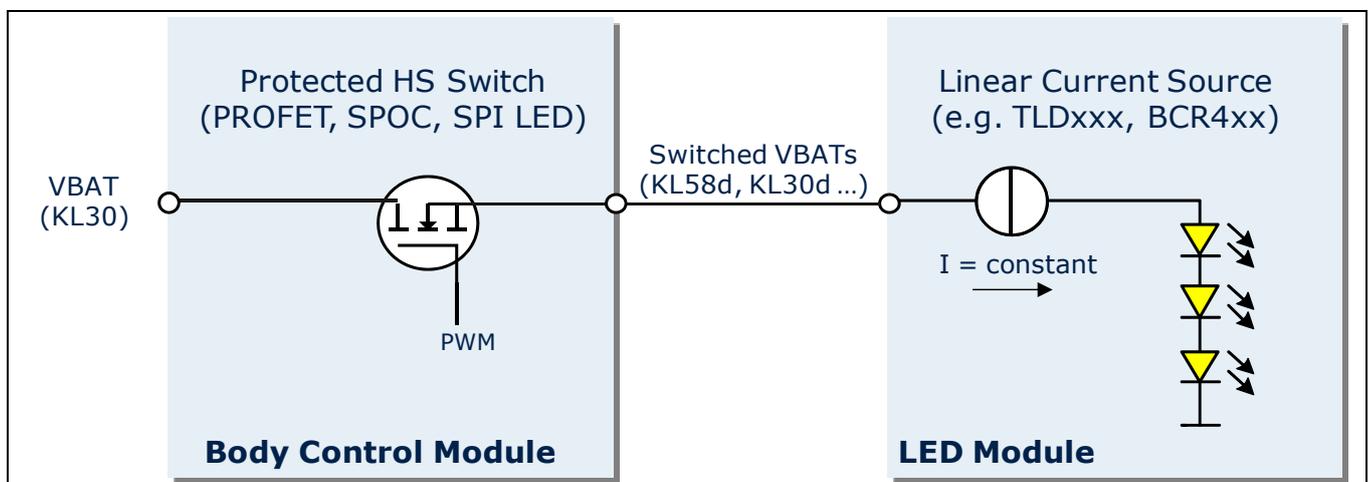


Figure 2 LED driving schematic

The LED current is controlled by the linear current source. The output current is constant and nearly fully independent of the V_{BATs} . The LED current can be adjusted very easily by using external resistors. Details about current control and diagnosis are explained later in this application note.

Pros

- LED can be used in the nominal operation condition → full brightness
- Stable brightness even during start stop
- Intrinsic overvoltage protection
- No LED degradation
- High temperature protection of LEDs possible
- Integrated diagnosis functions (optional)

Cons

- High power loss across the constant current source
- Increased components count
- Only limited LED chain length, dependent on the LED forward voltage V_F and minimum supply voltage

To increase the efficiency of the total system a so called Matrix setup could be used as described later in this application note.

3.3 DC/DC Converter in Constant Current Mode

A DC/DC converter in constant current mode provides a constant output current to the LED over the entire supply voltage range. The power loss inside the LED control circuit is reduced to a minimum, because the configuration is optimized to the LED chain length. Furthermore, diagnosis functions are provided by most DC/DC converters. The figure below shows a simplified LED module using a DC/DC converter.

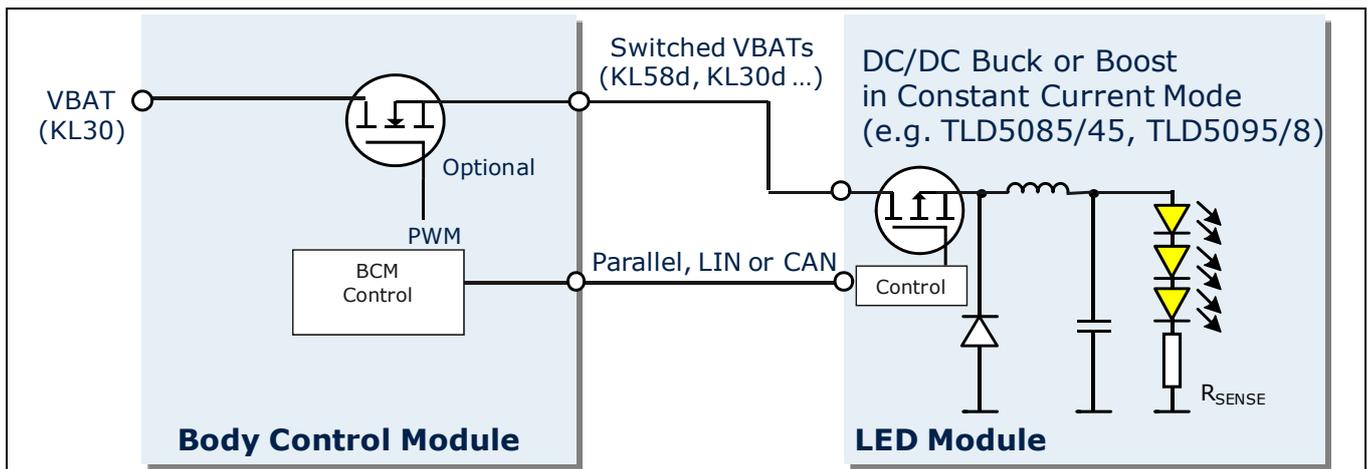


Figure 3 LED driving schematic

The LED current is controlled by the DC/DC converter. Different topologies (Buck, Boost, SEPIC, ...) can be used to fulfill requirements regarding LED chain length and supply voltage range. The output current is constant and nearly fully independent of the V_{BATs} . The LED current can be adjusted very easily by using external resistors.

