Optimising Reliability in LED Lighting Systems.

Presented by:

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Introduction

- LEDs are now being applied frequently in rolling stock interior lighting applications with varying degrees of success.

- Whilst the LED itself is a leading technology device, there are many implementation issues to be considered if reliability is to be optimised.

- This paper examines the key technical challenges to be addressed during the design process in order to achieve a reliable and successful product.

Technology Overview

- The LED makes use of a solid state junction to produce photons (light output).
- There are no fragile filaments or gas discharge processes to fail.
- This renders the device immune from the effects of shock and vibration (perfect for rolling stock applications).

Technology Overview

Long Life Reliability
does not cost the earth

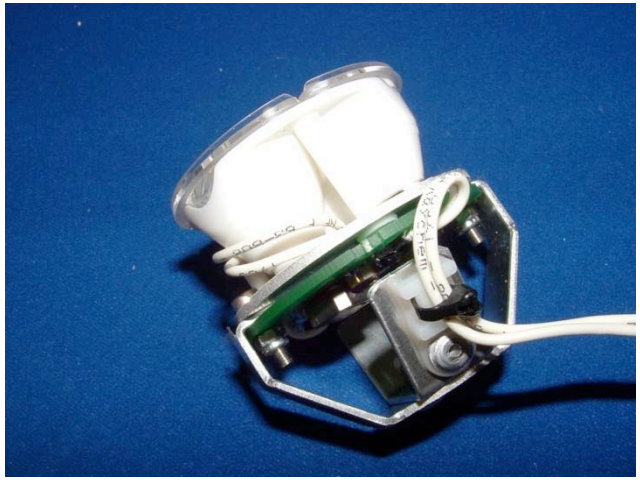
- A typical power LED:

- Typical body dimensions are around 8mm diameter.
- Smaller “second generation” power LEDs are now emerging.
- Unlike a filament lamp, the LED requires a specialist **constant current power supply** rather than a voltage regulated source.

Technology Overview
LED Power Supply Arrangements

Long Life Reliability
does not cost the earth

The constant current supply required by the LEDs may be generated either via a centrally located “bulk” power supply unit or via drive electronics built into each individual light head.



Technology Overview
Optics

- In order to produce a usable light output, carefully designed **secondary optics** or **diffusion techniques** are required to collect and focus the light output from the LEDs.

Technology Overview
Life Expectancy

- 50,000 - 100,000 hours to 70% of initial lumen output, **assuming optimum thermal management**.
- Millions of hours to total electrical failure.
- This compares to 3,000 hours for halogen and 20,000 hours for good quality fluorescent lamps.
- The high reliability results in significantly reduced vehicle operating and life cycle costs.

Technology Overview
Spectral Output

Long Life Reliability
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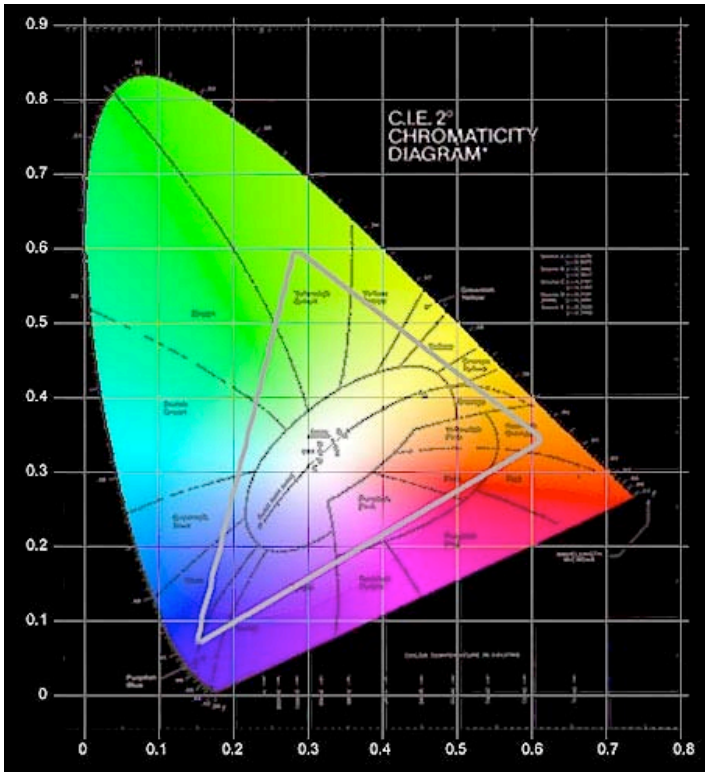
- LEDs are available with a wide choice of light output colours including white which is subdivided into various colour temperature groupings such as **warm white, natural white and cool white.**



Technology Overview Illustration of White Light Colour Temperature

- White Light LEDs are available in three distinct colour bands:

Warm White	2650 to 3500 K
Natural White	3500 to 4500 K
Cool/Pure White	4500 to 7500 K

- These categories are further subdivided down into manageable colour bins.

