➢Merits & demerits of various types of lamps and LED Technology

Incandescent Lamps, CFL Lamps , Fluorescent Tube & LEDs

- **Incandescent bulbs** work by conducting an electric current along a filament made of a long, thin piece of tungsten metal. The filament must be heated to temperatures of about 2,300 °C to glow and emit a white-hot light. But the process transforms only 5-10% of the electricity used into visible light. The rest is transformed into heat, which can eventually increase the temperature of a room.
- **CFL bulbs** are made of glass tubes filled with gas and a small amount of mercury. Light is emitted when mercury molecules in a CFL bulb become excited by electricity running between two electrodes at its base. The mercury emits an invisible ultraviolet light that becomes visible when it hits the white coating inside the CFL bulb.
- CFLs are simply smaller versions of full-sized fluorescent lighting. The only difference other than size is that the quality of light is much better. The most compelling reason to use them is energy efficiency.

Fluorescent Bulbs n LEDs

A Fluorescent Bulb is a low-pressure mercury-vapor gas discharge bulb that uses fluorescent to produce visible light. Mercury vapor is produced when an electric current makes contact with the gas, which produces short-wave ultraviolet light which then causes a coating on the inside of the bulb to light.

A fluorescent bulb is more efficient than an incandescent bulb but is less efficient than a LED bulb.

CFL Vs Incandescent Lamps… Adv/Disadv.

- **Advantages over incandescent lamps**:

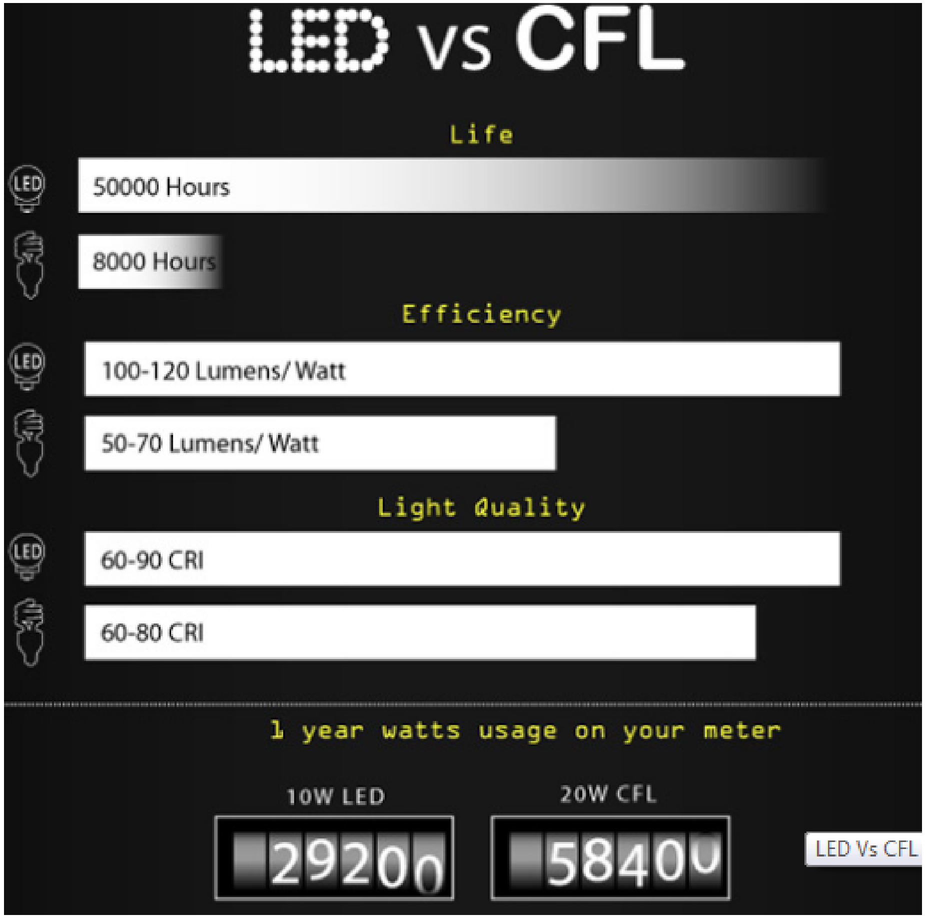
1) they last 8-10 times longer than incandescent lamps.
2) CFLs are up to four times more efficient than incandescent bulbs. Replace a 100-watt incandescent bulb with a 22-watt CFL and get the same amount of light. CFLs use 50 to 80 percent less energy than incandescent lights.
3) produce 90% less heat while providing more watts per lumen.
4) While, initially cost more, CFLs are less expensive in the long run since CFLs use a third of the electricity and last up to 10 times as long as incandescent bulbs.

Disadvantages of CFLs

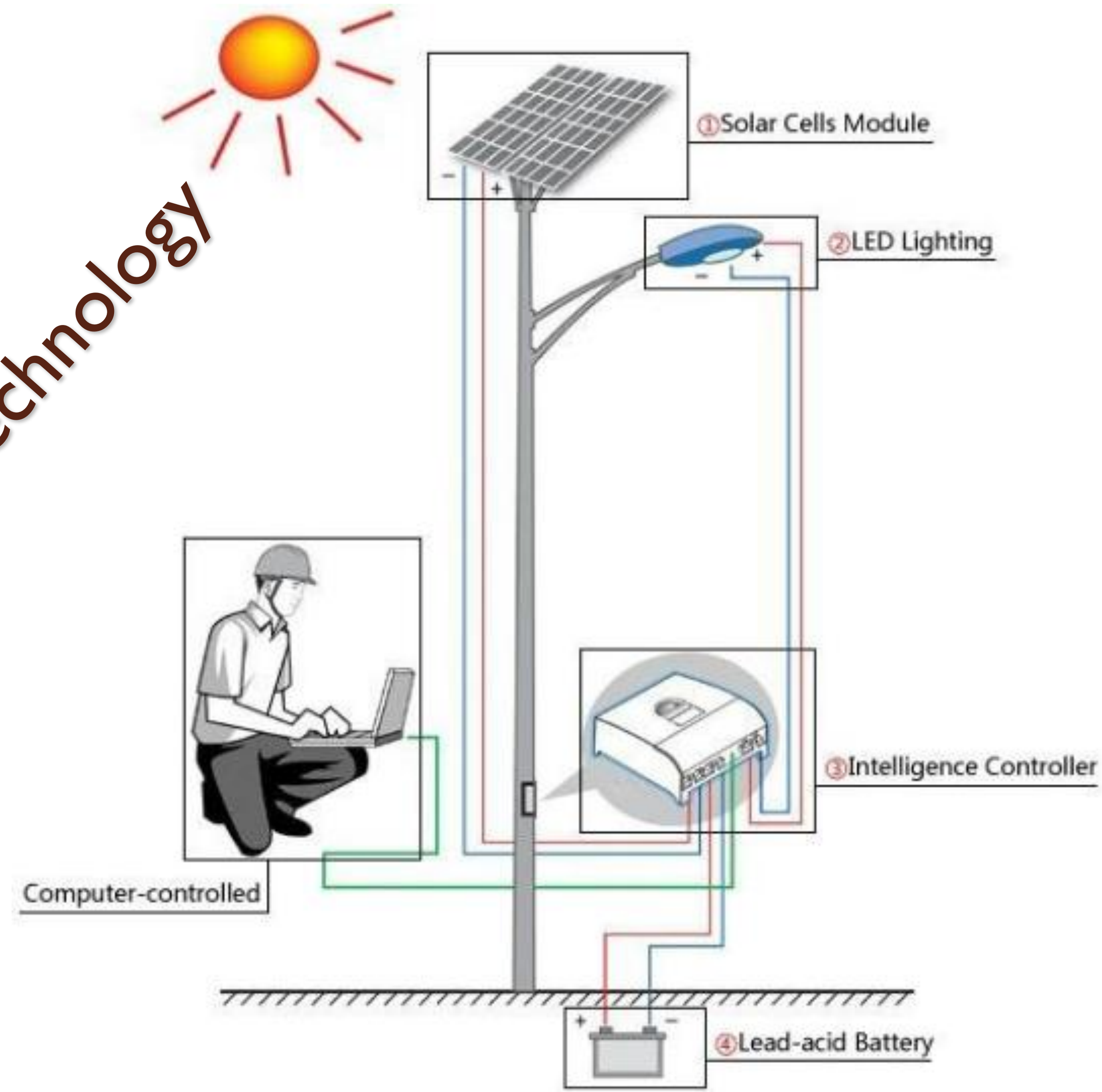
1) The only serious disadvantage is the mercury content in CFLs.
2) While CFLs are supposed to last about 10,000 hours, turning them on and off too frequently can reduce that lifetime substantially. They are unsuitable for places where you would turn on the light only briefly.
3) CFLs are not suitable for focused or spotlights or where narrow beams of light are required. They are meant only for ambient light.
4) Mercury is a toxic metal, and if the bulb is broken it needs to be disposed of carefully. CFLs, however, are nonlinear loads producing distorted currents with high *THD*.

CFL vs LED

LED, or light-emitting diode, are Solid State Lighting (SSL), organic light-emitting diodes (OLEDs) and light-emitting polymers (LEPs). LED lights are often more efficient, durable and longer lasting than other types of light bulbs.

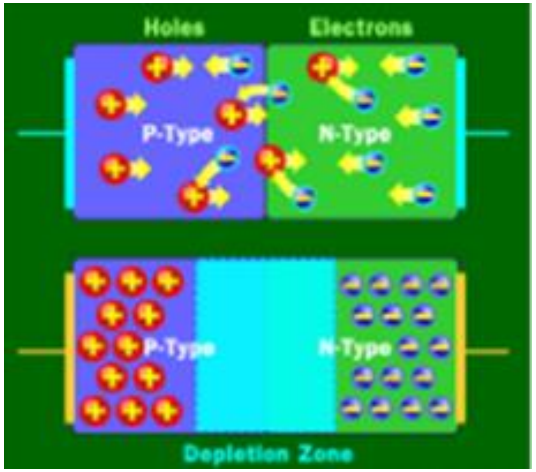


LED Technology



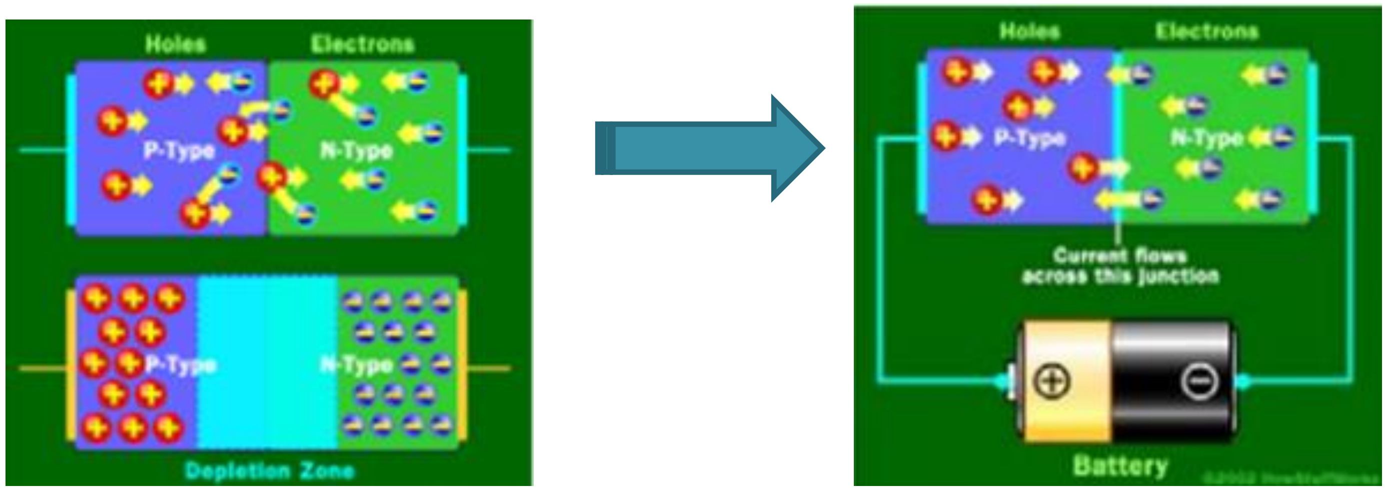
Light Emitting Diode (LED)

- Light Emitting Diode (LED) is a solid-state semiconductor devices, comprising N-type material bonded to a section of P-type material.
- The N-type layer provides electrons and a P-type provides holes for the electrons. Electrons from N-type materials fill holes from P-type materials, **forming a depletion zone**. The heart of LEDs is often called a "die" or "chip".
- Known as Solid State Lighting Technology (SSL)

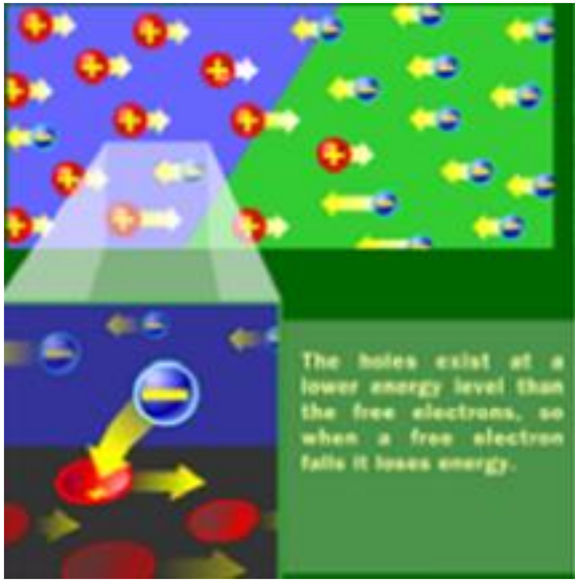


Light Emitting Diode (LED)

- When the negative end of the circuit is hooked up to N-type layer and the positive end is hooked up to P-type layer, electrons and holes move and the depletion zone disappears.

