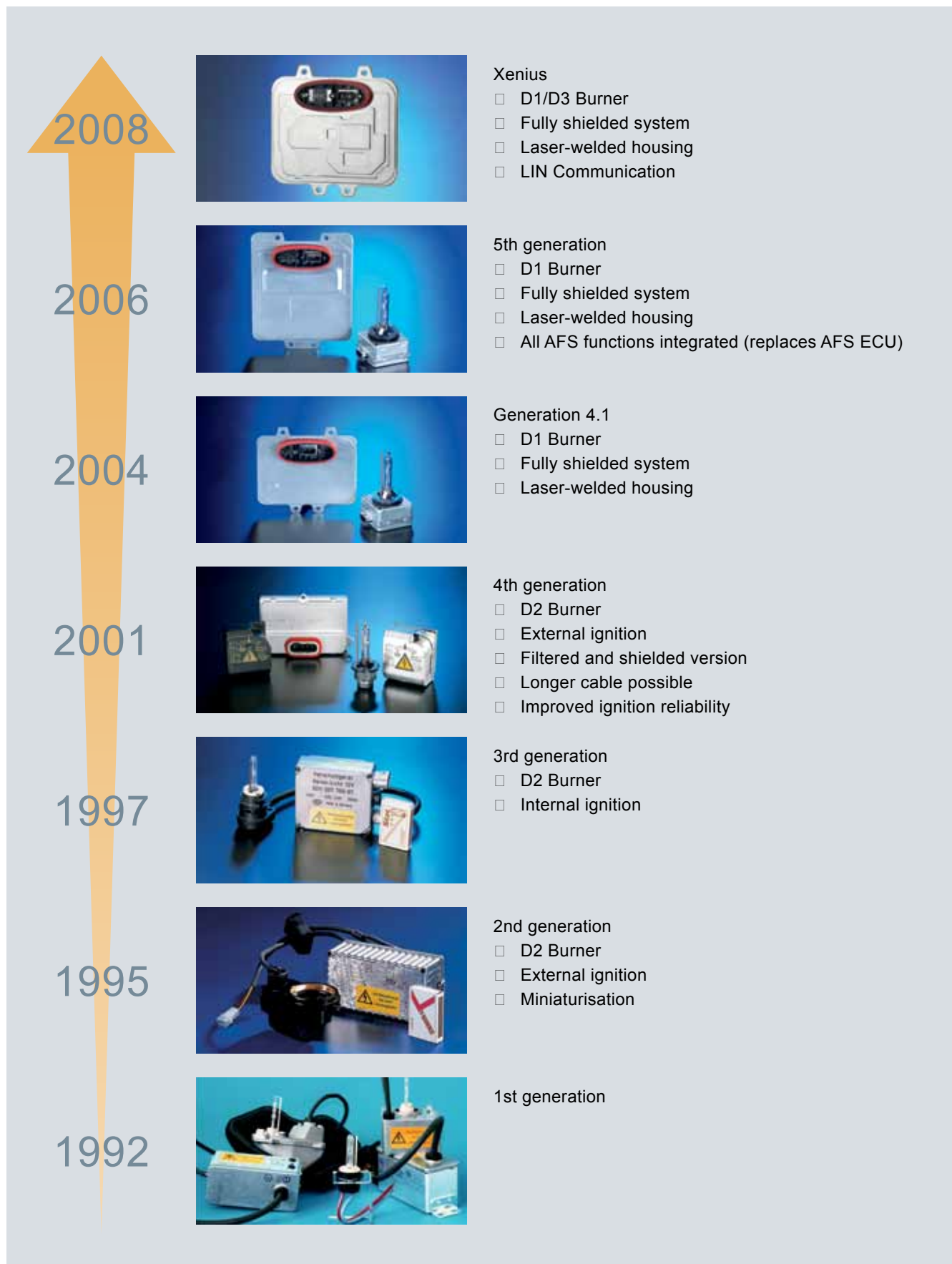
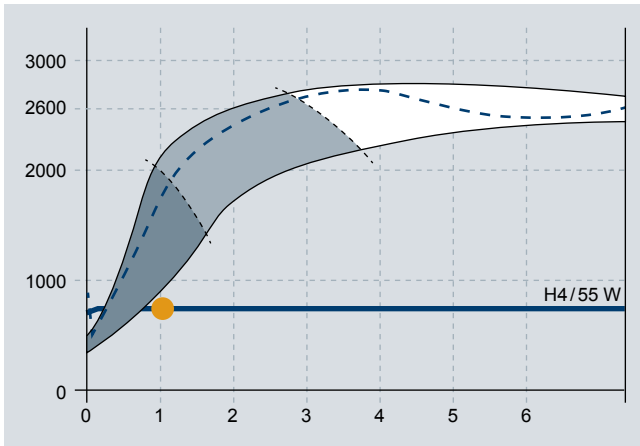


Stages of development of the electronic xenon ballasts manufactured by HELLA:





Switch-on process of a gas discharge light

### Structure and function of the electronic ballast

The electronic ballast (E) ignites the inert gas mixture in the light by means of a high-voltage impulse of up to 30 kV (4th generation), through which a spark flashes over between the light electrodes. It controls the light start-up so that it reaches the operating phase quickly and then regulates the light capacity to a constant 35 W (see fig.).

A DC converter generates the necessary voltages for the electronics and the light from the vehicle electrical system. The bridge circuit provides 300 Hz AC voltage to operate the xenon lights.