Technology Overview
Luminous efficacy

Long Life Reliability
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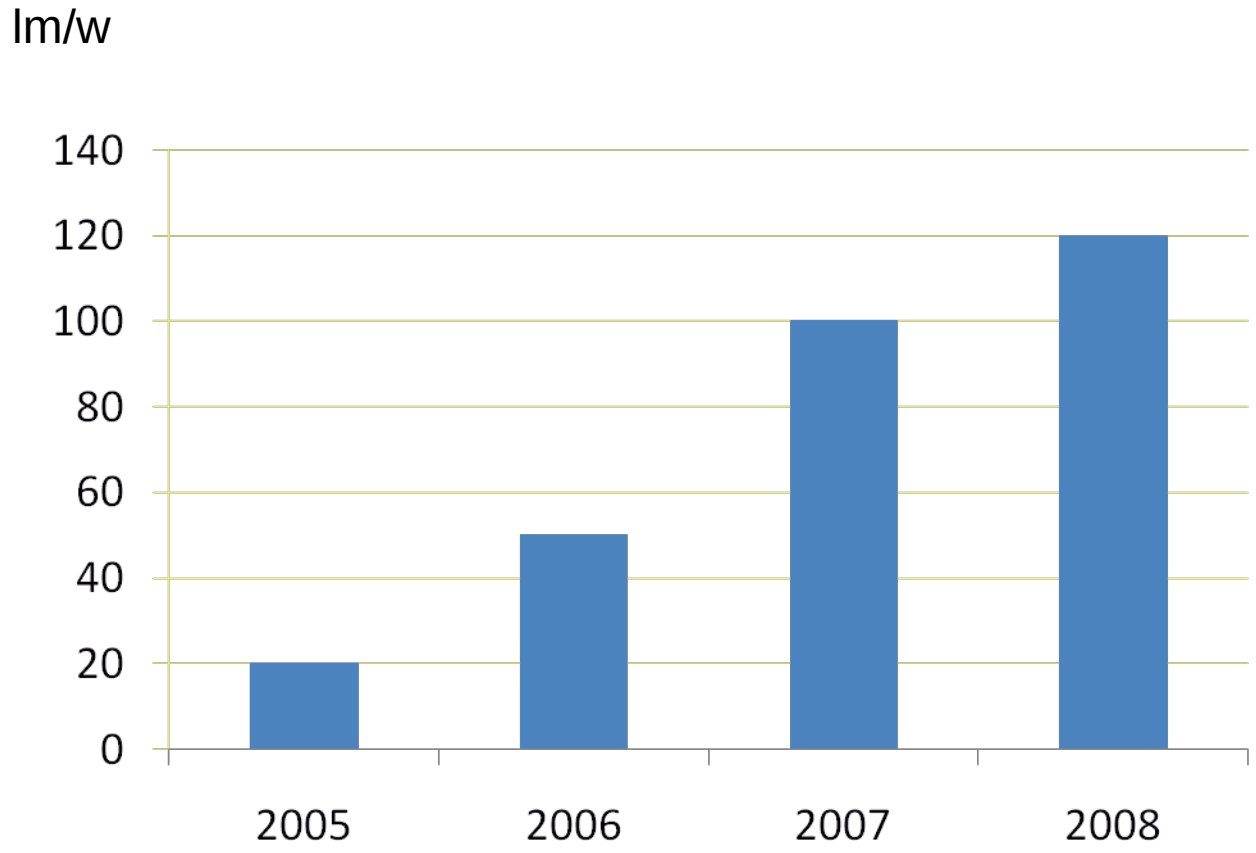
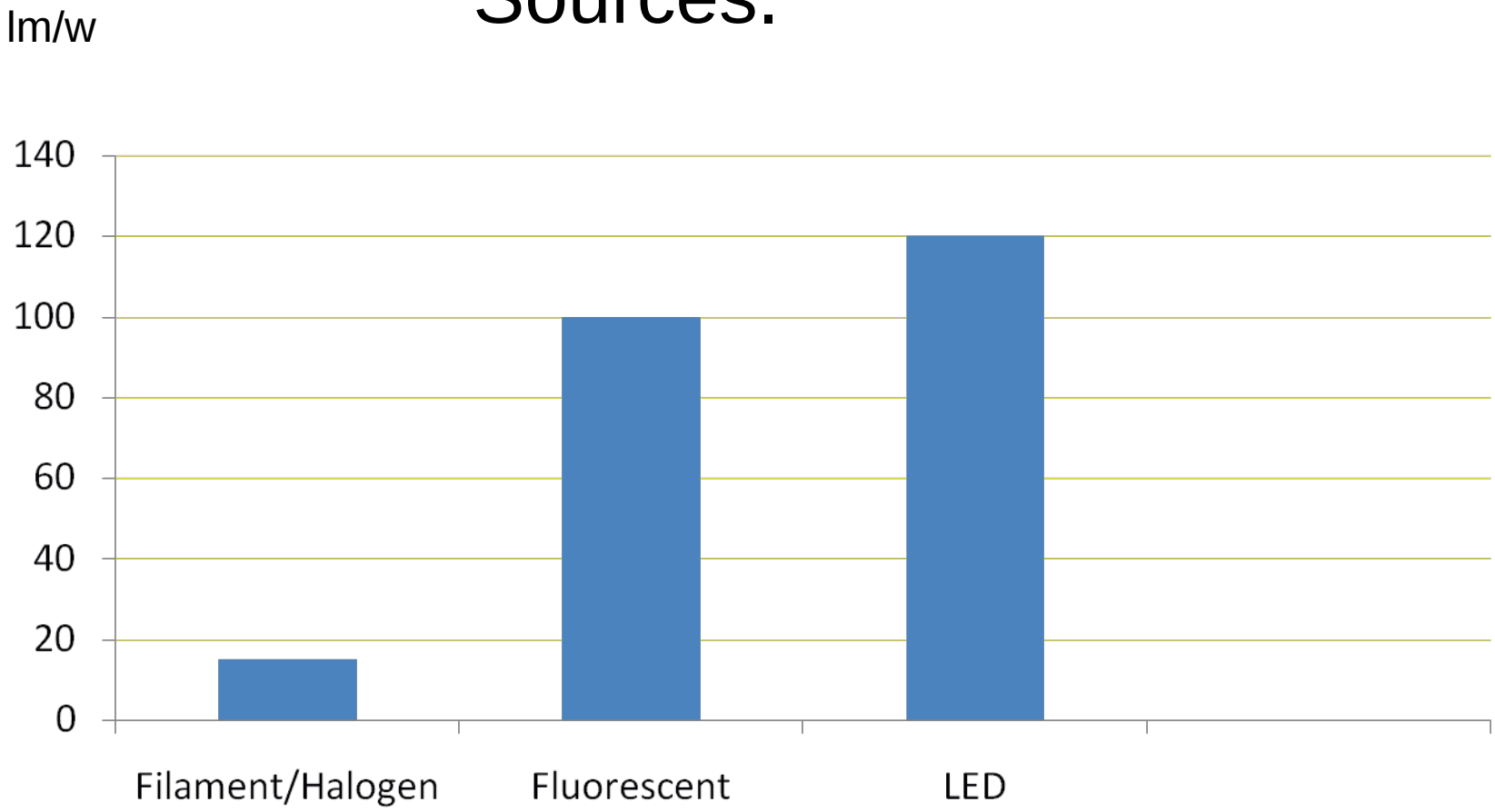