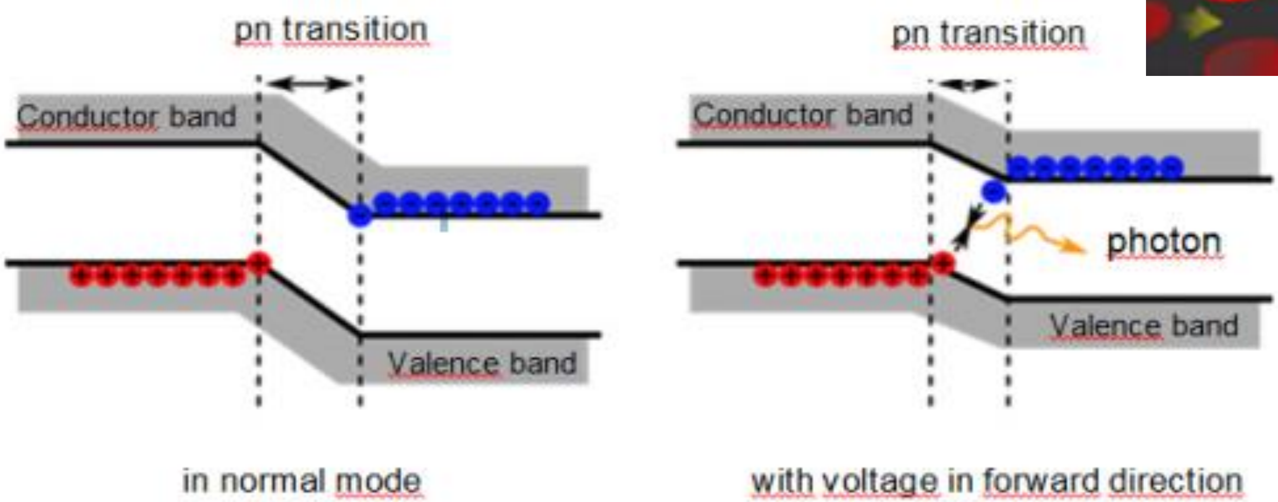


Light Emitting Diode (LED)



- Free electrons moving across a diode fall into holes in the P-type layer. This involves a drop from the **conduction band** to a lower orbital, so the electrons release energy in the form of photons.

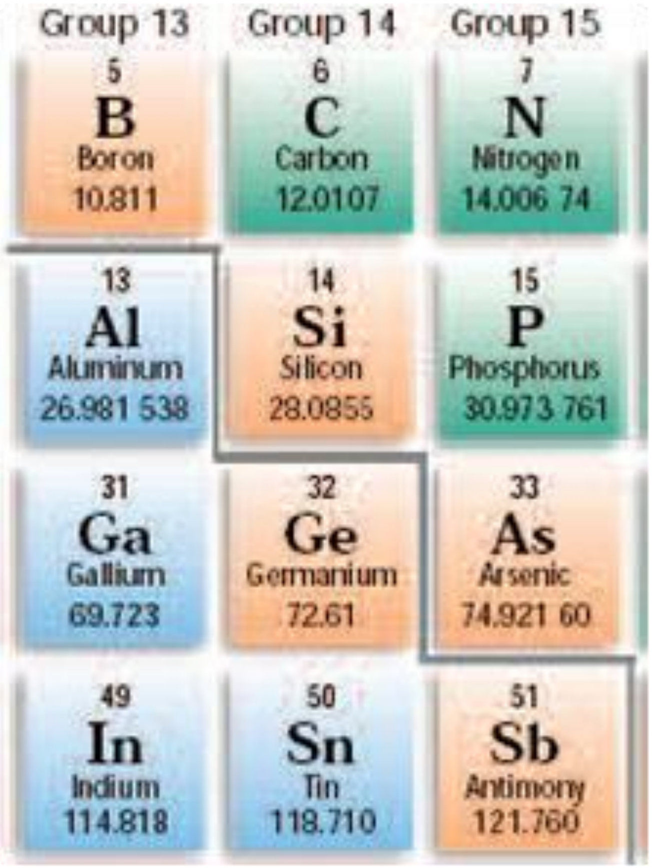
The wider the energy gap – the higher the spectral frequency of the emitted photon.



Recombination of electrons and electron imperfection at pn transition

Base Materials of LEDs

Out of the following 12 elements, elements that shaded orange are base materials; elements that shaded blue are p-type dopants; elements that shaded green are n-type dopants, are used in LED construction.



An LED is a p–n semiconductor device that emits light when a voltage is applied across its two terminals.

The *output power* of an LED is expressed by

$$P_{\text{out}} = \left[\frac{\eta h c}{e\lambda}\right] I$$

where I is the LED drive current (A),

λ is the wavelength of light.

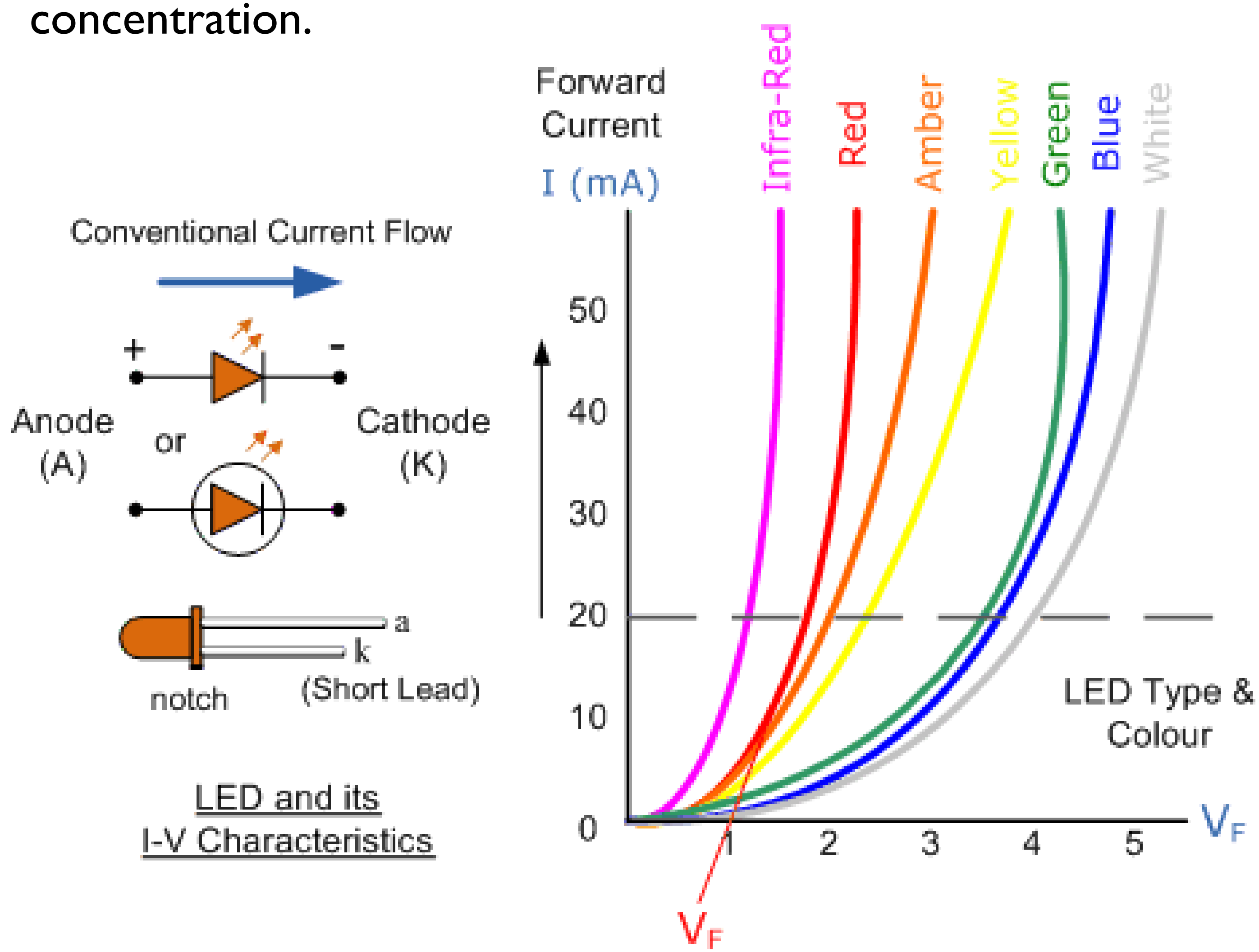
h is Planck's constant

e is the electron charge,

η is the quantum efficiency (relative recombination/total recombination).

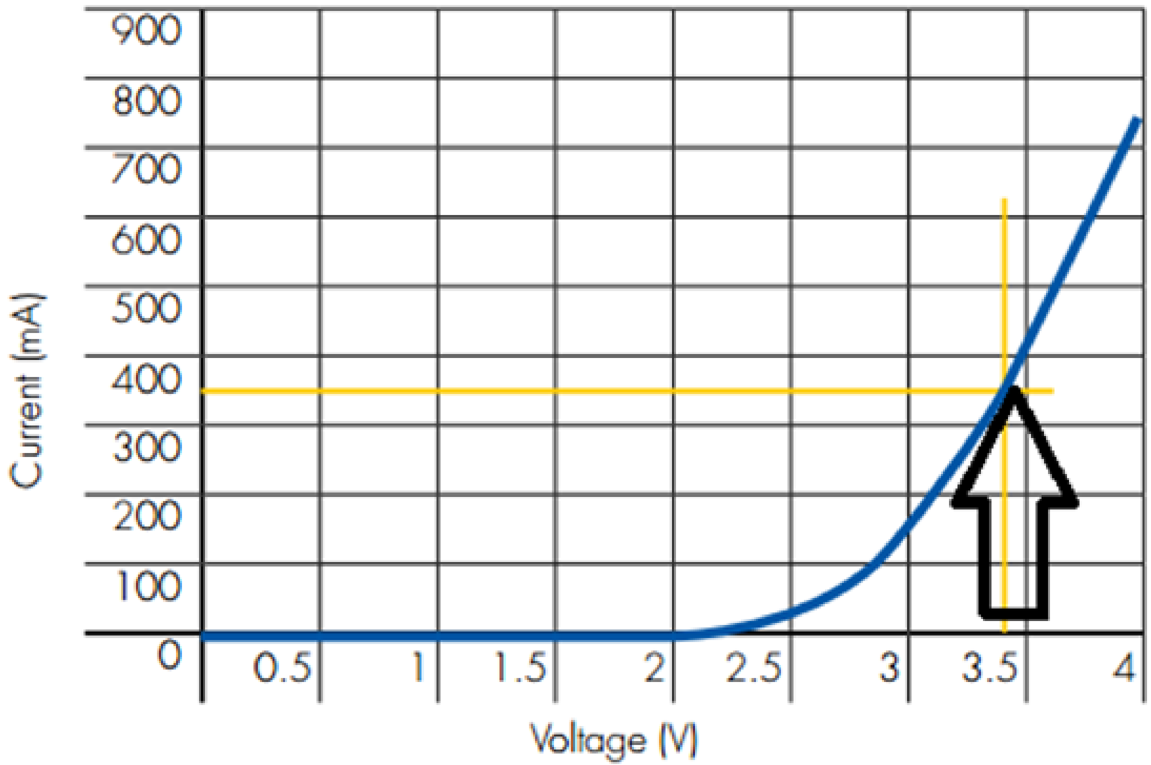
c is velocity of light

- An LED, being a diode, behaves like one, and its ***I-V Characteristic*** *has a similar profile as shown below.* Its output optical power depends on the current density, which depends on the applied voltage and electron concentration.