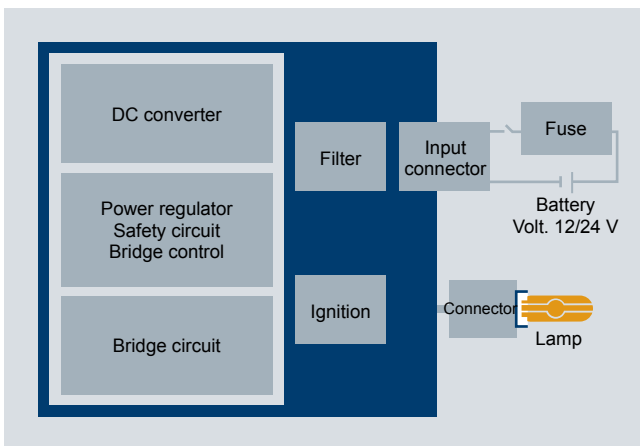
Several control and safety circuits are integrated in the device.

The system is switched off within 0.2 seconds in the event of:

- a missing or faulty burner
- damaged cable strand or light part
- differential current (fault current) greater than 30 mA, the switch-off time becomes shorter the greater the differential current

To protect the electronic ballast, a counter circuit makes sure that a faulty light is only ignited 7 times. It is then switched off.

If the cable plug is removed during operation, the voltage plugs are practically voltage-free (< 34 V) after < 0.5 seconds so that there is no imminent danger of an electric shock even if the hazard warnings are not heeded.



Circuit diagram of the electronic ballast system

### Properties and differences of 3rd/4th generation compared to 5th/6th generation

Features	3rd generation	4th generation	5th generation	6th generation (Xenius)
Burner	D2	D2	D1	D1/D3
Internal ignition	X			
External ignition		X		
Filtered and shielded version		X		
Fully shielded system			X	X
Longer cable possible		X		
Improved ignition reliability		X		
Laser-welded housing			X	X
All AFS functions integrated			X	
LIN Communication				X



Shielded



Filtered

### Ignition module

The different versions meet various limiting values in terms of electromagnetic compatibility.

The main differences between the 3rd and 4th xenon generation are an ignition unit with or without metal shielding and the cable assembly between the ballast and the ignition unit which is either shielded or non-shielded.

### Tips for dealing with electronic ballasts

#### Effects of ballast failure

A faulty ballast leads to complete headlight failure.

Possible causes for failure of the ballast are:

- Lack of voltage supply
- Lack of ground connection
- Faulty electronics in the device
- Internal short-circuits

#### Fault diagnosis

Check whether the ballast is attempting to ignite the light after the light has been switched on. Ignition attempts can be heard clearly near the headlight. If ignition attempts are unsuccessful, the xenon light should be checked by replacing it by the one from the other headlight and trying again.

If no ignition attempt is carried out, the fuse should be checked.

If the fuse is OK, check the voltage and ground supply directly at the ballast. Voltage must be at least 9 Volts. If the voltage and ground supplies and the xenon light are all OK, a faulty ballast is causing the problem.



Bi-xenon module

### Bi-xenon

Bi-xenon means that high and low beam are realised by a single projection module. This has the advantage of requiring only one electronic ballast. Thus, two light distribution patterns with a large luminous flux can be realised in a confined design space.



Illumination with good high beam

Illumination with Bi-xenon high beam

### Function

Thanks to the use of a movable shutter, the light can be switched mechanically between the light distributions for high and low beam. This means that apart from the setting mechanism for the shutter, no additional expenditure for a separate headlight with suitable control electronics is necessary. In addition, the high beam has a longer range and the edges of the road are illuminated significantly better.



### Information about the illegal conversion to xenon light

You simply buy a set, including cables, xenon light source and ballast, remove the halogen bulb from the headlight, saw a hole in the cover cap, insert the xenon light in the reflector, connect the electronic ballast to the vehicle electrical system and your xenon headlight is ready for use. This method endangers other road users due to extreme glare and is illegal. The general certification of the vehicle loses its validity and insurance protection is restricted. The only legal kind of conversion is by means of complete xenon headlight sets with type approval, including automatic headlight range adjustment and a headlight cleaning system.



#### Legal basis

In Europe, only complete xenon headlight systems may be retrofitted. These are made up of a set of type-approved headlights (with the mark E1 on the cover lens, for example), automatic headlight range adjustment and a headlight cleaning system (prescribed according to ECE regulation R48, national regulations must also be taken into consideration).

Every headlight is granted its design approval together with the light source (halogen or xenon) used for operation. If the light source is replaced by a different light source that has neither been granted type approval nor is foreseen for the design approval of the headlight, the design approval is no longer valid, thus invalidating the general vehicle certification (§ 19 StVZO, section 2, clause 2, no. 1). Driving without general vehicle certification leads to restrictions in insurance protection (§ 5, section 1, no. 3 KfzPflV, German compulsory insurance directive). Those who sell such lighting equipment which has no type approval have to be prepared for damages claims by buyers, too. Because when the seller passes on these parts, he not only guarantees that they may be used for the intended purpose, he also possibly takes over responsibility for the risk of damage as well – to an unlimited amount.

#### Technical background

High glare values: measurements in the lighting laboratory have proved that the active light distribution of a headlight that was originally developed for halogen bulbs and is now being operated illegally with a xenon light source no longer complies in any way with the lighting values originally calculated.

In the case of reflection systems, glare values were measured which exceed the permissible limiting values by a factor of up to 100.

These vehicle headlights then no longer have a cut-off and can no longer be adjusted either. The glare values correspond to those of spotlights. This leads to an enormous hazard for other road users.



The LED in the automotive industry – efficient, powerful, durable

These days, LEDs are used in almost all areas of our lives. They possess a number of positive features, which is the reason for their growing importance, particularly in the automotive industry. Some manufacturers already use LEDs as standard bulbs in the interior and exterior areas. The history of the LED began over 100 years ago.