Technology Overview
LED Luminous Efficacy.

A Comparison to Conventional Light Sources.



Technology Overview
Other LED Benefits

- Cool beam temperature due to absence of infra red content (30 C versus 90 C for halogen).
  - Results in increased passenger safety and comfort.
  - Reduced air conditioning loads.

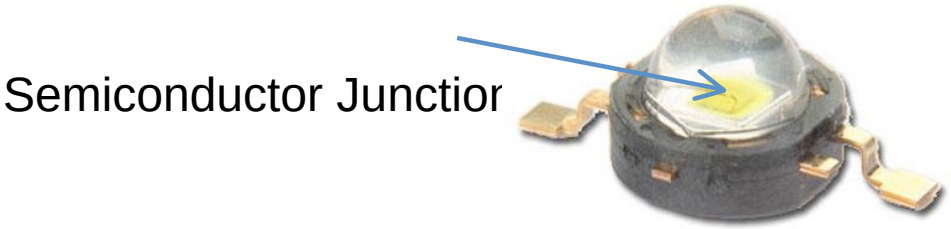
- Low power consumption and high luminous efficacy (lumens per watt).
  - This permits the design of highly effective emergency lighting systems with high light output and extended emergency lighting duration.

Long Life Reliability
does not cost the earth

What are the Factors Affecting Reliability?