Characteristic curve of a white high-performance LED

Nominal current 350 mA, Voltage 3.4 V



Operating point = intersection of the yellow auxiliary lines

LED's forward current, which has to be limited, defines the brightness of the **LED** a

Material Groups for LEDs

The two major material groups :

- **InGaP (Indium-Gallium phosphide) compounds**

  .... used to create red and amber

- **GaN (Gallium nitride) compounds**

  -------- used to create blue, cyan, and green.

- **Phosphides and nitrides of Aluminum, Indium, and Gallium**

  ------ produce light of different colors and efficacies

TYPES of LEDs

Standard through-hole LED:

Often used as indicator light source, although with low light output. Due to their shorter service life, higher probability of failure and sensitivity to UV radiation, they are not used in lighting technology.

SMD (surface mounted device) LED:

It consists of an LED chip protected by silicon coating mounted in or on a housing or a ceramic plate with contacts. This form of LED structur emits light perpendicular to the plane of the PN junction.

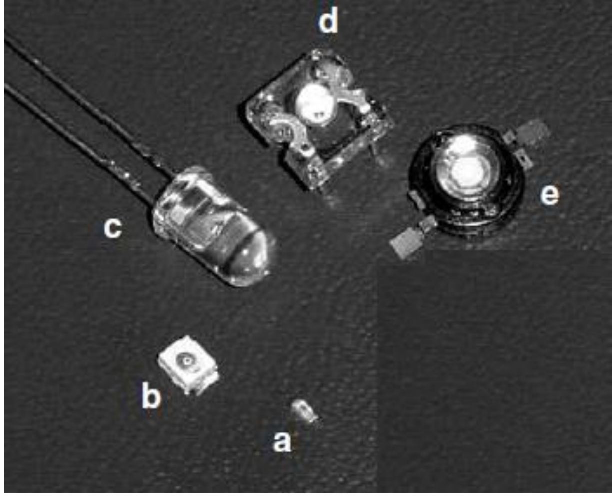
(**Reflow soldering**: A **solder** paste (a sticky mixture of powdered **solder** and flux) is used to temporarily attach one or several electrical components to their contact pads, after which the entire assembly is subjected to controlled heat, which melts the **solder**, permanently connecting the joint.)

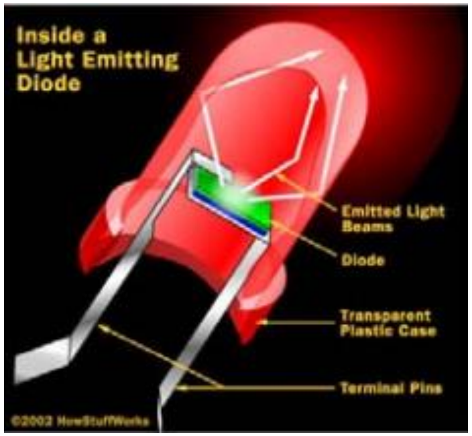
Edge emitting LED structure: This form of LED structure emits light in a plane parallel to the junction of the PN junction. In this configuration the light can be confined to a narrow angle.

CoB (Chip on board) LED:

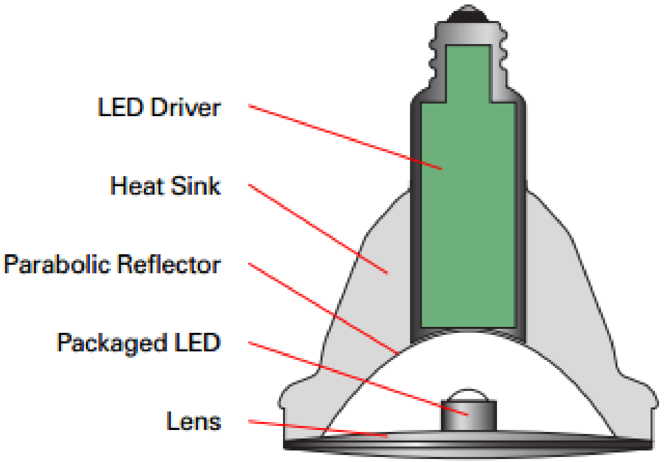
LED chip is mounted directly on the printed circuit board. This allows a dense arrangement of chips close to each other.

LEDs



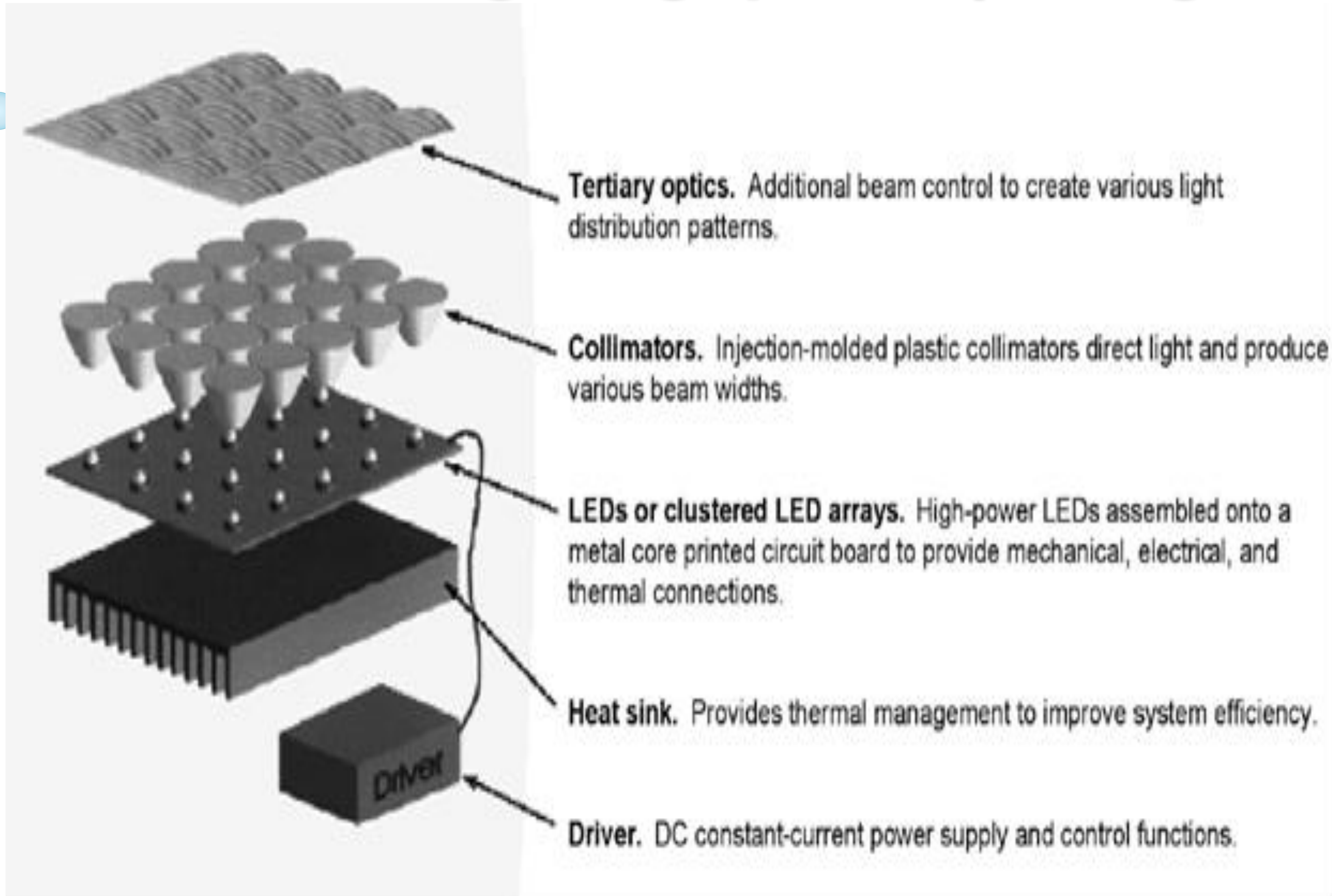


Diodes in LEDs are housed in a plastic bulb that concentrates the light in a particular direction. Most of the light from the diode bounces off the sides of the bulb, traveling on through the rounded end.



Typical residential LED lamp construction.

LED lighting system package



(LED)- Basic features..1

- No filament or Gas to burn out and do not get hot as light bulbs do. No smoke emission or flammability under malfunction.
- Low-voltage current driven device that converts electrical energy into visible light.
- No infra-red or ultraviolet energy is emitted in the beam of visible range.
- By using multiple dies or groups of packaged LEDs, the light needed by the application can be obtained.

LED... Basic features ..2

- Primary light from three individual LEDs (red, green, and blue) is mixed together, creating white light.
- As a luminance source, millions of colors can be produced, but it requires more complex driver electronics.
- Highest efficacy
- LEDs do not fail abruptly; instead, they dim with time. "100,000 hour" life is commonly cited.
- Extremely high reliability against mechanical shocks and vibrations and reasonably moisture-tolerant. However, the electronic circuitry that surrounds them in a system is not.
- **High brightness lighting depends on high operating current densities (and thus high junction temperatures.)**

(LED)... Basic features ..3

- **However,** a good rule of thumb is that the **higher the design junction temperature, the faster the light output will degrade.**

- One of the key limitations affecting LEDs is **temperature.** The maximum die junction temperature will vary from one LED manufacturer to another. A common maximum junction temperature rating is 135°C (275°F), although many manufacturers continue to improve upon this number.

- Temperature sensitivities of InGaN-based and AlInGaP-based LEDs are significantly different.

LED : Output…1

- The output of an LED is dissipated as light and heat. Light is emitted from the LED **die** in all directions.

- Based on shape of the die, the material from which it is constructed, and the package in which it is assembled, light from the surface of a packaged LED can be captured for use in lighting system.

- **Heat is not radiated (as it is with conventional lighting technology) but is retained in the LED package.**

- Heat must be effectively conducted away from the die by the packaging materials or the device leads. **Without proper thermal management**, internally-generated heat can cause packaged LEDs **to fail**.

LED : Output ..2

- **Luminous Flux** available from an LED varies according to the LED's color, and **depends on the current density**, the LED die can manage. Output is almost linear (upto certain range) with the drive current.
- For examples, small-signal white LEDs driven at 20-30 mA can produce approximately 2-4 lm in a 5-mm package when, driven at 350-1000 mA, power-packaged white LEDs can produce 25-120 lm
- **Significantly higher utilization efficiencies possible with LEDs in directional applications** relative to conventional sources as applicable in street lighting.

LED : Output ..3

- LEDs turn on rapidly unlike some light sources, and are easily dimmed allowing better and ease of control of the amount of light needed (advantage of harvesting daylights and occupancy factors)
- The best LEDs achieve 70 percent lumen maintenance at 50,000 hours of operation under standard use conditions.
- 5 to 10 times as much illumination per watt as incandescent bulbs - or even more.
- Offer precise control of light output, as opposed to incandescent bulbs, which spray their light in all directions.
- Tiny changes in the thickness of the layers can change the color of the LED's light. Most white-light LEDs have another layer called a phosphor. Tiny changes in the phosphor will lead to color changes that can make one white LED look bluish while another looks reddish and another yellowish.
- LEDs last 25 to 50 times as long as incandescent.