Four scientists contributed significantly to the discovery and development of the light-emitting diode (LED). The actual inventor is Henry Joseph Round. In 1907, he discovered that inorganic materials gave off light when current passed through them. In 1921, the Russian physicist Oleg Vladimirovich Losev independently researched the same process. In 1935, the scientist George Destriau rather accidentally discovered a lighting phenomenon in zinc sulfide that he called "Losev light". Some sources cite Nick Holonyak as the inventor of the LED.

However, his research was not in semiconductors, but

particularly in organic light emitting diodes (OLEDs).

The development of the LED

1907 Henry Joseph Round discovers the physical effect of electroluminescence.

1951 Great progress in semiconductor physics through the development of the transistor, which explains the light emission. First experiments with semiconductors.  
1957 Gallium arsenide (GaAs) and gallium phosphide (GaP) are researched intensively. When exposed to current, both materials emit red light.

1962 The first red LED of the type GaAsP is available.

1971 LEDs are now also available in green, orange and yellow.







1992 Shuji Nakamura uses SiC (silicon carbide) to create blue light. Thus a large spectrum of colours is available.

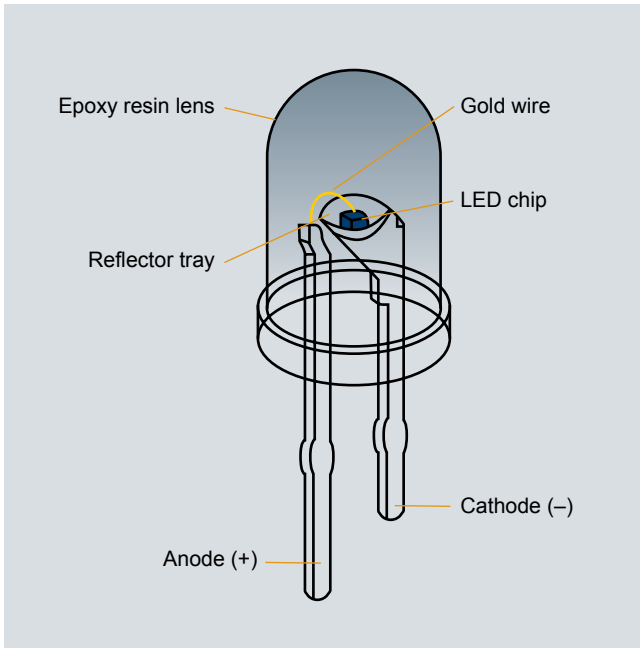
1993 Efficient InGaN diodes that emit in the blue and green spectrum, become available.

1995 Introduction of the first LED with white light (through luminescence conversion)

From the upper stoplight to all-LED headlights  
 It has only been a few years that LED technology has been used  
 for exterior lights on passenger cars. While LED initially were only used in the interior of the vehicle and as stoplights, they have recently also been employed as standard equipment in the front of the car. Due to technical progress they are ideal bulbs, particularly for the

automotive industry.

	<p>2011 All-LED headlights available for the Audi A6 (including AFS function)</p> <p>2010 All-LED headlights optionally available for the Audi A8 (including AFS function)</p> <p>2010 All-LED headlights available for the Audi A7. Mercedes also chooses LED technology and offers it in the CLS (Mercedes-Benz C 218) as optional equipment.</p>
	<p>2008 HELLA uses All-LED headlights in the Cadillac Escalade Platinum (Introduction USA 2009).</p> <p>2006 R8 (Audi/Automotive Lighting) is the first standard production vehicle to be equipped with an All-LED headlight. All lighting functions are taken over by LED (sales starting 2008). Lexus uses LEDs as standard equipment for the low beam in the LS 600H (sales starting in 2007).</p>
	<p>2005 HELLA manufactures the first two-colour LED headlights in the world (Golf V prototype) and produces an All-LED-stoplight (e. g. Golf V Plus).</p>
	<p>2004 LEDs are used in the front section of standard production vehicles (headlights Audi A8 W12; as a module in the Audi S6 / Porsche 911).</p> <p>2003 HELLA presents the first road legal All-LED headlight.</p>
	<p>2000 Combination rear lights for rear lights, indicators and stop lights available (Cadillac DeVille). Rear light with partial LED functions available.</p>
	<p>1992 First use of LEDs in exterior vehicle lights (third brake light)</p>



**LED basics – Definition, structure and function**

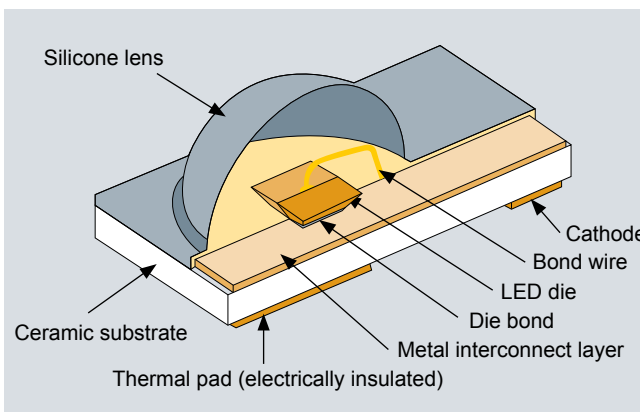
The light-emitting diode is also called luminescence diode or, in short, LED. LED stands for "light-emitting diode", as it turns electrical energy into light. Physically, it is a cold-light source and an electronic semiconductor component in optoelectronics, whose conductivity lies between that of conductors (e. g. metals, water, graphite) and non-conducting material (e. g. non-metals, glass, wood).