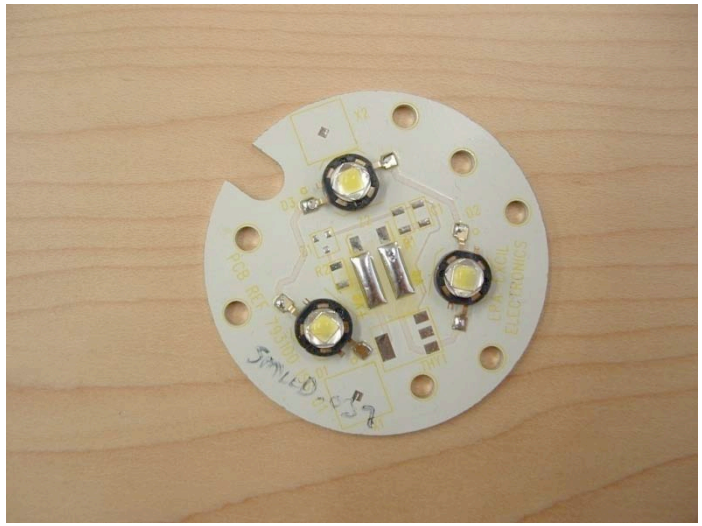
LED Operating Temperature (Thermal Management)

- LED life expectancy is critically dependent on operating temperature.
- The higher the LED junction temperature, the shorter the life.



- For a reliable product, heat has to be efficiently removed from the light producing semiconductor junction.
- Typically, an aluminium substrate circuit board is utilised as a means of transferring heat from the LED into a larger heat radiator.

Thermal Management



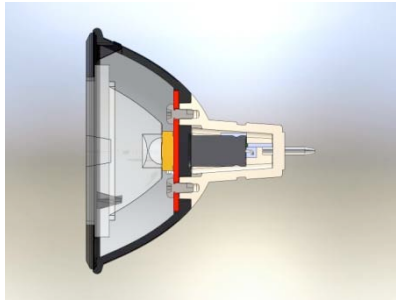
Three high brightness LEDs mounted to an aluminium substrate circuit board.

- A metallic slug on the rear of the LED makes good thermal contact with the aluminium substrate material.
- The conductive circuit tracks are insulated from the aluminium via an intermediate, thermally conductive dielectric layer.

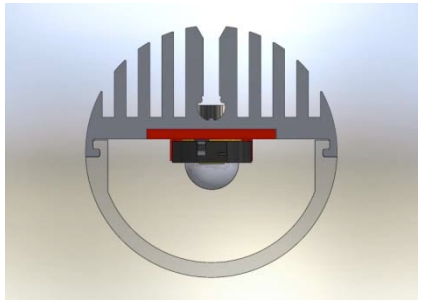
Thermal Management

- The aluminium substrate assembly is in turn mounted with good thermal contact to the main heat radiator/heat sink.
- Often, the luminaire enclosure itself is able to provide ample heat sinking.
- When designing the thermal management system, careful consideration should be given to the operating temperature range of the product to ensure that safe junction temperatures are not exceeded.

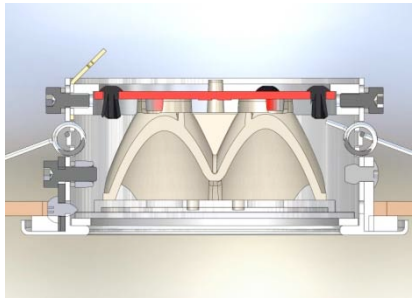
Thermal Management Examples

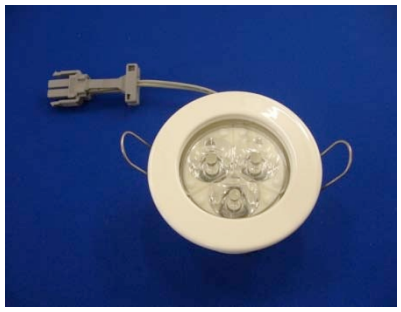


MR16, LED halogen replacement.



LED, fluorescent lamp replacement.