LED : Output ..4

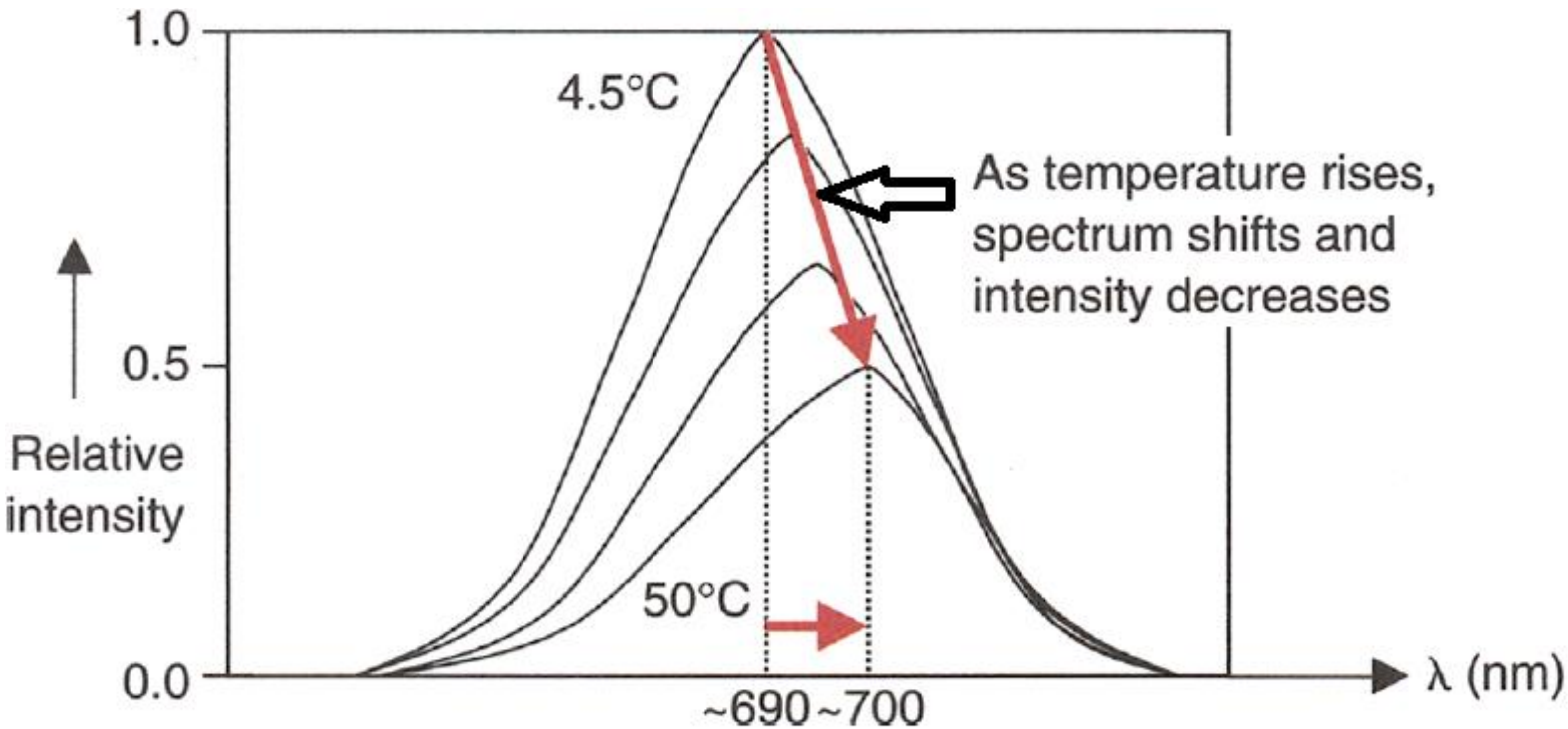
Thermal Runaway:

➢**LED diode Forward Voltage is the amount of volts the light emitting diode requires to conduct electricity and light up.**

➢ **As temperature increases, the forward voltage of the LED decreases, causing the LED to draw more current.**

➢**The LED will continue to get hotter and draw more current until the LED burns itself out, this is known as Thermal Runaway.**

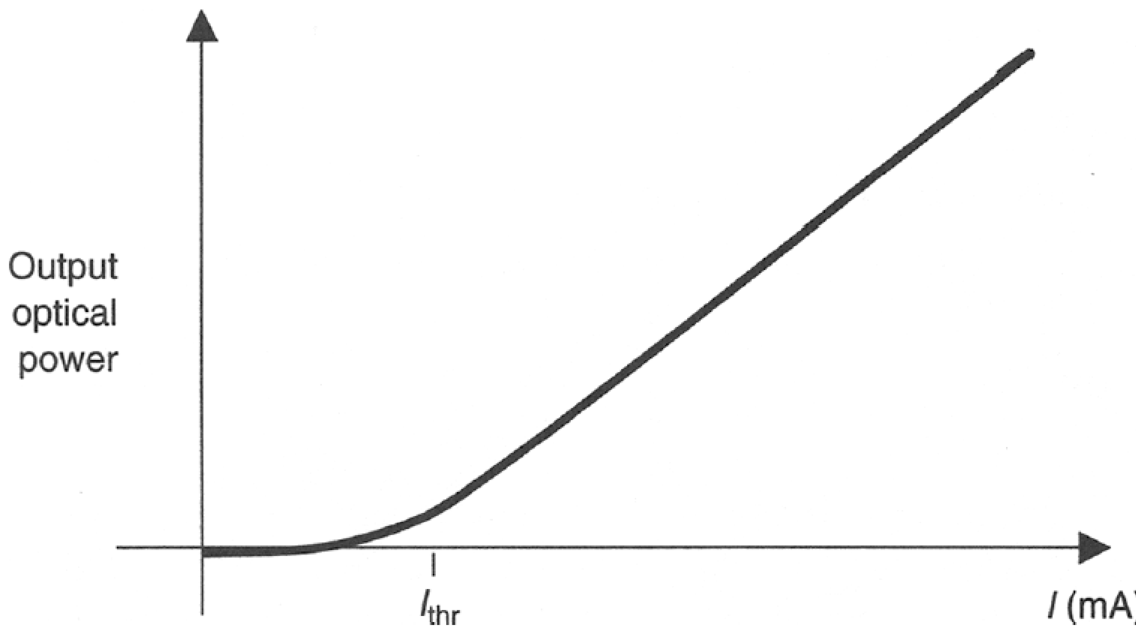
- **Temperature has an adverse effect on the stability of an LED device . As temperature rises, its spectrum shifts and its intensity decreases, as shown in the figure**



The spectral output of LEDs in the range of emitted wavelengths depends on the absolute junction temperature.

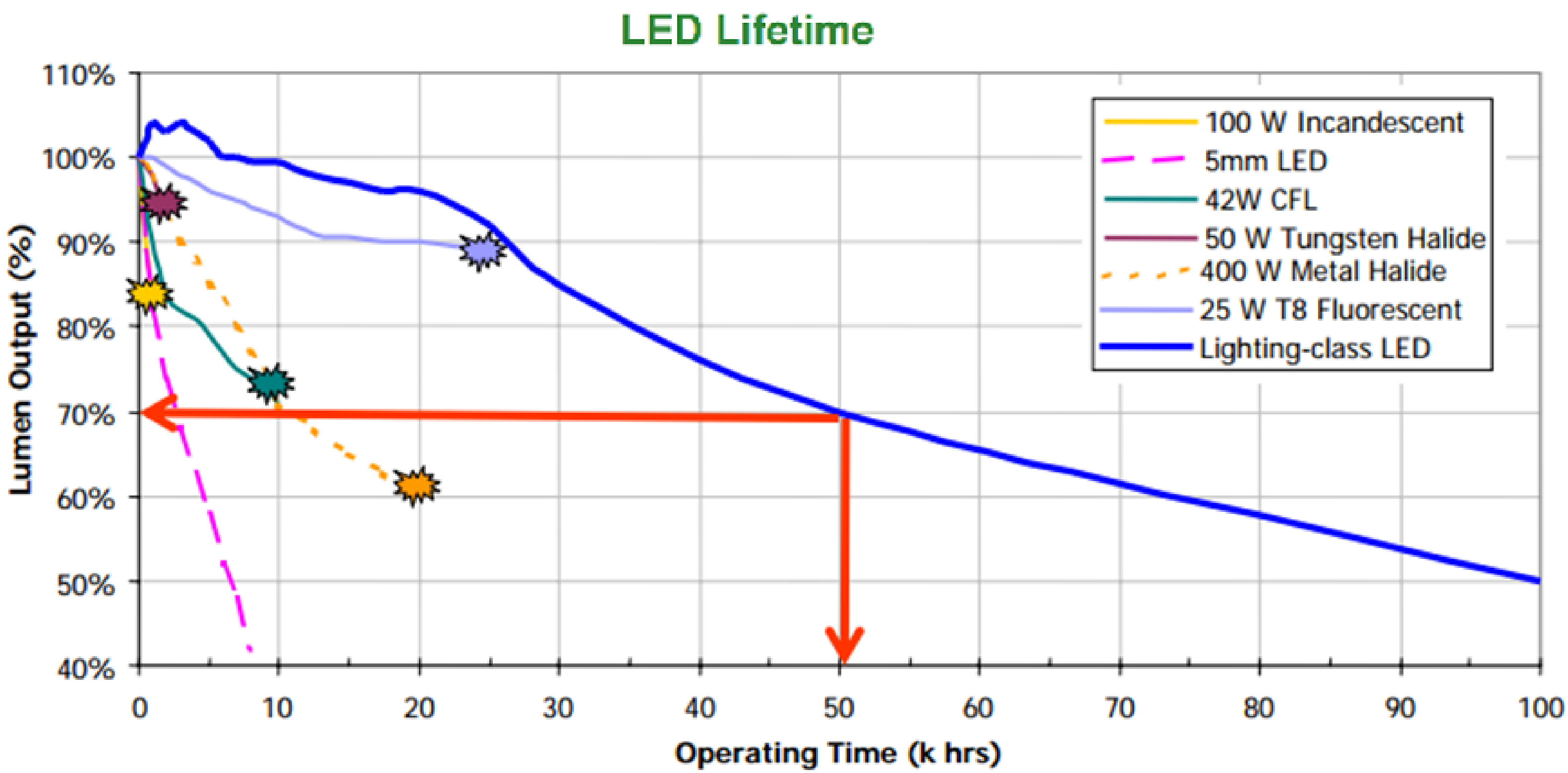
Light Emitting Diode (LED) –

- **Forward voltage of LEDs varies non-linearly with current. The light output is proportional to current and over certain regions of current it follows almost linear relationship.**



An LED behaves like a diode.

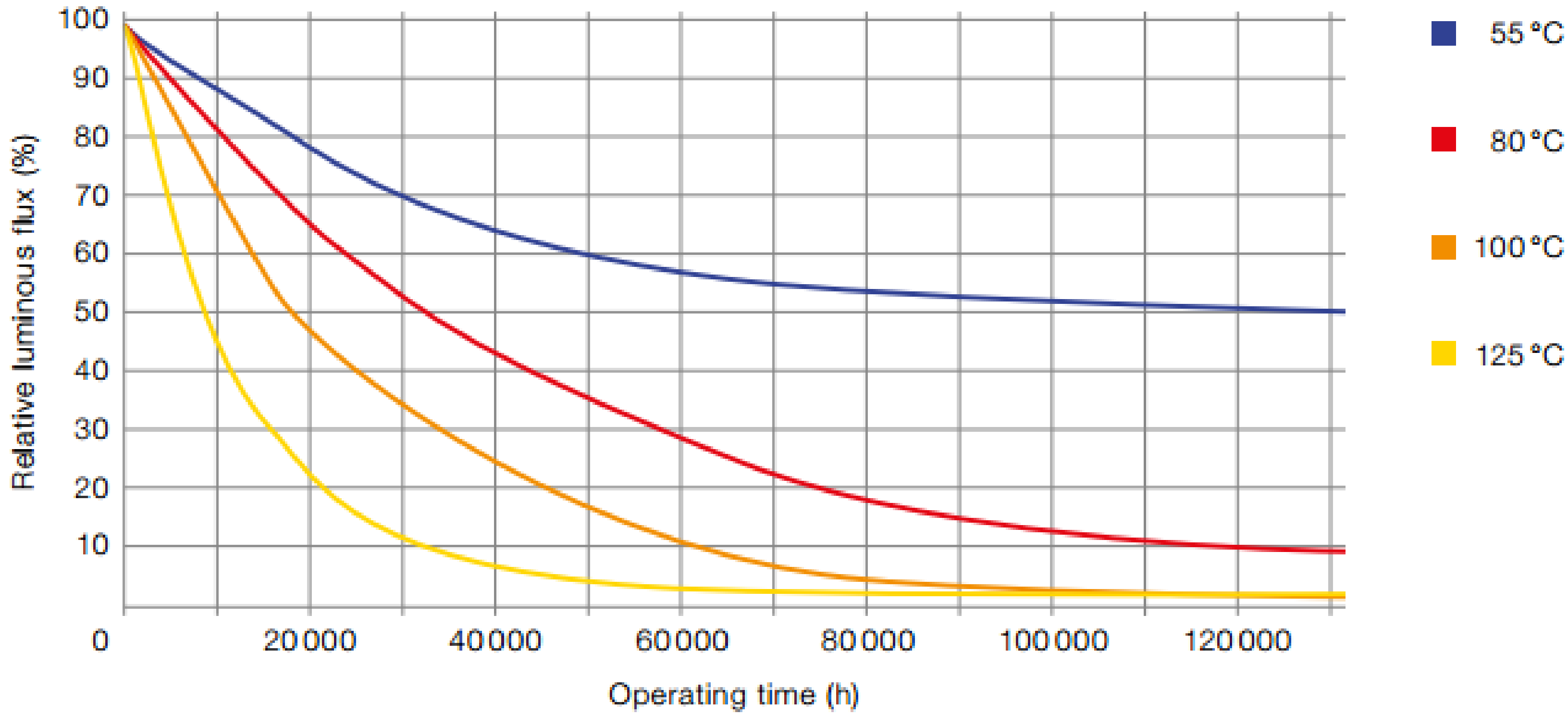
Light Emitting Diode (LED) - Lifetime



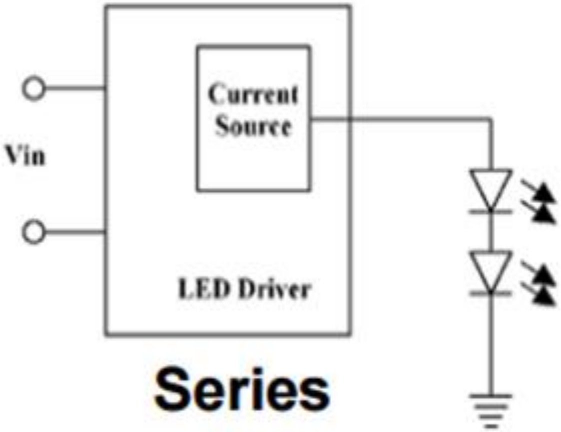
Courtesy LRC, Rensselaer Polytechnic Institute