Pros

- Highest efficiency
- LED can be used in the nominal operation condition → full brightness
- Stable brightness even during start stop
- High brightness LEDs capable
- Various topologies possible
- Intrinsic overvoltage protection
- No LED degradation
- High temperature protection of LEDs possible
- Integrated diagnosis functions (optional)

Cons

- Increased components count
- PCB layout needs to be optimized regarding EMC performance

3.4 DC/DC Converter combined with Constant Current Source – Matrix Setup

A DC/DC converter in constant voltage mode is combined with one or more linear current sources. The DC/DC converter provides an output voltage, which is optimized for the required LED chain length. The DC/DC's output voltage is converted into a constant output current by the linear current sources. This system allows a more efficient LED controlled compared to a pure linear current source solution as described before. The figure below shows a simplified LED module using the Matrix setup.

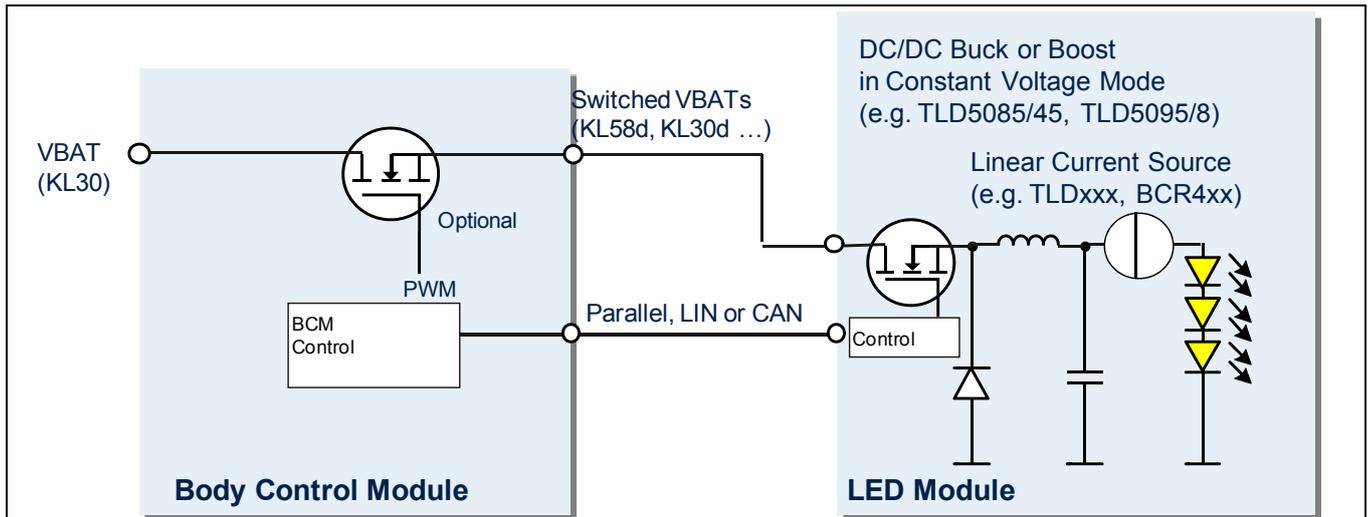


Figure 4 LED driving schematic

The LED current is controlled by the linear current source. The DC/DC converter output voltage is adjusted to the LEDs forward voltage. Different topologies (Buck, Boost, SEPIC, ...) can be used to fulfill requirements regarding LED chain length and supply voltage range. The output current is constant and nearly fully independent of the V_{BATs} . The LED current can be adjusted very easily by using external resistors.

Pros

- One DC/DC converter for multiple linear current sources
- Current source supply, which is the DC/DC output, optimized to LED forward voltage
- LED can be used in the nominal operation condition → full brightness
- Stable brightness even during start stop
- Various topologies possible
- Higher efficiency than pure linear current source solution
- Intrinsic overvoltage protection
- No LED degradation
- High temperature protection of LEDs possible
- Integrated diagnosis functions (optional)

Cons

- Increased components count
- PCB layout needs to be optimized regarding EMC performance

4 Infineon® Basic LED Driver

Infineon provides numerous automotive qualified constant current source products for optimized LED control within automotive interior and exterior lighting applications. In the following explanation an overview of all current available products is given.

Table 1 Infineon® Basic LED Driver Overview

	Current		Open Load Detection	PWM/Enable	Hi/Low Current Switch	Package
	mA	adj.				
BCR40xU	10-50 _{typ}	✓				SC-74
BCR420U	150 _{typ}	✓				SC-74
BCR421U	150 _{typ}	✓		✓		SC-74
TLD1211SJ	85 _{typ}	✓		✓		DSO-8
TLE4240-2M	60 _{typ}					SCT-595
TLE4240-3M	60 _{typ}		✓			SCT-595
TLE4241GM	70 _{max}	✓	✓	✓	✓	DSO-8
TLE4242G	450 _{typ}	✓	✓	✓		TO-263
TLD1211SJ + ext NPN	<2500	✓		✓		DSO-8

4.1 BCR4xx Family - Low Cost Linear Current Sources

The BCR4xx family includes low cost constant current source LED drivers offering current adjustment features without diagnostic functions for easiest design in.