**Structure**

LEDs are available in different sizes, shapes and colours, depending on requirements. The classic version (standard LED) has a cylindrical shape and is closed by a hemisphere at the spot where the light is emitted.

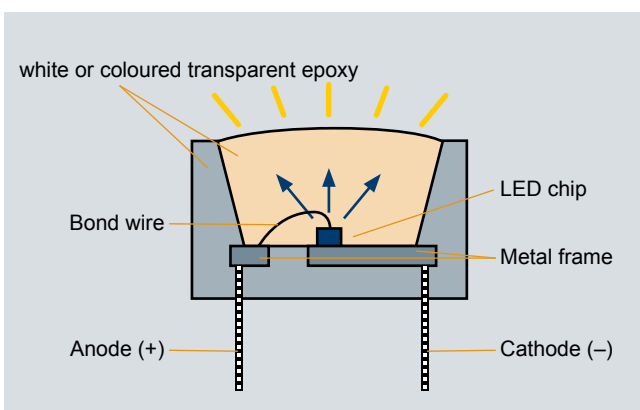
Simple LEDs consist of the following components

- LED chip
- Reflector tray (with contact to cathode)
- Gold wire (contact to anode)
- Plastic lens (combines and holds components)



**Small and durable – The high-performance diode**

High-performance diodes possess a large metal blank that allows for a better heat regulation. As the heat is discharged more easily, more current can flow through the diode, the light emission covers more area, and the light output is higher. Compared to a simple 5 mm LED, the heat resistance is reduced tenfold. In practical terms, this means that a high-performance diode, such as the Luxeon Rebel, has a square emission area of about 1 mm and an efficiency of approx. 40-100 Lumen. The power of a normal 5 mm standard LED pales in comparison to this. With a size of 0.25 mm and a power of less than 0.1 W and 20-30 mA, it reaches an efficiency of 1-2 Lumen.



The small, flat shape of LEDs offers considerable leeway for path-breaking product designs: for example the "LEDayFlex" daytime running light module for passenger cars, trucks and caravans.



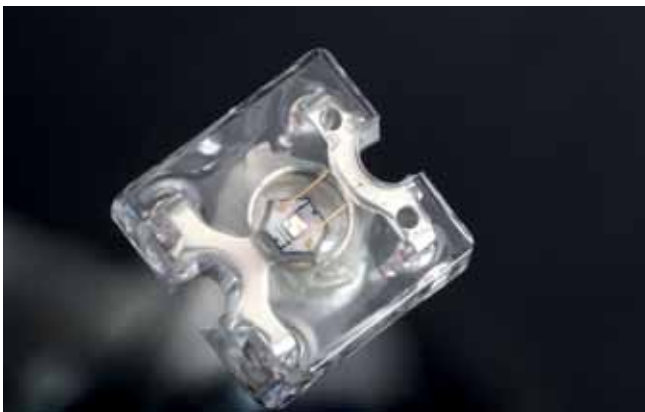
## Designs

There are different types and designs of LEDs. According to their area of application, they differ in structure, power and service life. Among the most important LEDs are:



### 1. Ledged LEDs

Ledged LEDs are the forerunners of all LEDs, and they are mainly used for control purposes. Nowadays they are used as a combination of several LEDs in LED spotlights, fluorescent tubes, modules or tubes. They are available in 3, 5 and 10 mm sizes. You recognize the cathode, the negative pole of a ledged LED by the fact that it is shorter than the anode (positive pole) and that the plastic coating is flattened. The exit angle of the light is determined by the lens shape of the housing.



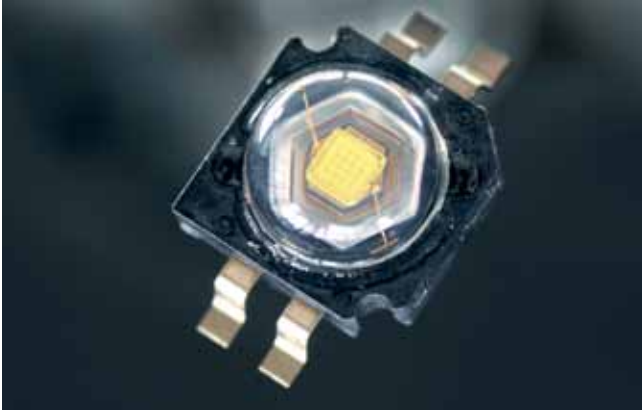
### 2. SuperFlux

SuperFlux LEDs are more powerful than regular ledged LEDs, and they have up to four chips (semiconductor crystals). Among the commonly used models are "Piranha" and "Spider". They offer a broad beam angle and are particularly used for area lighting, as the light is emitted over an area. A good heat dissipation is achieved via four contacts, which can be individually controlled. The structure of the High Flux ensures a long service life and makes them an efficient bulb that can be universally used.



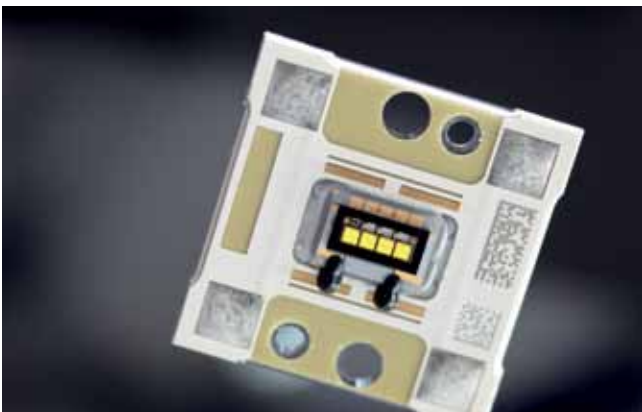
### 3. SMD

SMD stands for "Surface Mounted Device" which means that this diode is used surface-mounted. SMD-LEDs usually consist of three to four chips and have solder contacts, which are soldered to the PCB or connection surface. Regarding the current density, they are relatively insensitive and therefore can shine intensively. There are numerous versions of SMD LEDs. Size, shape of housing and luminous flux strength can be chosen variably. They are used in combination with other SMD LEDs in LED fluorescent tubes or modules. In the automotive industry, they are primarily used for indicators, stoplights or daytime running lights.