➢ **High efficacy and long lifetime reduces maintenance cost , which is critical for commercial lighting.**

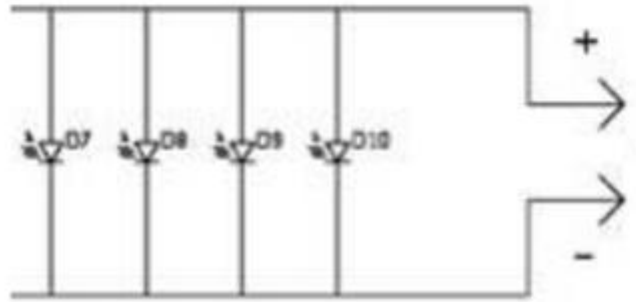
LED – flux degradation with time



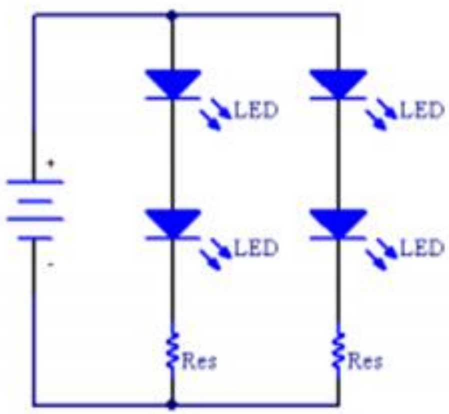
Arrangement of LEDs



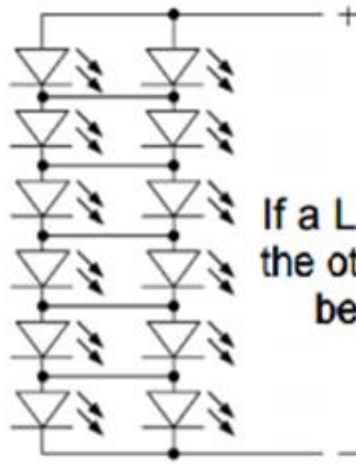
Series



Parallel

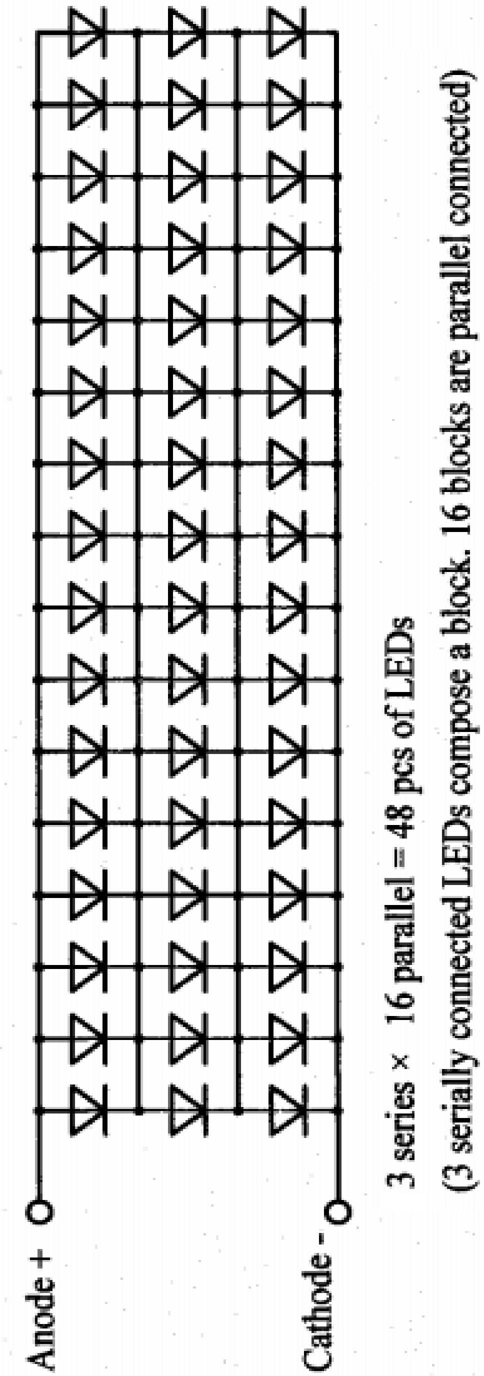


Series-Parallel



If a LED fails open the other LEDs may be overdriven

Cross connect



The arrangement of LEDs and the luminaire specifications dictate the fundamental driver requirements

Light Emitting Diode (LED) – Power Supply

- **LEDs are low-voltage current (mA) driven devices.** A well regulated DC current to the LEDs in any given configurations is reqd. to ensure the required lumen output, color and long operating life of the LEDs.
  (when LED is on, the voltage it uses is somewhere between 2.5V-3.2 V)
- **The LED driver needs to provide a well-regulated DC current** to ensure the required lumen output, color and long operating life across a range of operating conditions.
- A single DC power source may **drive** one LED or a cluster of LEDs, **or typical LED drivers/ Chip may be employed.**
- **Cannot be directly powered from the AC line.**
  (Fluorescent lamps and low voltage halogen bulbs also cannot be powered directly from the ac line and require a magnetic or electronic ballast to transform the ac line into an appropriate signal for the lamp) .

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Light Emitting Diode (LED) – Drivers…I

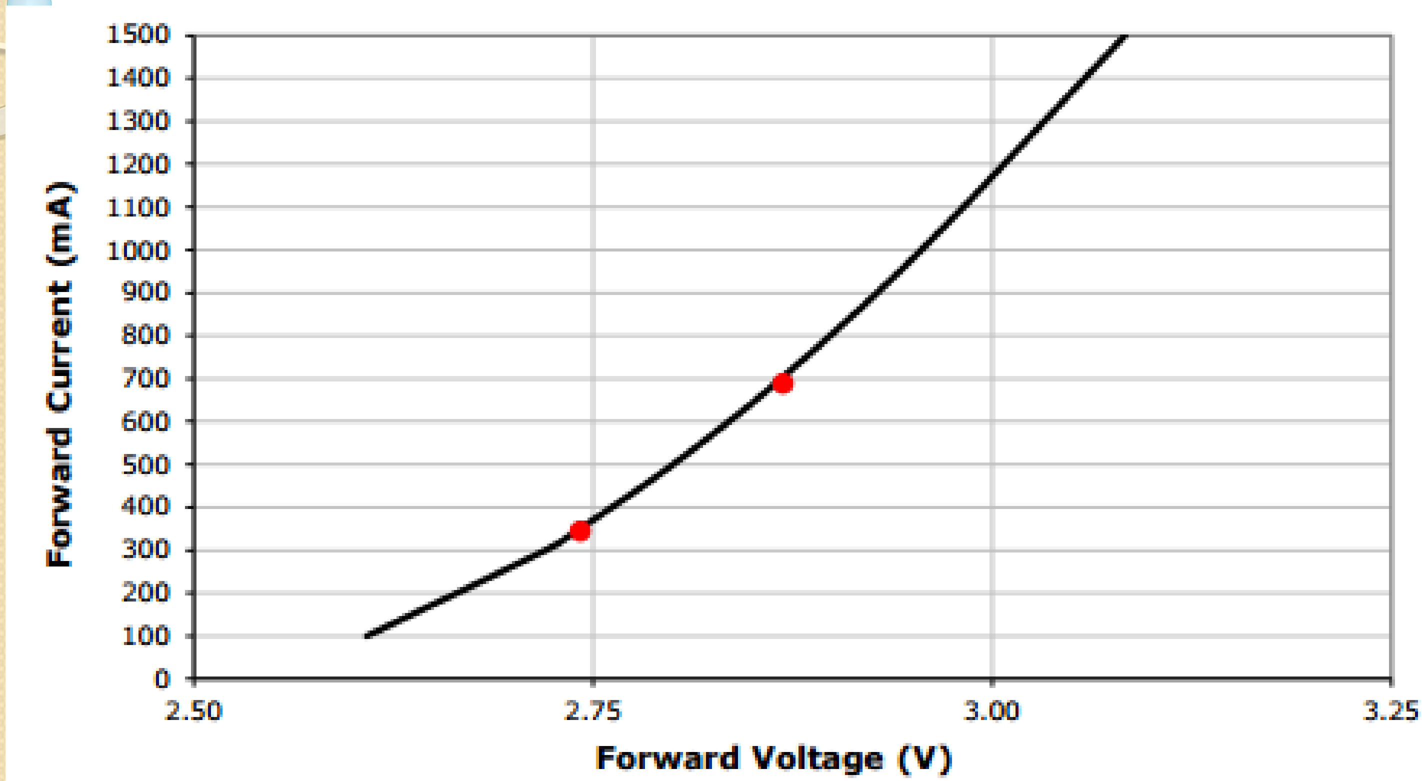
➢ **Typical LED Driver**

- *An LED driver is an electrical device that regulates power to an LED or a string of LEDs.*
- *Provide accurate drive current for the LEDs in a chosen configuration.*
- *Provide galvanic isolation between primary and secondary. (i.e. no direct conduction path)*
- *Regulate against any LED voltage variations and potential shorting of one or more LEDs in a string*
- *Regulate the LED current for any input voltage level within the specified operating range.*
- *Provide protection against overvoltage, short circuit, overload, and other abnormal operating conditions.*

- *Provide harmonic reduction (THD) and power factor correction (PFC), if required, to meet regulatory requirements.*
- *Provide ripple suppressor/ ripple attenuation*
- *Limit the heat generation and temperature rise.*
- *LED should be driven well within its ratings. Overdriving a LED will drastically reduce its lifetime, although it will increase the light output.*
- *Using a suitable LED driver is important in preventing damage to your LEDs as the forward voltage (Vf) of a high-power LED changes with temperature.*
- *As temperature increases, the forward voltage of the LED decreases, causing the LED to draw more current. The LED will continue to get hotter and draw more current until the LED burns itself out ..... a case of* ***Thermal Runaway.***
- Constant current LED driver helps avoid thermal runaway

Constant Current LED Drivers VS. Constant Voltage LED Drivers ?

Forward voltage varies non-linearly with current, but the light output is proportional to current. Over certain regions of current it can be approximated in a linear relationship.



- **When the LED is turned on, even the smallest 5% change in voltage (2.74V to 2.87V) can create a 100% increase in current as shown with the red marks- current rises from 350mA to 700mA.**

Constant Current LED Drivers vs. Constant Voltage LED Drivers ?