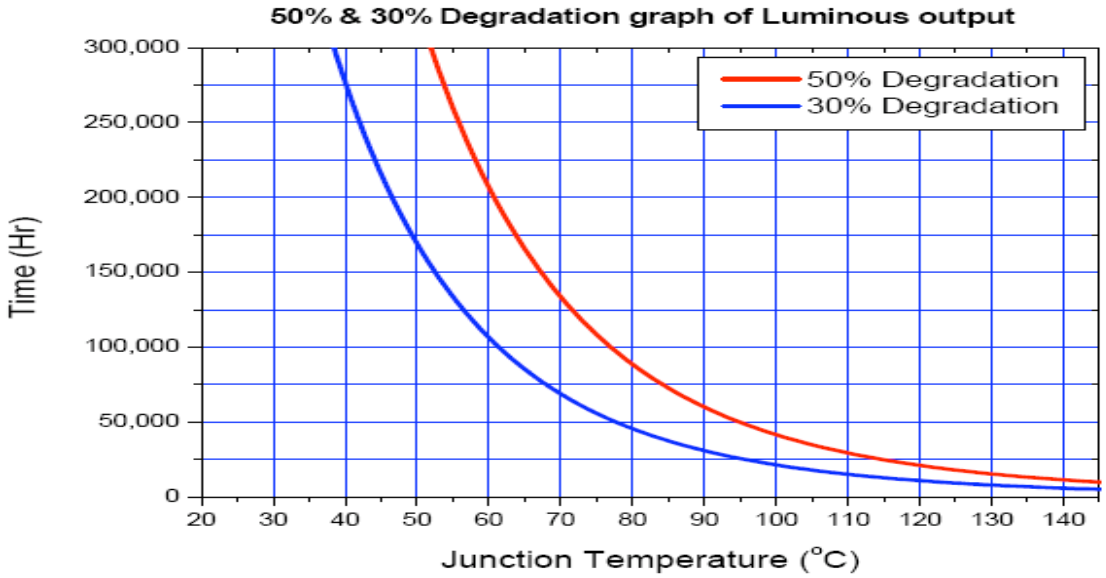




General purpose down light.
The luminaire enclosure forms the heat sink.

Thermal Management

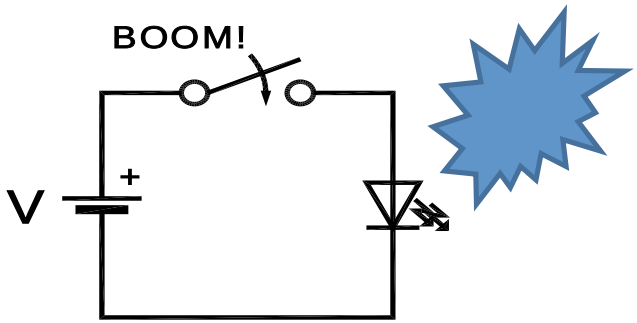
- This life expectancy curve from a leading LED manufacturer stresses the importance of correct thermal management.



- Illustrating that with good thermal design, long service life can be realised.

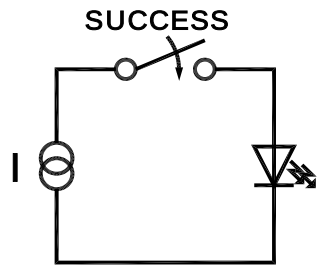
Electrical Drive Conditions

- The LED performs electrically as a diode junction.
- There is no built in mechanism to limit current in the forward direction.
- Therefore, connection to a standard voltage regulated power supply is not recommended!



Electrical Drive Conditions

- The device requires a specialist “Constant current” power supply.



- Failure to drive in any other manner will result in an unreliable system or even instant device failure!

Electrical Drive Conditions

- Ideally, the LED current must be held constant over the full permitted range of vehicle supply regulation.

- The LED must also be protected from the supply borne surges and transients as described by railway standards EN50155 and RIA12.

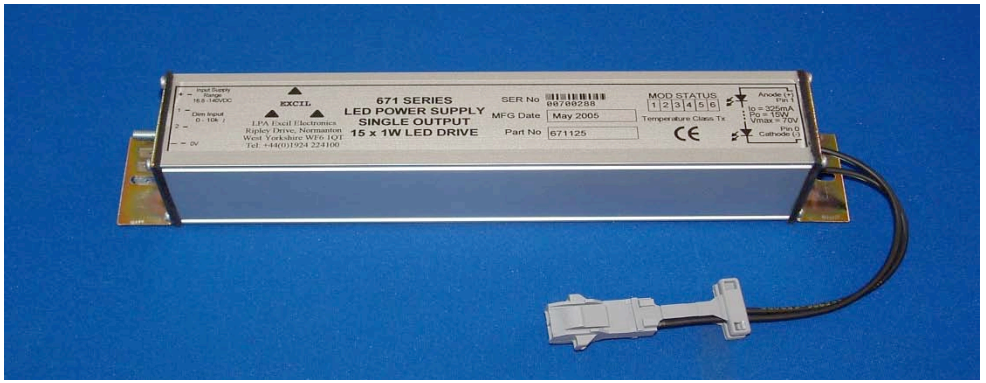
Electrical Drive Conditions

- LPA-Excil have advised on numerous cases where the primary cause of poor reliability is inadequate or incorrectly designed power supply electronics.
- Commercial grade power supplies **are not** suitable for the railway market!
- Power supplies must be designed specifically to meet the arduous railway standards.
- By careful power supply electronics design, extremely high reliability is attainable.