Table 2 BCR4xx Product and Feature Overview

Product type	Package	Topology	Input voltage min [V]	Input voltage max [V]	Output current [mA]	Inhibit	PWM	Open load detection
BCR420U	PG-SC74-6	Linear	4.5	40	150			
BRC421U	PG-SC74-6	Linear	4.5	40	150	✓	✓	
BCR401U	PG-SC74-6	Linear	4.5	40	10			
BCR402U	PG-SC74-6	Linear	4.5	40	20			
BCR405U	PG-SC74-6	Linear	4.5	40	50			

Key Features:

- Low cost technology & package
- Output current adjustable by usage of external resistor, without external resistor output current is fixed to specified value
- Suitable for Pulse Width Modulation (PWM)
- Negative temperature coefficient (LED protection @ high temperatures)
- Available in several package options: SOT143R, SOT343, SC74
- Possibility to operate as control circuit with an external NPN-power transistor as output stage
- Automotive Qualified

4.1.1 Integrated Output Stage Usage

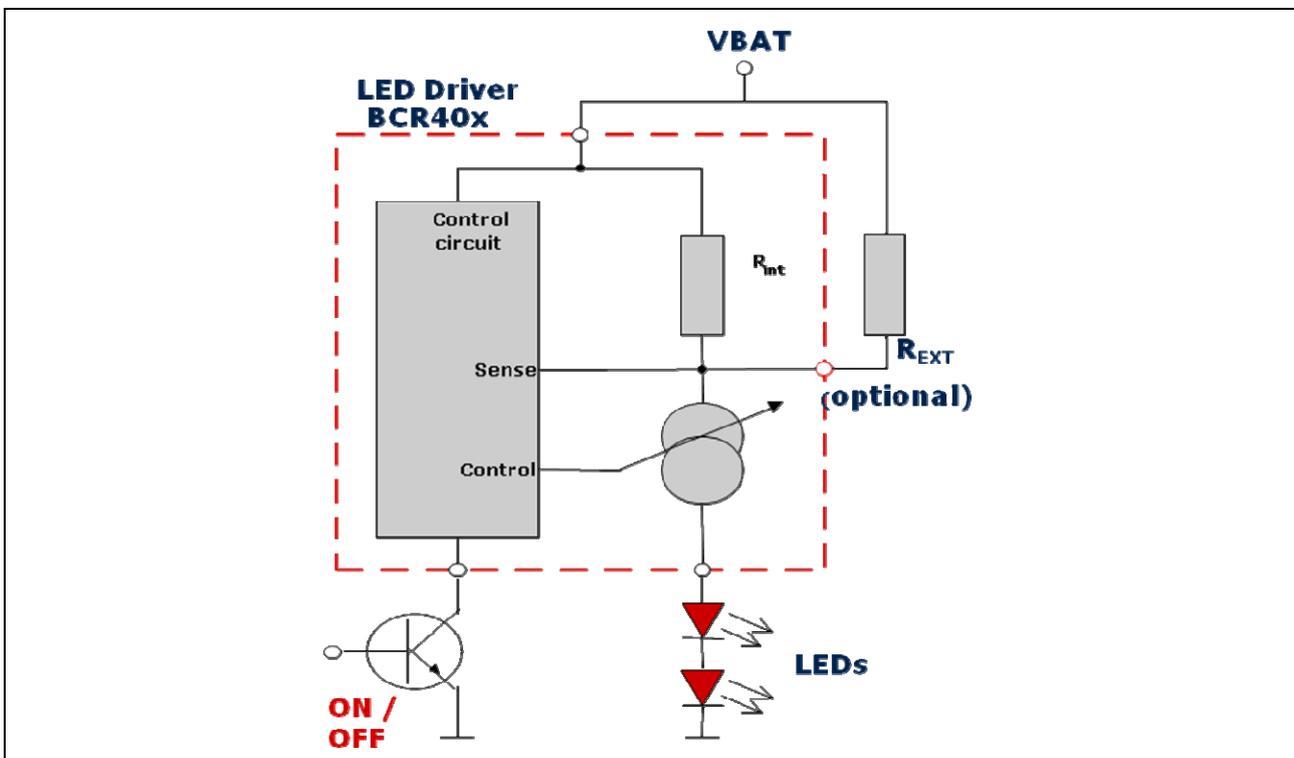


Figure 5 Schematic

The LED current can be adjusted by using the external resistor R_{EXT} . If no external resistor is mounted, the LED current is fixed to the specified value according to the data sheet. With equipped R_{EXT} the output current is defined by the following equation. The values used for the example are based on the BCR401:

$$(4) \quad I_{OUT} = \frac{V_{drop}^*}{\frac{R_{int}^{**} \cdot R_{EXT}}{R_{int}^{**} + R_{EXT}}} \approx \frac{0.91V}{91\Omega + R_{EXT}}$$

With:

* V_{drop} according to data sheet graph “reference voltage (V_{drop}) versus I_{OUT} ”, typ. 0.91V

** R_{int} according to data sheet parameter R_{int} , typ. 91 Ω

4.1.2 External Output Stage Usage

The devices of the BCR4xx family can be used also as control IC for an external NPN-transistor as output stage for high LED currents according to the following schematic. The basic LED driver is driving only a very small current, which is the base current for the external NPN transistor. Therefore, in a lot of cases the BCR401 devices are sufficient.