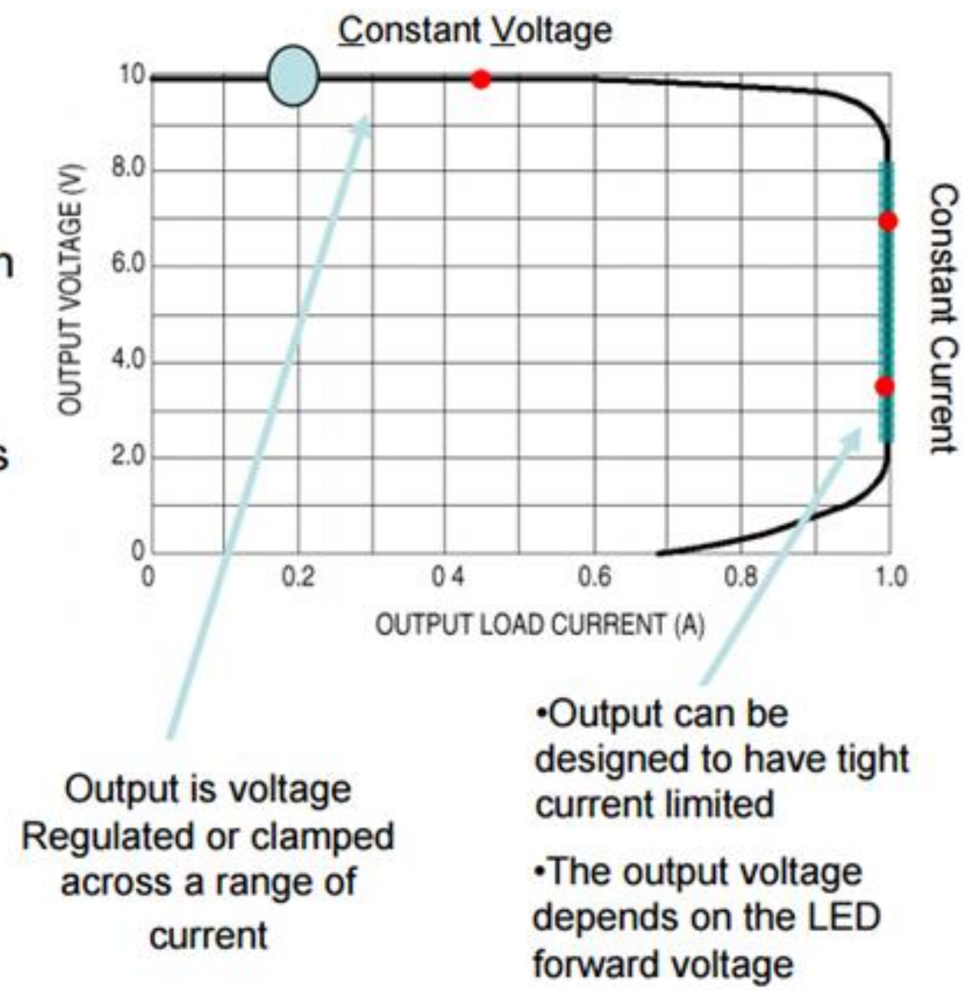
- If there is no current limiting device, the current would continue to rise as temperature did. The excess forward current would result in extra heat within the system, leading the LED to thermal runaway.

- It is preferable to use the constant current LED driver that compensates for the changes in the forward voltage while delivering a constant current to the LED.

Light Emitting Diode – Drivers…2

Driver Operation

- Constant Voltage and Constant Current Regions
- Range of current and/or voltage regulation is driver/design specific
- Some drivers are designed for constant power so LED forward voltage determines current

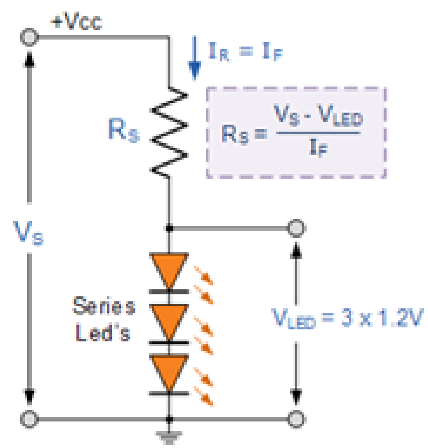


LED – Drivers..3

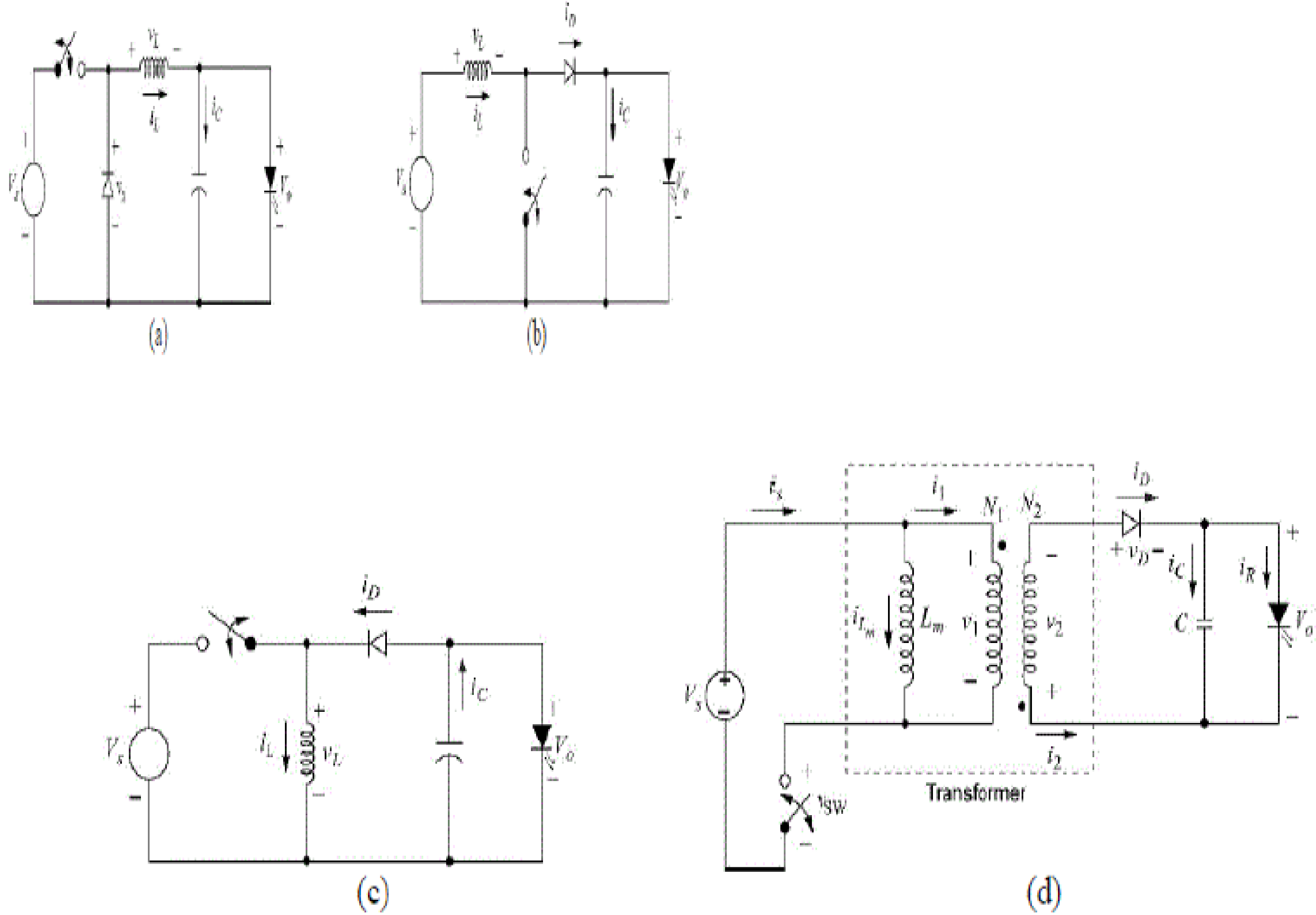
The LEDs current limiting and setting can be done with different methods:

1. A resistor to limit the forward current

LED's in Series



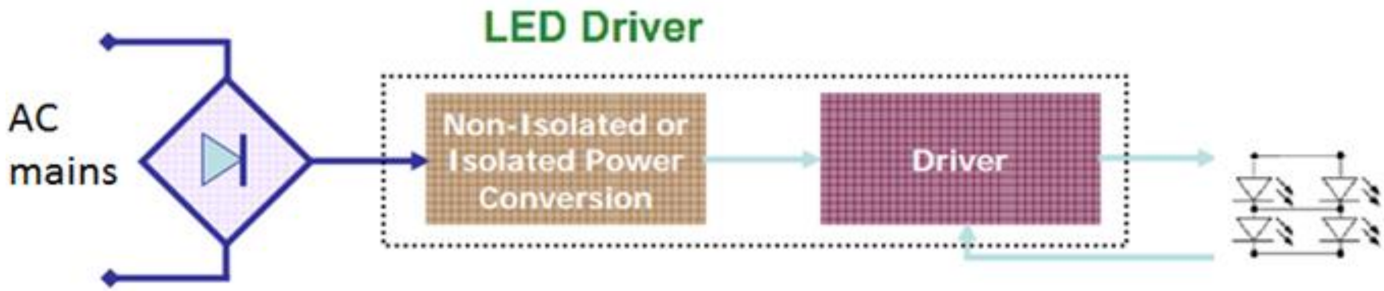
- The array may be a single string of LEDs or a series parallel combination of LEDs.
- Resistor may be designed (in series or in parallel combination)
- A Buck/Boost/ Buck-Boost types of DC-DC converter in constant current (CC)mode may be employed to work out the LED output voltage range of the driver with suitable Duty ratio.



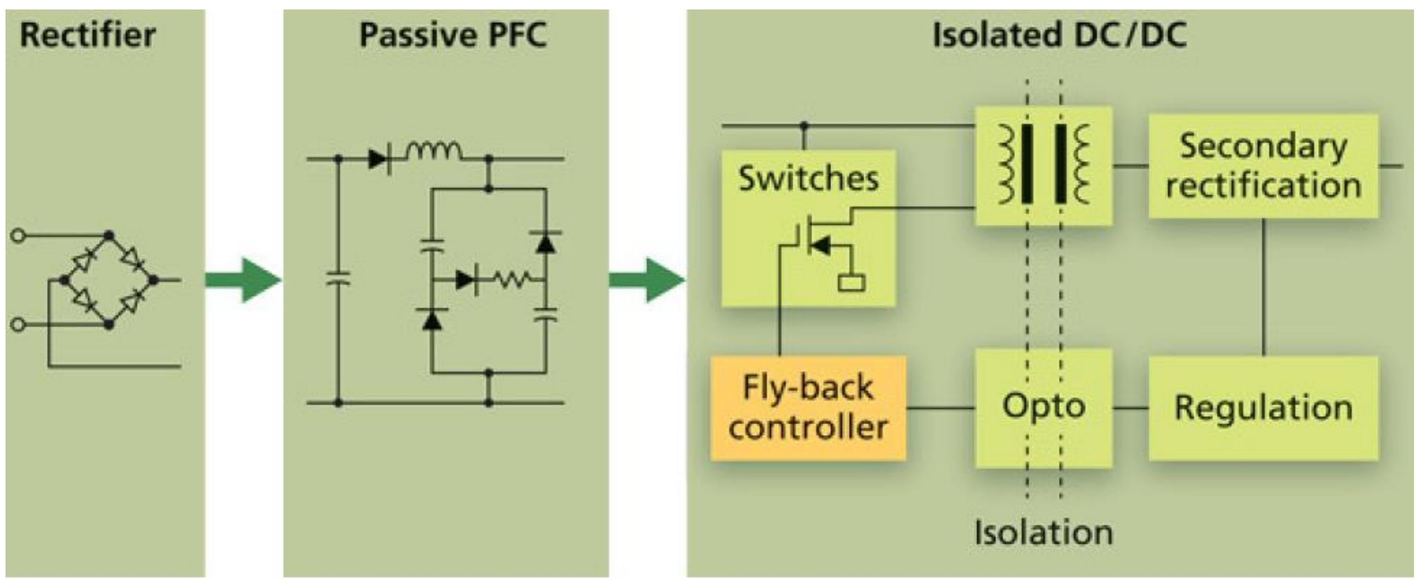
Different types of switch mode converters to drive power LEDs a) buck converter b) boost converter c) buck-boost converter and d) Flyback converter.