The LPA Excil Power Supply Solution

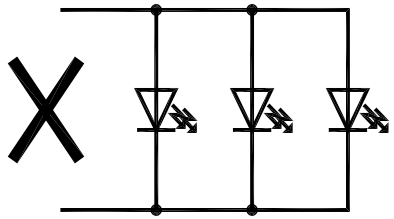
Long Life Reliability
does not cost the earth

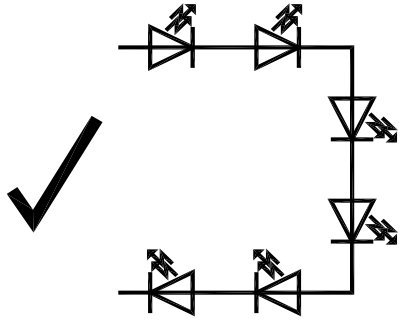
- Provides constant current output over the input range 16.8 to 140V DC.
- Meets all railway industry standards including EMC, shock and vibration, transients, environmental and safety etc.
- Protects the LEDs from vehicle supply borne surges and transients.
- Comprehensive electrical protection features.
- Also available in AC supply input variants.



Circuit Connection

- Because LEDs require constant current drive, devices must be connected in series.
- Parallel connection will result in unequal current share due to differing forward voltages, this will result in poor reliability.





Circuit Connection

- Because devices are in series, precautions must be taken to ensure that device failure does not result in failure of the whole chain of LEDs.
- In order to guarantee reliability, open circuit device failure must be considered.

High Brightness Versus Signal LEDs

Long Life Reliability
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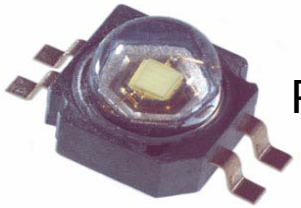
- Two general LED categories exist:



Power types

Standard or
“signal types”

- Power types have been developed specifically for the illumination market, generally speaking, signal types are merely an evolution of old indicator LED technology.
- Where reliability is a prime consideration, only power types should be considered for illumination applications as they offer:
  - Better luminous efficacy (lm/W).
  - Better lumen maintenance and hence longer life.
  - Better and more controllable colour binning.
  - Superior colour rendering

Compliance With Railway Standards

- Commercial and industrial designs will not return the necessary levels of reliability!
- The railway environment is very arduous and product must be designed specifically to meet the standards:
  - EMC EN50121-3-2
  - Shock and vibration (EN61373)
    - Consideration should be given to the mechanical robustness of the solution.
  - Surge and transient (EN50155 + RIA12).
  - Lighting EN13272
  - Environmental and safety EN50155
  - This list is not exhaustive and excludes any contract specific standards!

Reliability Summary
-Key Factors-

- Thermal management.
- Design and quality of the drive electronics.
- Electrical connection.
- Choice of LED type.
- Systems have to be specifically designed to meet the arduous railway environment

Standards compliance.

Product Examples

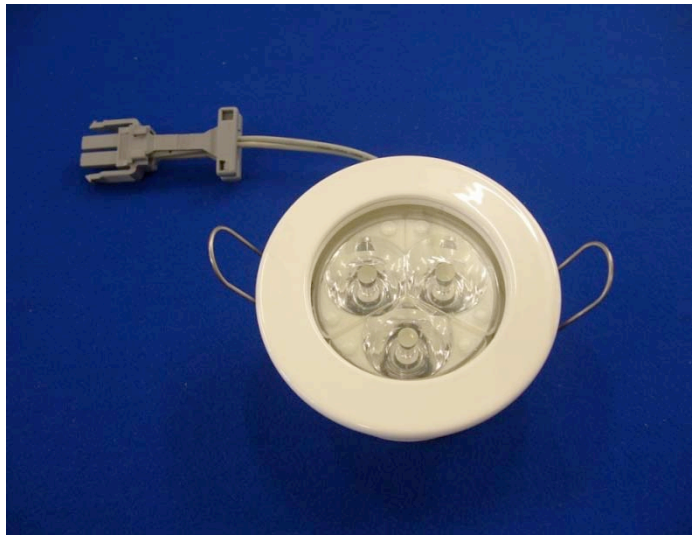
Examples of successful LED products and applications:

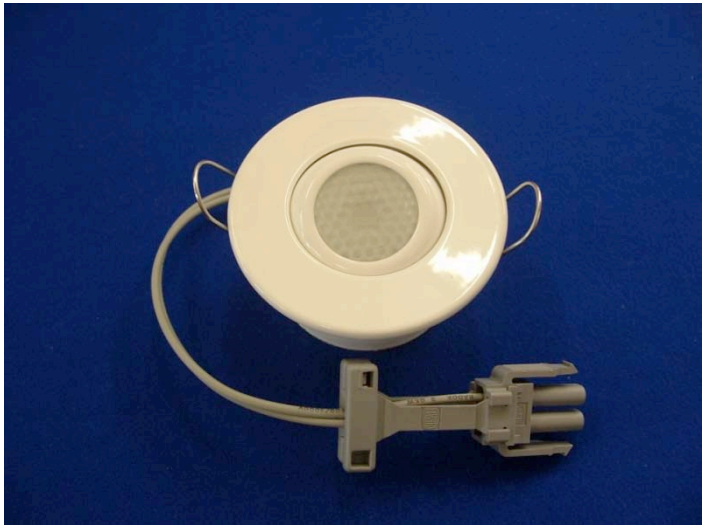
Product Examples

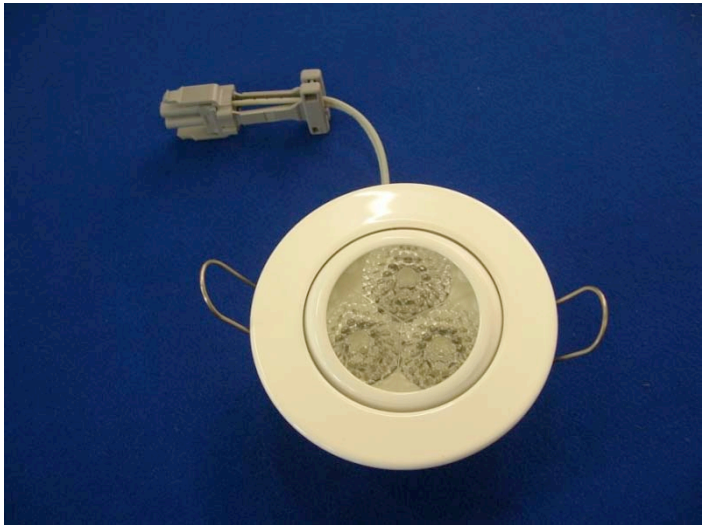
General LED Down Lights

Triple and Single LED

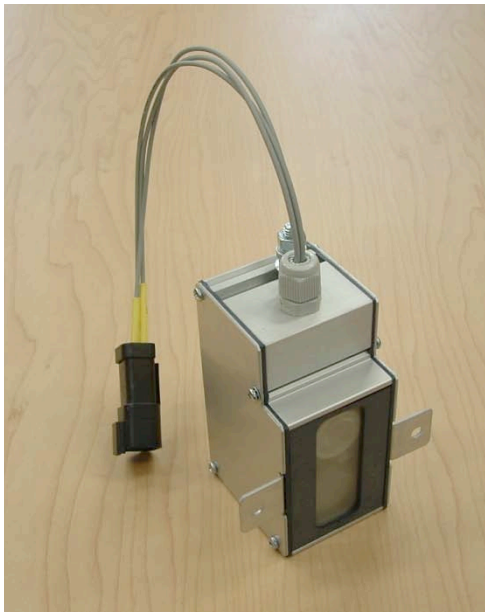
Long Life Reliability
does not cost the earth







Product Examples
Standard Step Light - Rail



- Meets Department of Transport guidelines for vehicle accessibility.
- Produces in excess of 100 lux at the egress point.
- Integrated power supply for 67 to 140V DC continuous operating range.
- Utilises two high brightness white LEDs.

Product Examples

Self Contained LED Emergency Light

Provides in excess of three hours emergency lighting duration from built-in replacable batteries in the event of power failure.

Complies with Euro norm lighting standard EN13272.

Various LED Lamp Replacements

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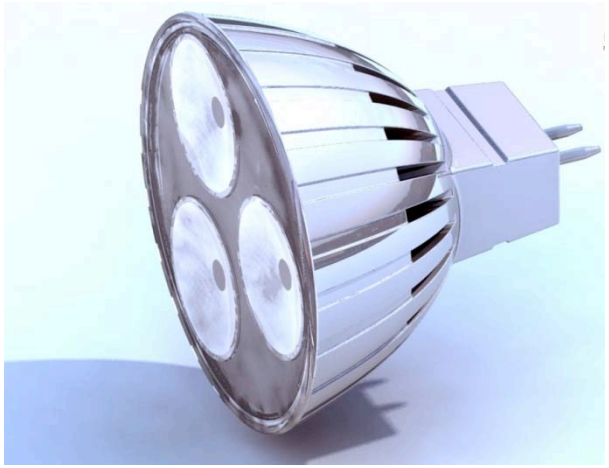
T8 and T5 Fluorescent



MR16 Halogen

Product Examples.
LED Flat Panel Luminaire
The “LumiPanel”

- 12 to 13 years “fit and forget” service life.
- Approximately half the weight of the equivalent fluorescent luminaire.
- Two rows meet EN13272 illumination standards.
- Only 18mm depth.