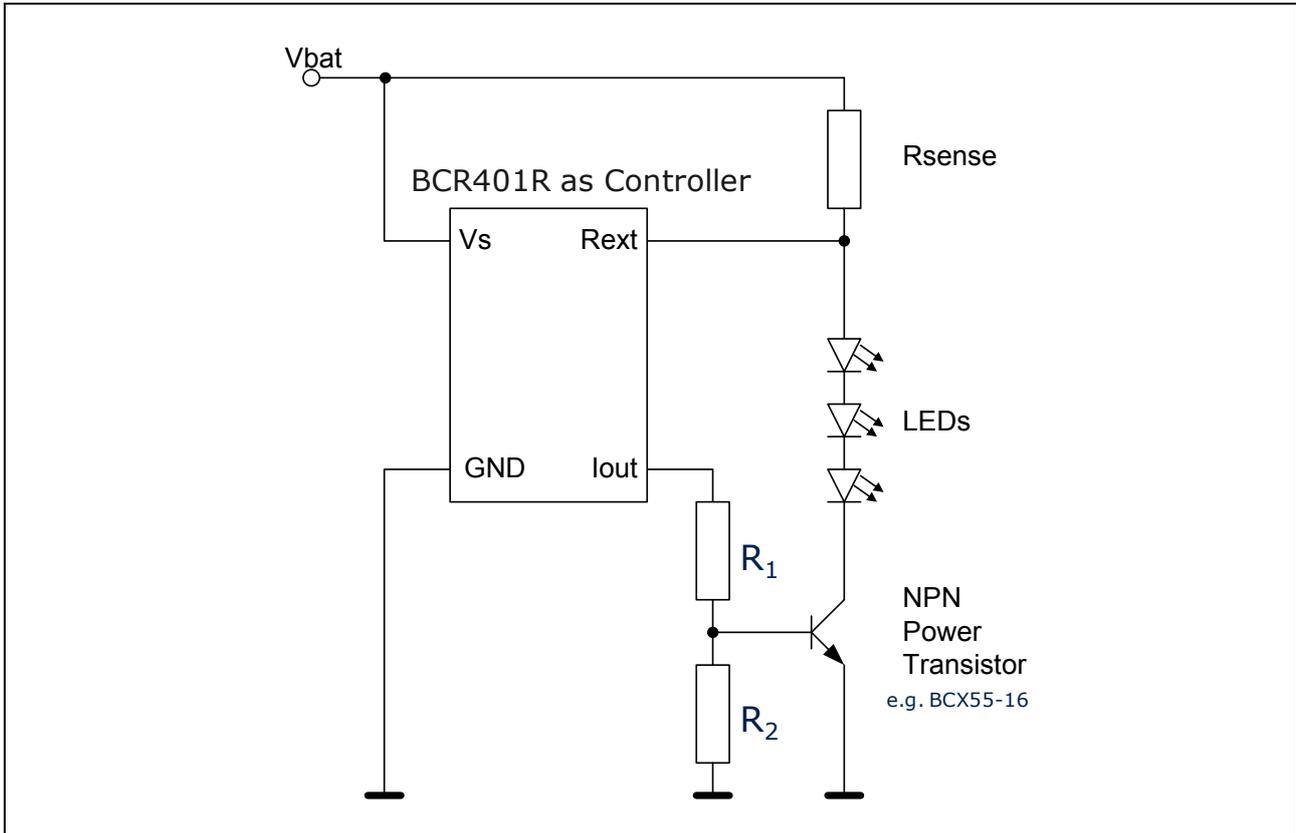


Figure 6 Schematic

The resistors R_{sense} , R_1 and R_2 can be calculated according to the following equations. All parameters marked

with a star * are related to the transistor's data sheet.
$$I_{LED} = \frac{V_{drop}}{\frac{R_{int} \cdot R_{sense}}{R_{int} + R_{sense}}}$$

The transistor base current is defined by:

(6)
$$I_B = \frac{I_{LED}}{B^*}$$
 B...DC current gain of transistor

The resistor R_2 is calculated according:

(7)
$$R_2 = \frac{V_{BE(on)}^*}{I_{R2}} \quad I_{R2} = 2 \dots 10 \cdot I_B$$

The resistor R_1 is calculated according:

(8)
$$R_1 = \frac{V_{BAT(min)} - V_{S(min)} - V_{BE(on)}^*}{I_B + I_{R2}}$$

4.2 TLD1211SJ - Linear LED Driver

The TLD1211SJ is a linear current source providing currents up to 85mA and having an integrated high temperature current reduction feature to protect the connected LEDs against to high temperatures. Furthermore, it supports the current control function of an external NPN transistor.