Light Emitting Diode – Drivers…4

II. AC-DC and/or DC-DC converters in constant current (CC) mode



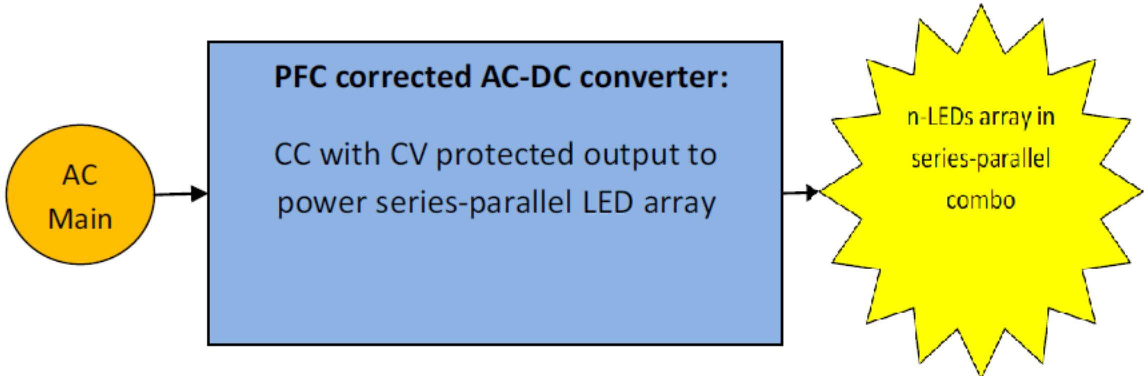
Ac-Dc power conversion and driver regulation can be merged together into a single driver or separated into two stages



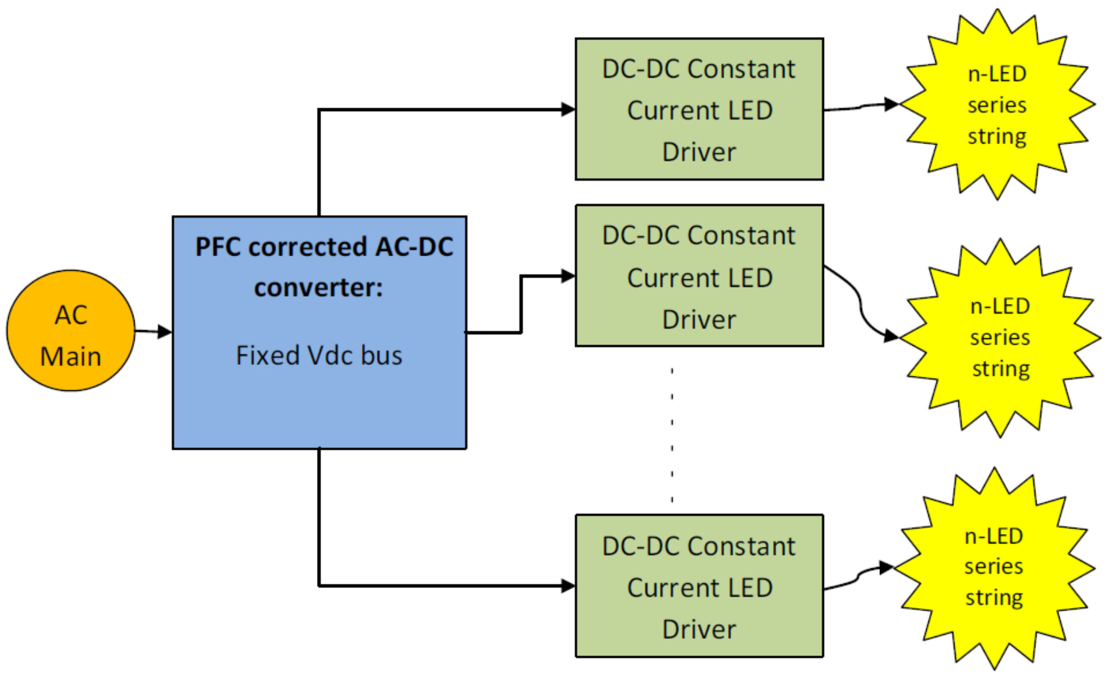
Passive PFC stage plus a DC/DC-converter stage in an LED driver.

Light Emitting Diode (LED) – Drivers..5

- **AC-DC and/or DC-DC converters in constant current (CC) mode**

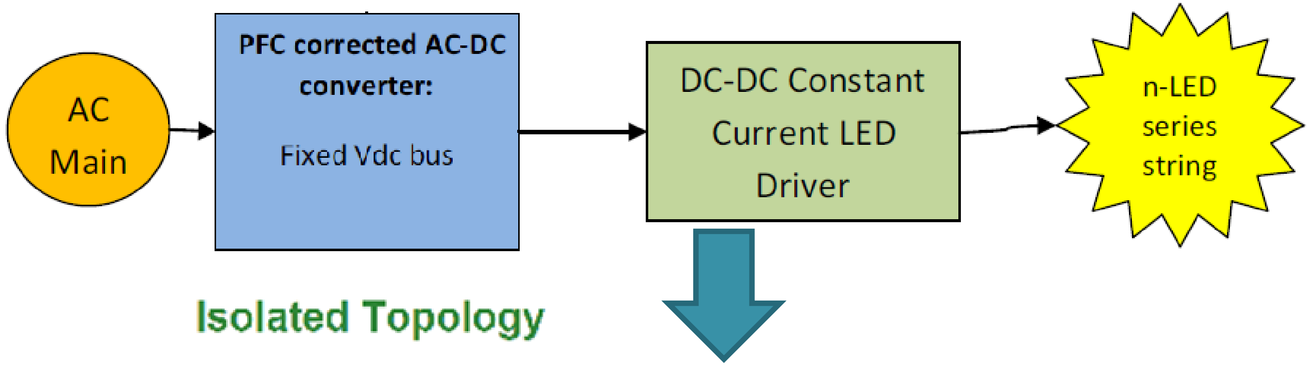


Single Stage Integrated LED Driver

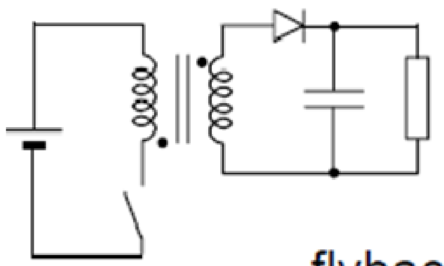


Two-Stage LED Driver with Single Front-End Converter (LED Power Supply)

Light Emitting Diode (LED) – Drivers…6

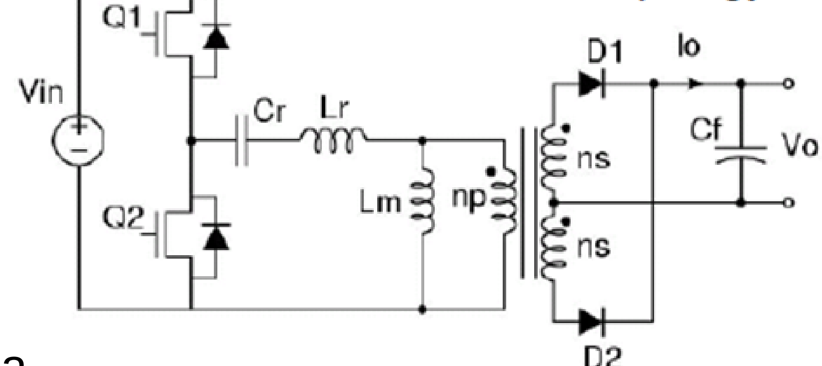


Isolated Topology

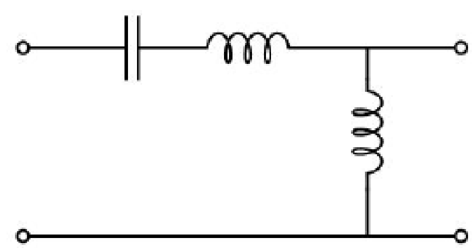


flyback

LLC HB resonant topology

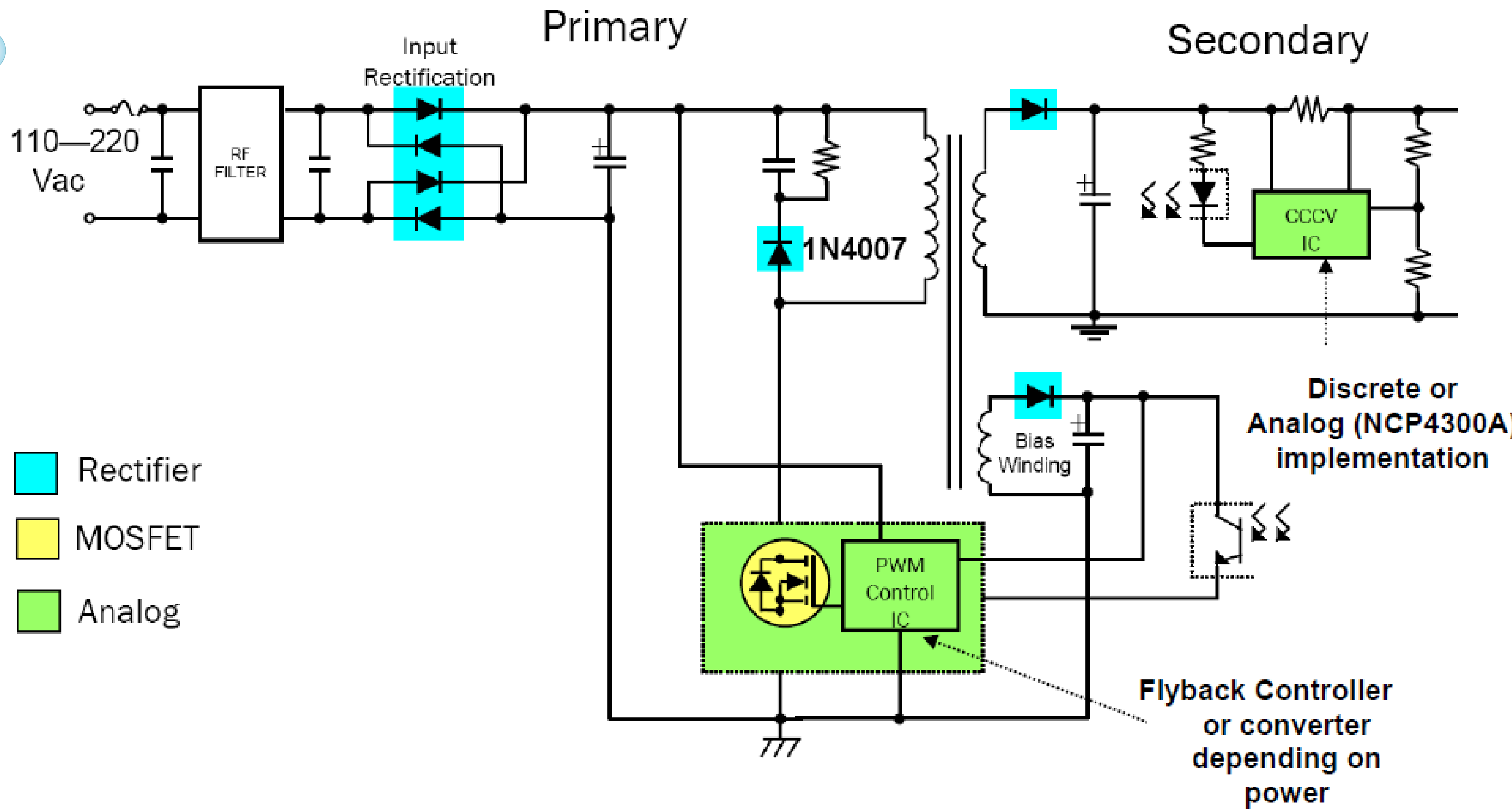


The LLC resonant converter is a modified LC series resonant converter implemented by placing a shunt inductor across the transformer primary winding

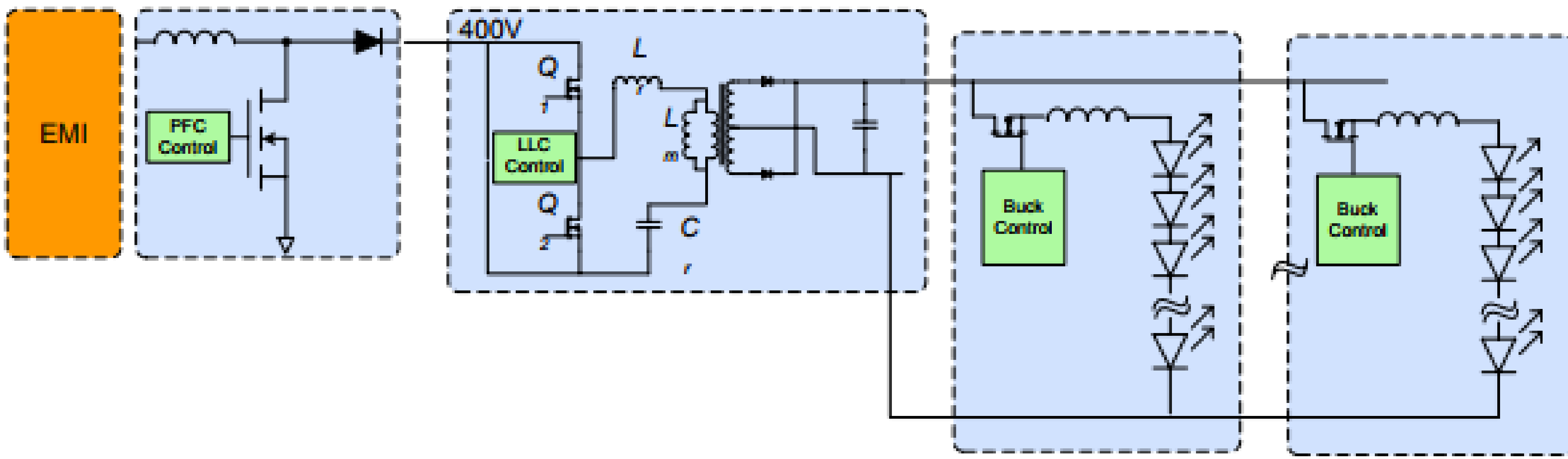


LLC Resonant Tank

Light Emitting Diode (LED) – Typical Driver…7



Off-line LED Driver



Traditional high wattage off-line LED lighting driver topology

LED Dimming

- **Two principle methods of dimming - Analog and Digital which has an impact on the Driver design.**

- **Forward voltage varies non-linearly with current,**
- **Light output is proportional to current. Over certain regions of current it can be approximated in a linear relationship.**

- **Analogy dimming**:

The output current of the LED driver is reduced in order to achieve reduced light output. As the current is reduced, the forward voltage of the LEDs as well as the junction temperature of the LED is reduced.