Bespoke Products

Long Life Reliability
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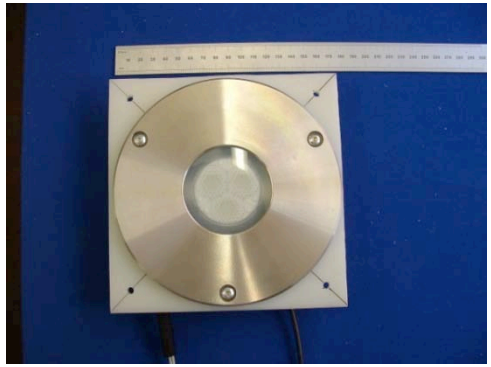
IDF (NAT).

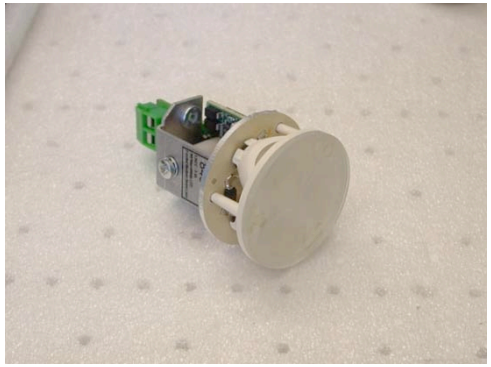
AGC LED replacement for halogen.

Balcony Light.



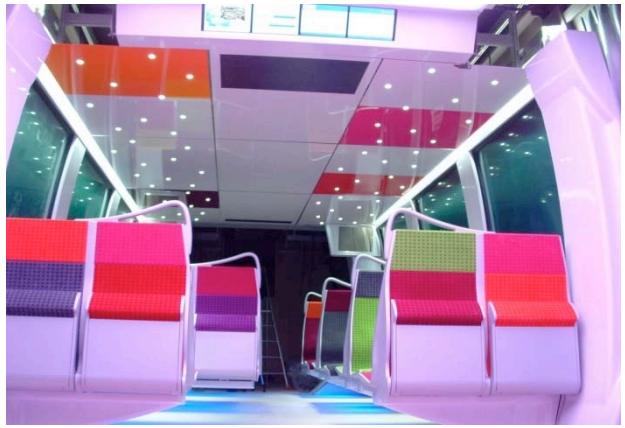
Circular step light.

Eurostar LED replacement for halogen.

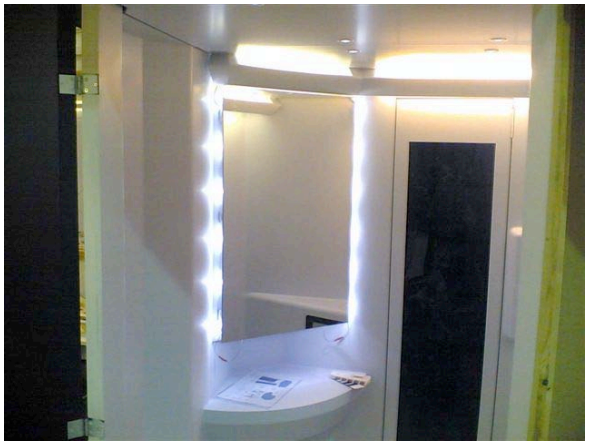


ZTER LED replacement for halogen.

Application Examples



SNCF-NAT The first interior to utilise LEDs as the sole source of illumination.



Heathrow Express-Toilet Mirror Effects Lighting.

SNCF-Mooviter/ZTER

SNCF-AGC

Conclusions

What advantages do LEDs offer ?

- When applied correctly:
  - Ultra high reliability resulting in significantly reduced vehicle operating costs.
- Case studies have illustrated that the payback period can be under 2 years.
- Low power consumption.
  - Offers huge energy savings.
  - Maximises emergency lighting performance.
- Reduced weight.
- Reduced environmental impact (elimination of lamp disposals).
- Low temperature light beam resulting in a more comfortable and less hazardous passenger environment.

--- All crucial factors in modern, competitive rolling stock operation.

Thank You

Any Questions?