Key Features:

- Max. Output current 85mA
- Temperature dependent current reduction
- External Transistor Option LED currents up to 2.5A
- Improved precision of output current: +/- 10% in whole operating range (V_{supply} ; T_j)
- Over voltage protection
- Enable input for PWM operation
- DSO-8 package
- Automotive Qualified

4.2.1 Integrated Output Stage Usage

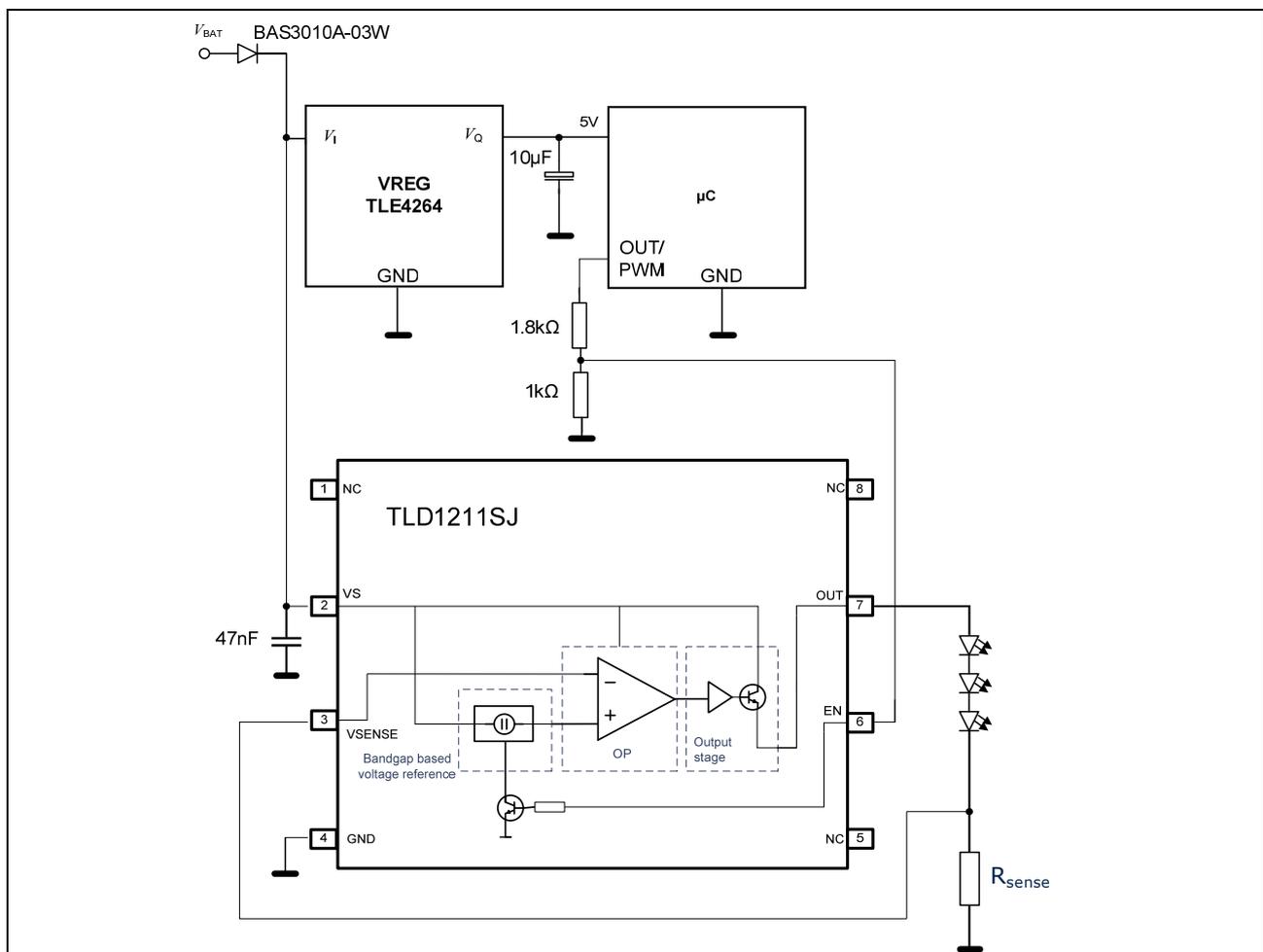


Figure 7 Schematic

The LED current can be adjusted by the sense resistor R_{sense} :

$$(9) \quad I_{OUT} = \frac{V_{sense}^*}{R_{sense}}$$

With V_{sense} according to datasheet parameter 4.3.9, typ. 150mV

4.2.2 External Output Stage Usage

The TLD1211SJ can be used also as control IC for an external NPN-transistor as output stage for high LED currents according to the following schematic. The basic LED driver is driving only a very small current, which is the base current for the external NPN transistor.