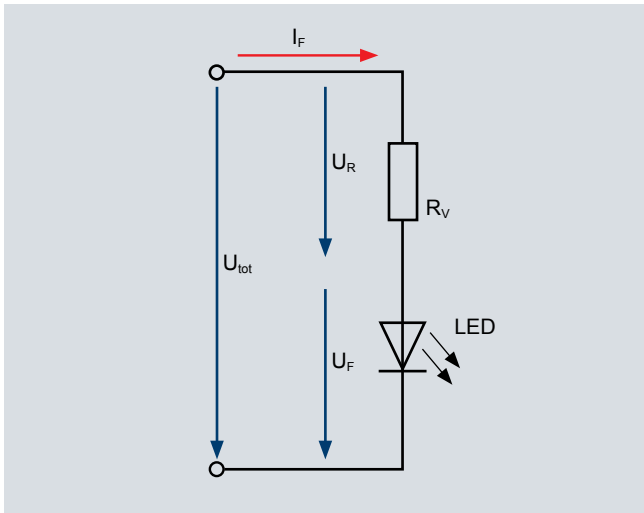
#### 4. High Power

High Power LEDs are powerful and robust LEDs, which can be operated at currents of 1000 mA under ideal operating conditions. They are often used on metal-core PCBs. Their unusual design places increased demands on thermal management.



#### 5. COB

The "Chip On Board" LED (COB) is the most advanced LED. It has this name, because it is directly attached to the PCB. This is achieved by so-called "bundling" which attaches chips through a fully automated process on the gold-plated PCB. The contact to the opposite pole is achieved via a gold or aluminium wire. As COB LEDs do not use reflectors or lens optics, the beam angle of the emitted light is very wide. The greatest advantages of the COB technology are the high output, the homogenous illumination and the numerous areas of application.



### Electrical properties –

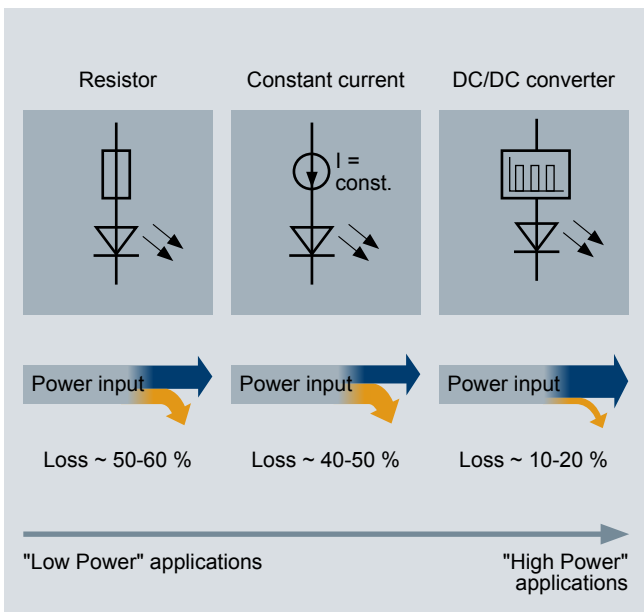
why too much current is damaging

If voltage is applied to an LED, the resistance falls to zero. LEDs are very sensitive components, and if the permissible current is exceeded even by a small quantity, they may be destroyed. Therefore it is important never to connect LEDs directly to a voltage source. They may only be connected if a current limiter or dropping resistor are built into the circuit. High-performance LEDs are controlled via an electronic ballast that provides a constant current.

The adjacent graphic shows the circuit required for an optional functioning of the LED. In this case, a dropping resistor is used as a limiter which controls the forward current  $I_F$  that flows through the LED. In order to choose the proper resistor, the forward voltage  $U_F$  must be determined beforehand.

$$R_V = \frac{U_{tot} - U_F}{I_F}$$

In order to calculate the dropping resistor  $R_V$ , you need to know the total voltage, the forward voltage and the forward current. The units are entered into the adjacent formula:

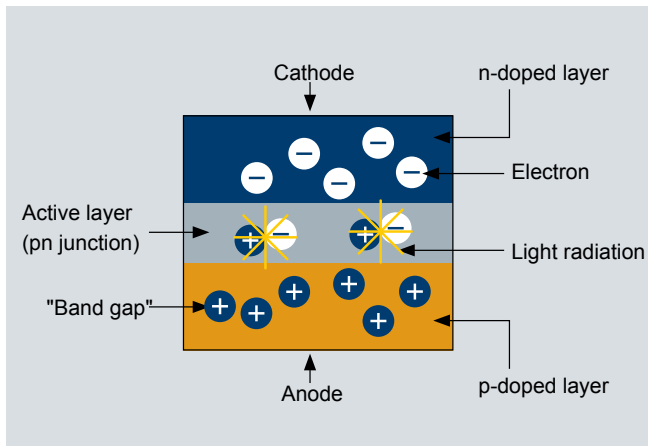


### LED control

As LEDs require only little current, they already illuminate when they receive only a fraction (a few mA) of the permitted forward current. This is often enough to provide light. As already mentioned, there are different ways of operating LEDs, depending of area of application.