But, 50% reduction (say) in LED current may not result in a 50% reduction in light output so the **dimming curve is not linear**.

Reducing the current by 50% will also reduce the forward voltage of the LED so the power will be reduced by more than 50%.

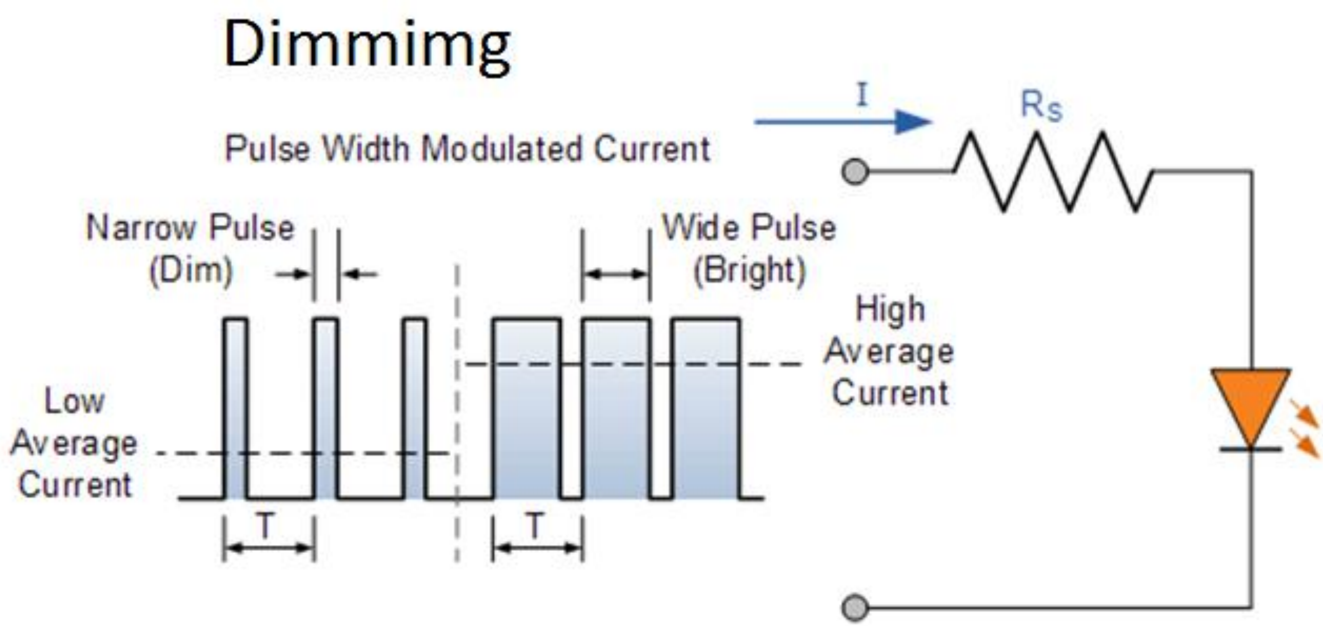
Thus, the **efficacy of the LEDs (lm/W) improves as the LEDs are dimmed**.

The variation of the LED forward voltage may be about 20−25% as the current is varied from 100% to 10%. For example a typical white LED may have a forward voltage of 3.4V at 700 mA. This drops to 2.95 V at 70 mA. In effect, color of the LED can experience color point shift when the current is changed over a wide range. So it is not typically used in applications where the color temperature must be tightly controlled.

Light Emitting Diode (LED) – LED Dimming..2

Digital dimming:

In digital dimming where the LED current is pulsed between a regulated current and zero at a high frequency with a controllable duty cycle (lower the duty cycle for more dimming).



Light Emitting Diode (LED) – LED Dimming..3

Digital dimming features:

- The frequency of the pulse train is high enough for the human eye to not perceive the changing amplitude as flicker, yet low enough not to interfere with the stability of the LED driver circuit (typically in the range of 200 Hz to a few kHz).
- With such dimming, **the color temperature of LED is maintained** as the drive current (when present) is always constant and at a regulated level.
- The LED forward voltage is fairly constant, and only varies by the change in junction temperature.
- While digital dimming adds increased complexity to the circuit implementation, it offers significant benefit in better linearity, more predictable lumen output and a well defined color point for the LEDs.

Design Factors to Consider

- Output Power
  - Range of LED forward voltage
  - Current – target, maximum
  - LED arrangement
- Power Source
  - Vac or other
  - Low Voltage Lighting (landscape, track etc)
  - Solar / Battery
- Functional Requirements
  - Dimming
  - Analog, Digital dimming
  - Lighting Control – occupancy, motion, timer
- Additional Requirements
  - Efficiency
  - Power Factor
  - Size
  - Cost
  - Fault handling (short circuit, open circuit, overload, over temperature
  - Standards – Safety
  - Reliability

Light Emitting Diode (LED) – Applications

Traffic Signage –traffic signals, pedestrian signs, highway sign panels, railroad signals, marine navigation, and beacon lights at airports.

Architectural – widely adapt to multiple

exterior tasks (viz. bridges, stairs, walkways, elevator, Garden building structure outlines, Street lights, etc.) *and interior tasks (viz* . lighting in many clubs and restaurants, Mall, food courts, kiosks, seasonal displays, movie theaters, gaming, etc.)

Automotive – switch indicators and map lights, stop lamps, rear combi-lamps (stop, turn, tail), side marker lights, etc.

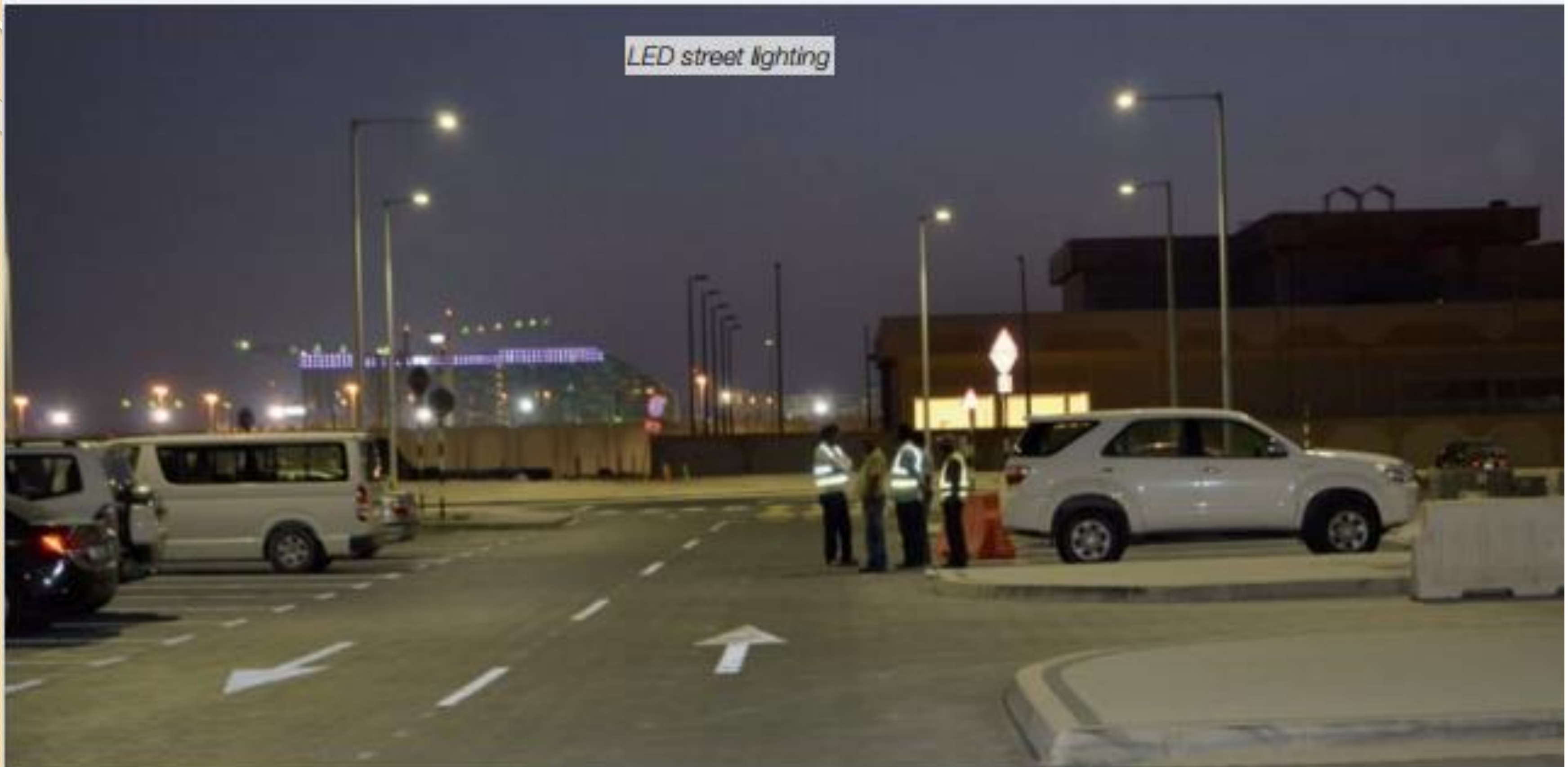
Light Emitting Diode (LED) – Applications

Displays –moving messages, marquis, building façade graphics, scoreboards, TVs.

Task Lighting –*for* desks, workstations; *downlighting* for elevators; *portable lighting for flashlights, miners' lights,* and dive lights.

Medical Lighting – *Dental headlamps and microscope.*

Examples..1



Examples..2

LED Street Light….Spec.

Typical LED Street light Luminaire Specification

Sr. No.	Tests Parameters	Requirements	Referred standard IS/IEC
1	Lumen per Watt	Low Output (<9000 lm) 65 lm/W; Mid Output (9000 to <23000 lm) 80 lm/W; High Output (≥23000 lm) 100 lm/W	16103 (Part 2)
2	C R I	≥ 60	16103 (Part 2)
3	Minimum rated life (L70 /B50)	50,000 h	16103 (Part 2)
4	Rated voltage	Upto and including 250 V, Operating range 140V to 270V AC, 50 Hz	IS 16103 (Part 2)
5	Power Factor	> 0.9	IS 16103 (Part 2)
6	T H D	Not more than 20%	14700 (Part 3/Sec 2)
7	Driver	Accessible for easy replacement.	-
8	CCT	3000K (3045±175) 3500K (3465±245) 4000K (3985±275) 5000K (5028±283) 5700K (5665±355) 6500K (6530±510)	IS 16103 (Part 2), IS 16105 and IS 16106
9	Junction Temperature	Less than 90° C @ ambient 25 degrees C. To be calculated by measuring at solder point and adding thermal resistance.	-
10	Capacity to withstand surges	Upto 4 KV	IEC 61000-4-5
11	Warrantee	2 years	-

High brightness LED that produces over 50 lumens and high power LED is in terms of power consumption (W)

Glimpses of LED Technology

Traffic Signals

Airplane Lighting

Bridge Illumination

Indoor Lighting Fixtures

LED Strips

60W 1200 Lumen Light

THANKS