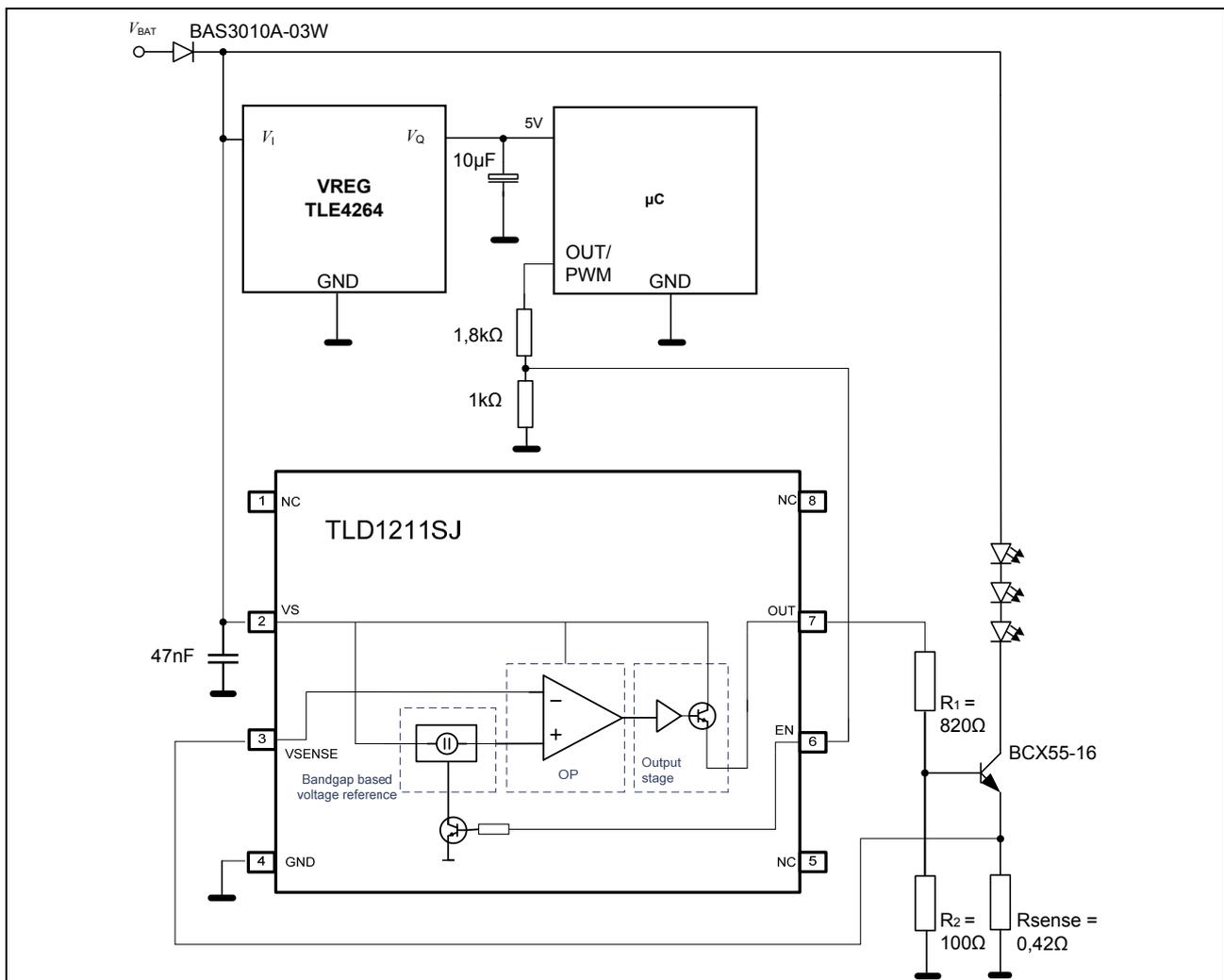


Figure 8 Schematic

The resistors R_{sense} , R_1 and R_2 can be calculated according to the following equations. All parameters marked with a star * are related to the transistor's data sheet. $I_B = \frac{I_{LED}}{B^*}$ B ...DC current gain of transistor

$$(11) \quad R_{sense} = \frac{V_{sense}}{I_{sense}} \text{ with } I_{sense} = I_{Load} + I_B$$

The resistor R_2 is calculated according:

$$(12) I_{R2} = n \cdot I_B \text{ with } n = 2 \dots 10$$

$$(13) R_2 = \frac{V_{BE}^* + V_{sense}}{I_{R2}} \text{ with } I_{sense} = I_{Load} + I_B$$

The resistor R_1 is calculated according:

$$(14) R_1 = \frac{V_{OUT} - V_{BE}^* - V_{sense}}{I_B + I_{R2}} \text{ with } V_{OUT} = V_S - V_{drop}^{**}$$

** V_{drop} is the datasheet parameter 4.3.11 ($V_S - V_{out}$), max. 1.3V

4.3 TLE4240-2/-3M - Linear LED Driver

The TLE4240-2/-3M is a linear current source with a fixed output current of typically 60mA. The TLE4240-3M offers an open load diagnosis.

Key Features:

- Constant Output Current of typ. 60 mA
- Low dropout voltage
- Open Load Diagnosis Output (Version TLE4240-3 only)
- Safe Operation Area circuit monitoring drop voltage
- Short Circuit Protection to GND and VBAT (up to 45V)
- Reverse polarity protected
- Package SCT-595
- Automotive Qualified