Here are three of these ways.

Three ways of controlling LEDs



But what do LEDs consist of?

Basically, an LED consists of several layers of semiconductor compounds. Semiconductors, such as silicon, are materials whose electrical conductivity lies between that of conductors, such as the metals silver and copper, and non-conducting materials (insulators) such as Teflon or quartz glass. The conductivity of semi-conductors can be strongly influenced by adding electrically active foreign matter (doping). The different semi-conductor layers together make up the LED chip. The structure and type of these layers (various semi-conductors) has a crucial bearing on the light yield (efficiency) and light colour of the LED. This LED chip is coated with a plastic (epoxide resin lens) which is responsible for the LED's beam characteristics – whilst at the same time protecting the diode.

When a current flows through the LED (from the anode + to cathode –), light is produced (emitted)

The adjacent diagram explains the functioning of an LED: Foreign atoms have been added to the n-doped layer to create a surplus of electrons. In the p-doped layer, there are only a small number of these charge-carriers. This produces so-called electron holes (band gaps). When a voltage (+) is applied across the p-doped layer and n-doped layer (-), the charge-carriers move towards each other. At the pn junction, recombination takes place (where oppositely-charged particles combine to form a neutral entity). This process releases energy in the form of light.

## Basic properties

Service life – how temperature development affects the service life

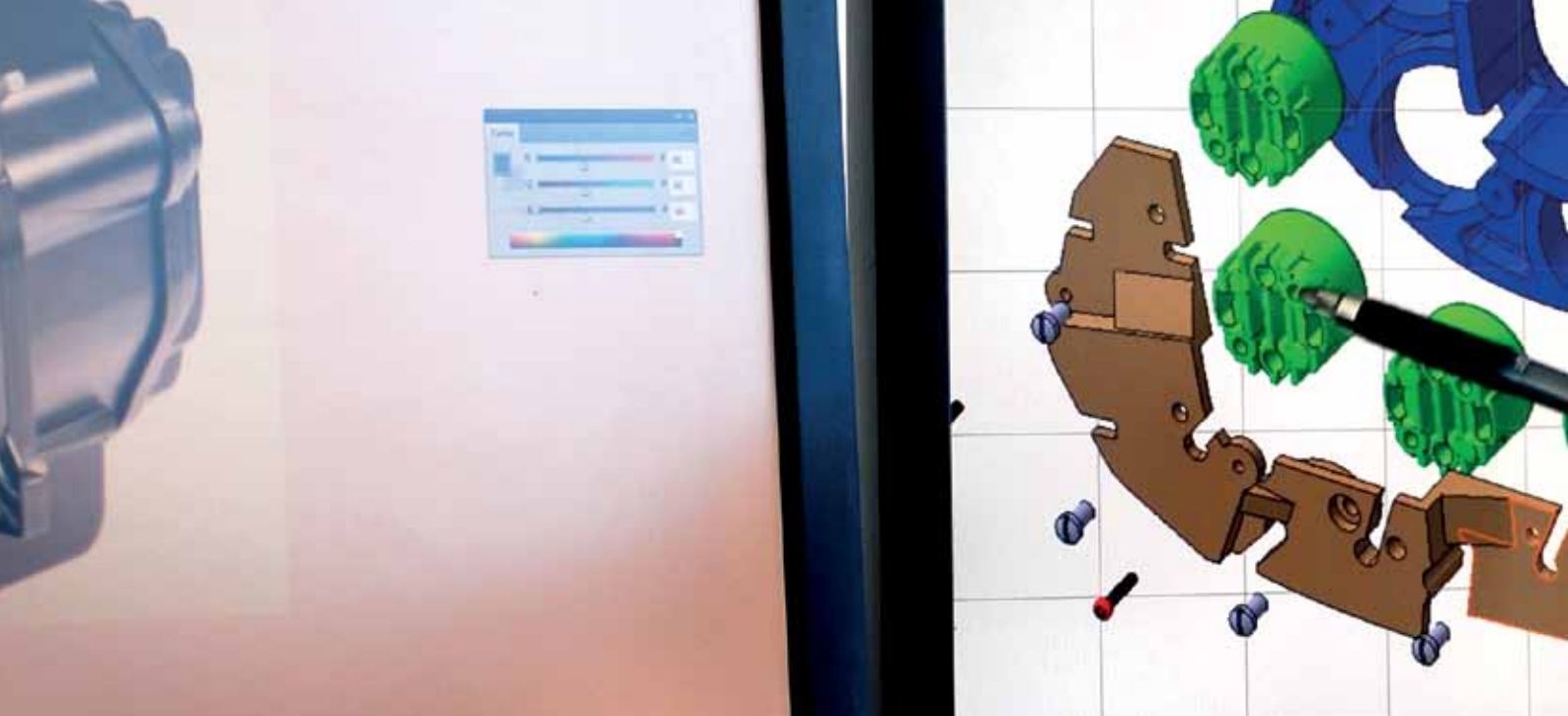
The service life or also the light degeneration of an LED refers to the period after which the light output sinks to half of its original value. The functioning of an LED depends on several factors. The semiconductor material used is as important as the operating conditions or the degeneration of the silicon crystal.

The actual value of the service life cannot be generally determined, though. While standard LEDs may last up to 100,000 hours, high-performance LEDs can be used for only about a quarter to a half of that time (25,000-50,000). If both diodes were to be used non-stop, they could be used continually for eleven and more than two years, respectively.