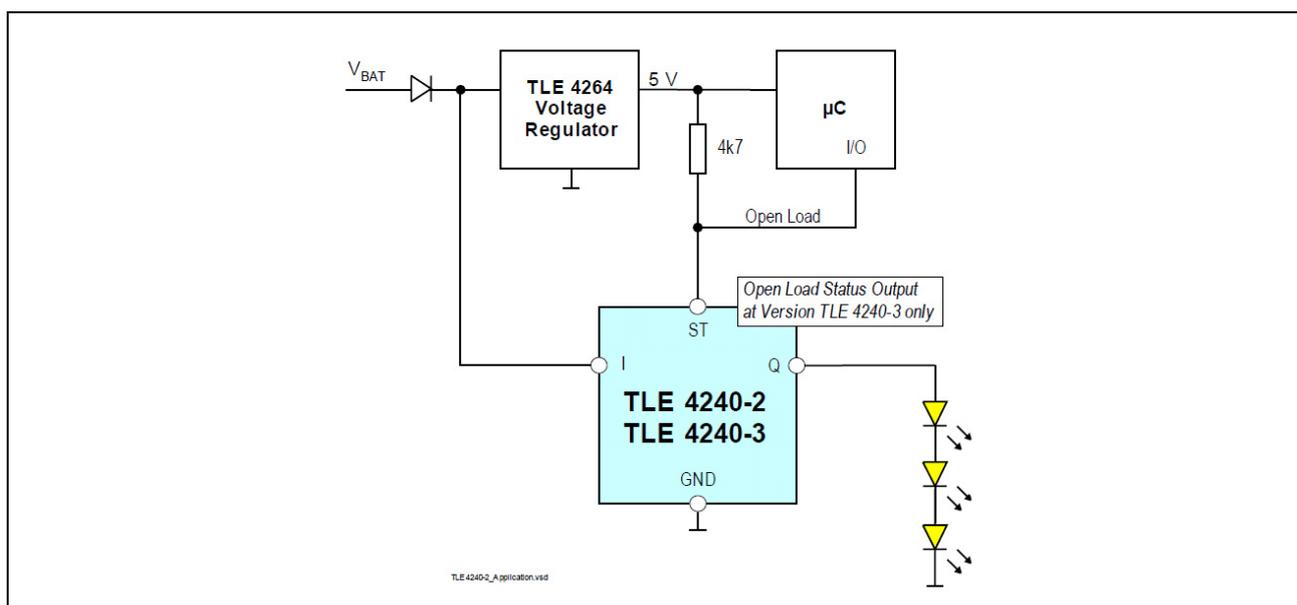


Figure 9 Schematic

The status pin ST is an open collector pin. In normal load condition ST-pin is high impedance → HIGH. In open load condition ST-pin is pulled to GND → LOW.

4.4 TLE4241GM - Linear Dual Mode LED Driver

The TLE4241GM is a dual mode linear current source with adjustable output current up to 70mA. By applying a low or high signal at the SET-pin the output current can be changed by a ratio of typ. 7.

Key Features:

- Adjustable Constant Output Current up to 70 mA
- Low Dropout Voltage
- Dual Mode for Tail and Stop Light (low/high current SET)
- PWM Input (e. g. for individual dimming) up to 1kHz
- Open Load Diagnosis Output
- Input Voltage Range up to 45 V
- Reverse Polarity Protected
- Short Circuit Protection to GND and VBAT
- Small SMD Package: P-DSO-8
- Operating range: -40...150 °C
- Over-Temperature Protection
- Automotive Qualified

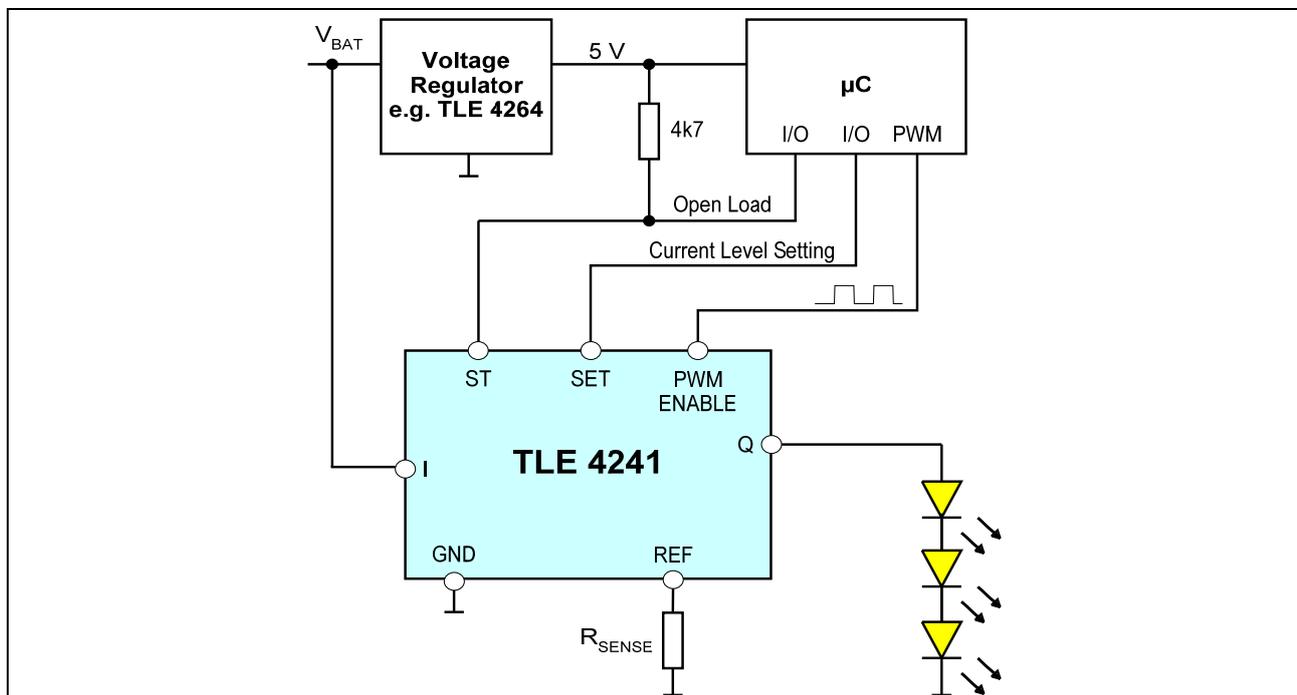


Figure 10 Schematic

When the SET-pin is at low potential the output current is the low level. As soon as the SET-pin is switched to high potential (up to V_{BAT}) the high output current is active. The output current can be adjusted additionally by the sense resistor R_{SENSE} .

If the SET-pin is connected to high potential (e.g. 5V) the high output current can be calculated:

$$(15) I_{Q,typ,SET=H} = \frac{V_{ref}^*}{R_{ref}} \cdot 487 + 0.1$$

If the SET-pin is connected to low potential (0V):

$$(16) I_{Q,typ,SET=L} = \frac{\frac{V_{ref}^*}{R_{ref}} \cdot 487 + 0.1}{I_{QH} / I_{QL}^{**}}$$

* According to data sheet diagram “Reference voltage versus junction temperature”, typ. 1.2V

** I_{QH}/I_{QL} is the data sheet parameter “current ratio”, typ. 7

4.5 TLE4242G - Linear 1 Watt LED Driver

The TLE4242G is a linear current source for driving high brightness LEDs up to 1W. It provides a PWM input and a diagnosis output.

Key Features:

- Adjustable Output Current up to 500mA
- Low dropout voltage
- PWM Input (dimming, switching between brake and tail light, ...)
- Diagnosis Output
- Over-Temperature Protection
- Short Circuit Protection to GND and VBAT
- Reverse Polarity Protected
- Input Voltage Range up to 45 V
- Package TO-263-7
- Automotive Qualified

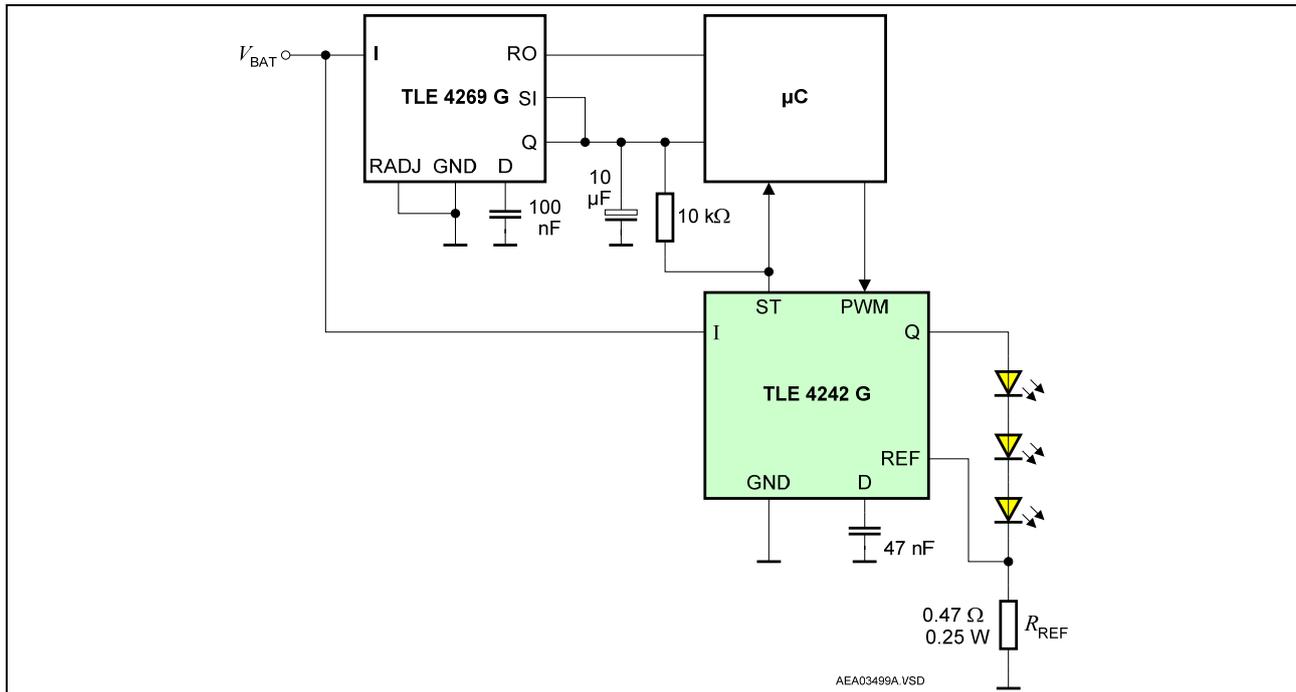


Figure 11 Schematic

The output current can be adjusted by the reference resistor R_{REF} .

If the SET-pin is connected to high potential (e.g. 5V) the high output current can be calculated:

$$(17) I_{Q,typ} = \frac{V_{ref}^*}{R_{ref}}$$

* According to data sheet diagram "Reference voltage versus junction temperature", typ. 177mV

The diagnosis response time can be adjusted by the capacitor connected to the diagnosis-pin D:

$$(18) t_{STHL,typ} = \frac{C_D}{47nF} \cdot 10ms \quad t_{STLH,typ} = \frac{C_D}{47nF} \cdot 10\mu s$$

5 Conclusion

Infineon® Basic LED Drivers are able to drive small signal LEDs up to high brightness LEDs. The dimensioning of the required external components is supported by this application note.

6 Additional Information

- For further technical details, please contact us.
- Existing App. Notes
 - AN101, Using Infineon's BCR400 Family of Constant-Current, Linear-Mode LED Drivers for Lighting Applications from 10 mA - 700 mA
 - AN97, Using BCR402R/BCR402U at High Supply Voltages
- For further information you may contact <http://www.infineon.com/automotive-leddrivers>

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