The service life greatly depends on the location and the provided current density. The higher the current flow, the more the diode heats up. This shortens the service life. The ambient temperature is also relevant for the service life, as the diode generally fails sooner, if it is warmer. Basically, the intensity of the light radiation in LEDs continually decreases over time. This is an advantage, as unlike traditional lamps (incandescent, halogen), an LED doesn't suddenly leave you standing in the dark. Even if the light output is reduced, it normally does not suddenly fail. The plastic normally used in the lenses of LEDs gradually becomes hazy, which also affects the light yield negatively.

Main factors affecting the service life

- Temperature
- Current density
- Degeneration of the silicon crystal



### Thermal management

The thermal management plays a decisive role in the use of LEDs, as these components react very sensitively to heat.

LEDs are cold-light sources, as they emit light, but almost no UV or IR radiation. The emitted light appears cool and does not heat illuminated objects. However, the LED is warmed by the process used to create the light. Up to 85

% of the energy is converted into heat.

The lower the temperature, the brighter and longer the LED shines. Therefore, appropriate cooling must be provided. Besides the heat generated by the LED, other heat sources such as engine heat, sunlight exposure, etc. must be taken into consideration for headlights and lamps. Therefore, different techniques for increasing heat transfer or dissipation are being used these days, depending in the type and application of an LED.



### Examples

- a) Finned heat sink (see illustration left)
- b) Pin heat sink
- c) Heat sink with heat pipe'

Furthermore, it is usually possible to regulate the current for the LEDs. Under extreme conditions the power of the LED can be reduced to a certain level in order to lower heat production.



In order to improve cooling further, the air circulation is raised by axial or radial blowers between the cooling elements. Here is the axial blower in the Audi A8.



### Advantages of the LED

LEDs are superior in several aspects. They might be more expensive originally than normal light bulbs or halogen lamps, but their use pays for itself in a short time. The automotive industry in particular uses the positive features of the LED and employs it increasingly in new vehicles due to the following advantages:

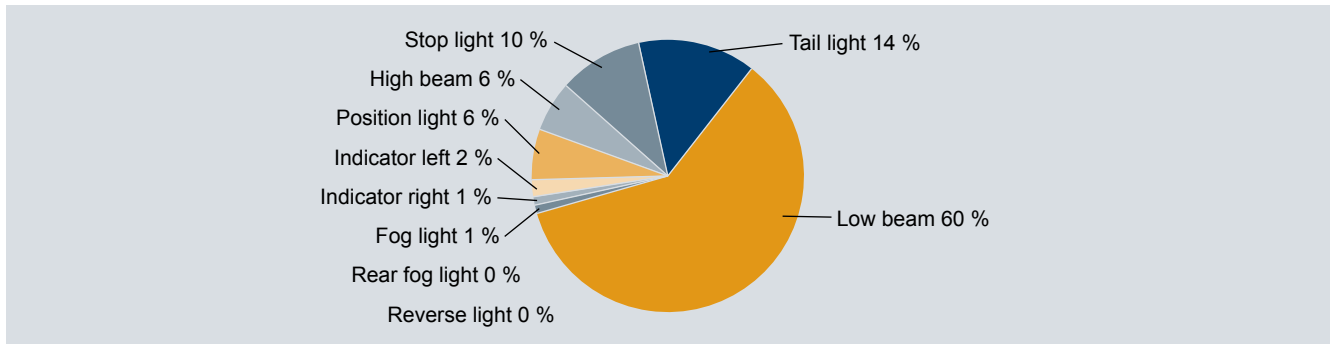
Light source	Luminous flux [lm]	Efficiency [lm/W]	Colour temperature [K]	Luminance [Mcd/m <sup>2</sup> ]
Conventional bulb W5W	~ 50	~ 8	~ 2700	~ 5
Halogen lamp H7	~ 1100	~ 25	~ 3200	~ 30
Gas discharge D2S	~ 3200	~ 90	~ 4000	~ 90
LED 2.5 Watts	~ 120 (2010) ~ 175 (2013)	~ 50 (2010) ~ 70 (2013)	~ 6500	~ 45 (2010) ~ 70 (2013)

### Main advantages

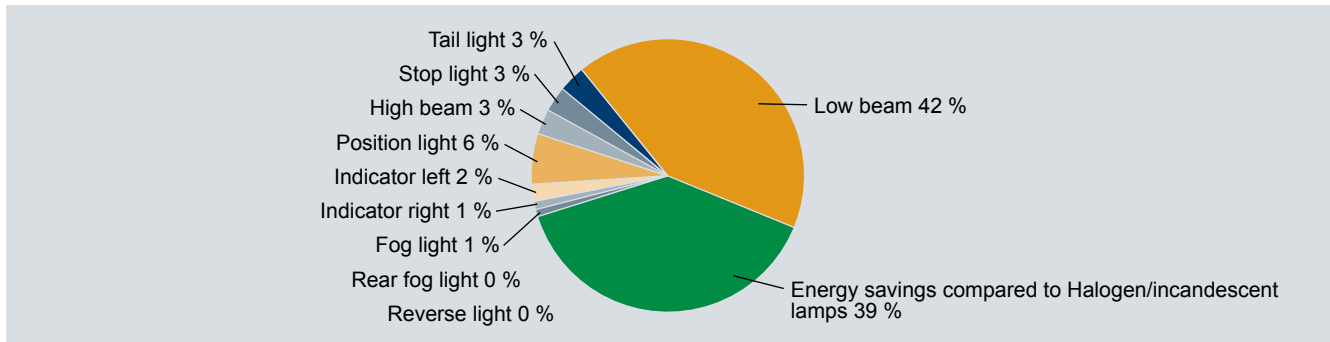
- Low energy consumption
- High service life
- Impact and vibration-resistant
- Reduced heat build-up
- No maintenance or cleaning costs
- Mercury-free
- Good glare limitation
- Inertialess switching and modulation
- High-quality light projection
- Numerous designs (can be used almost everywhere)
- Individual bulb configuration
- Light temperature remains during dimming
- Light colour can be regulated
- Low production costs
- Increased amount of light per chip
- Extremely few early failures
- Very compact measurements
- No UV or IR radiation
- Low power consumption
- Directional light – Lambertian radiator with 120° beam angle
- High saturation

Optimising energy consumption and possible savings by using LEDs

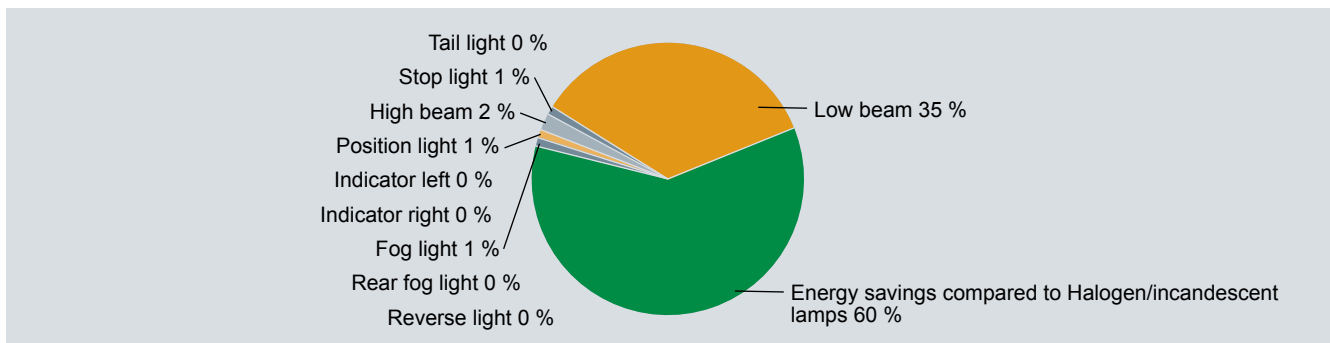
Environmental protection and increasing fuel prices are the most convincing arguments showing that saving energy is more important than ever these days. When buying a new vehicle, consumers focus clearly on the fuel consumption. Though often they ignore the potential savings related to the energy consumption of the vehicle lighting system.



The above graphic represents 100 % of the energy requirements of a vehicle that is equipped with a combination of incandescent lamps (rear lights) and Halogen lamps (headlights). It is easy to see the greatest consumer of electrical energy. 60 % of the required energy are needs just for the low beam.



Just using a combination of Xenon lights and LEDs allowed the energy consumption to be lowered by 39 %.



If only LED lights are used, the energy consumption is decreased by 60 %.

## Fuel savings through combination of various bulbs

### Fuel consumption and CO<sub>2</sub> emission for an average operating time of the lighting system

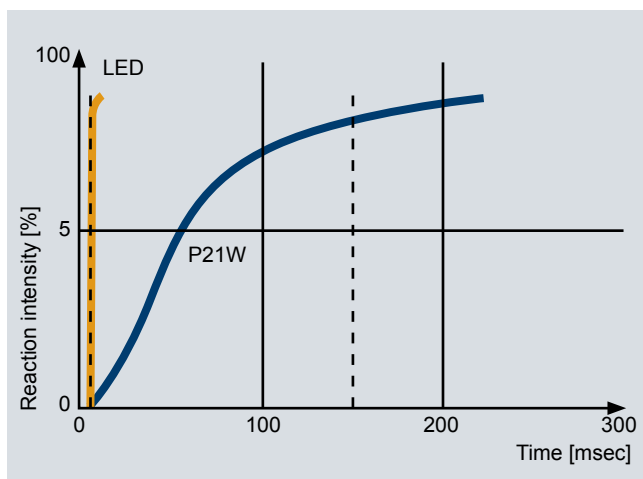
Vehicle configuration (Headlight/rear light)	Fuel consumption [l/100 km]	CO <sub>2</sub> emission [kg/100 km]	Decrease
Halogen/conventional	~ 0.126	~ 0.297	–
Xenon/LED	~ 0.077	~ 0.182	39 %
LED/LED (Potential for 2015)	~ 0.051	~ 0.120	60 %

### Additional fuel consumption and CO<sub>2</sub> emission for daytime running lights

Daytime running light system	Fuel consumption [l/100 km]	CO <sub>2</sub> emission [kg/100 km]	Decrease
Halogen headlight	~ 0.138	~ 0.326	–
LED (separate daytime running light function)	~ 0.013	~ 0.031	91 %

### Fuel consumption according to lighting configuration (OE car)

Bulb comparison	Fuel consumption
Halogen/incandescent configuration	0.10 – 0.25 l /100 km
Xenon/LED configuration	0.05 – 0.15 l /100 km
Full LED configuration (Potential 2015)	0.03 – 0.09 l /100 km



Reduced stopping distance – with LED, you are on the safe side

The number of vehicles on the road is increasing worldwide. The increased traffic density on the roads leads to more frequent rear-end collisions. To avoid these, the driver must perceive light signals quickly. While a conventional incandescent bulb needs up to 0.2 seconds to light up, an LED reacts immediately. It does not require a warm-up phase and lights up immediately as soon as the brake pedal is depressed. The rear vehicle can thus react more quickly to the braking action of the vehicle in front.

#### Example

Two vehicles are driving in the same direction at a speed of 100 km/h (safety distance 50 m). The vehicle in front brakes, and the driver of the second vehicle reacts to the LEDs lighting up immediately and stops at almost the same moment. This reduces the stopping distance by almost 5 m and represents an enormous increase in safety.