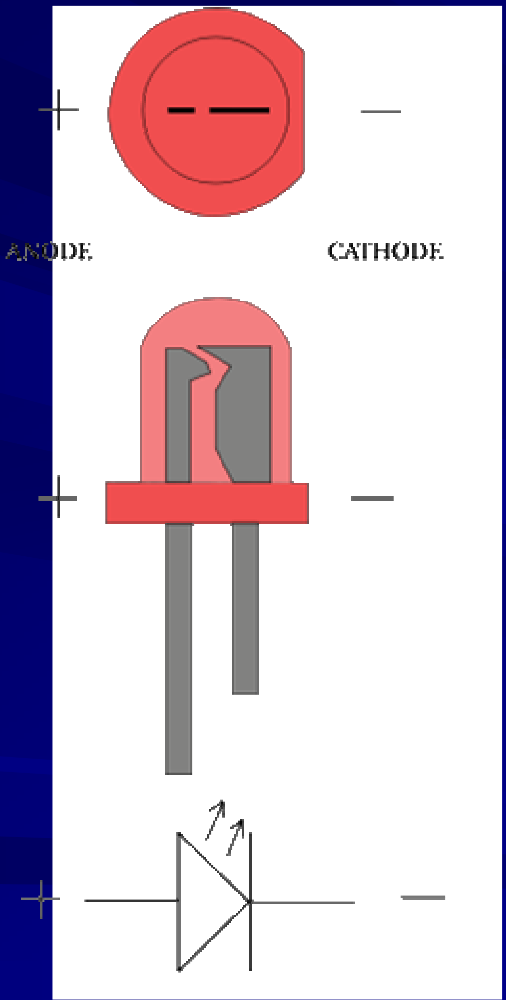
Solid State LED Driver Application Note

Light Emitting Diodes (LED)

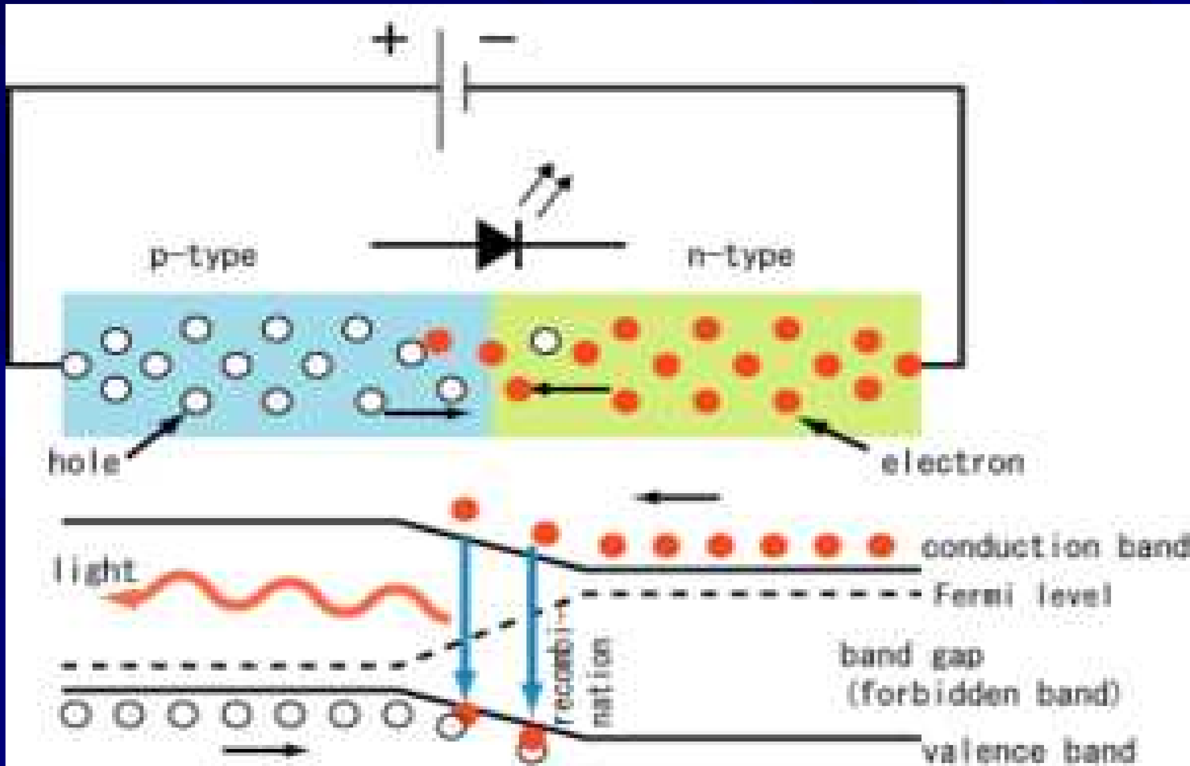
- **Global Solid State LED Lighting Market forecast to Grow 30.9% to nearly $1.3bn in 2013**

Light Emitting Diodes (LED)



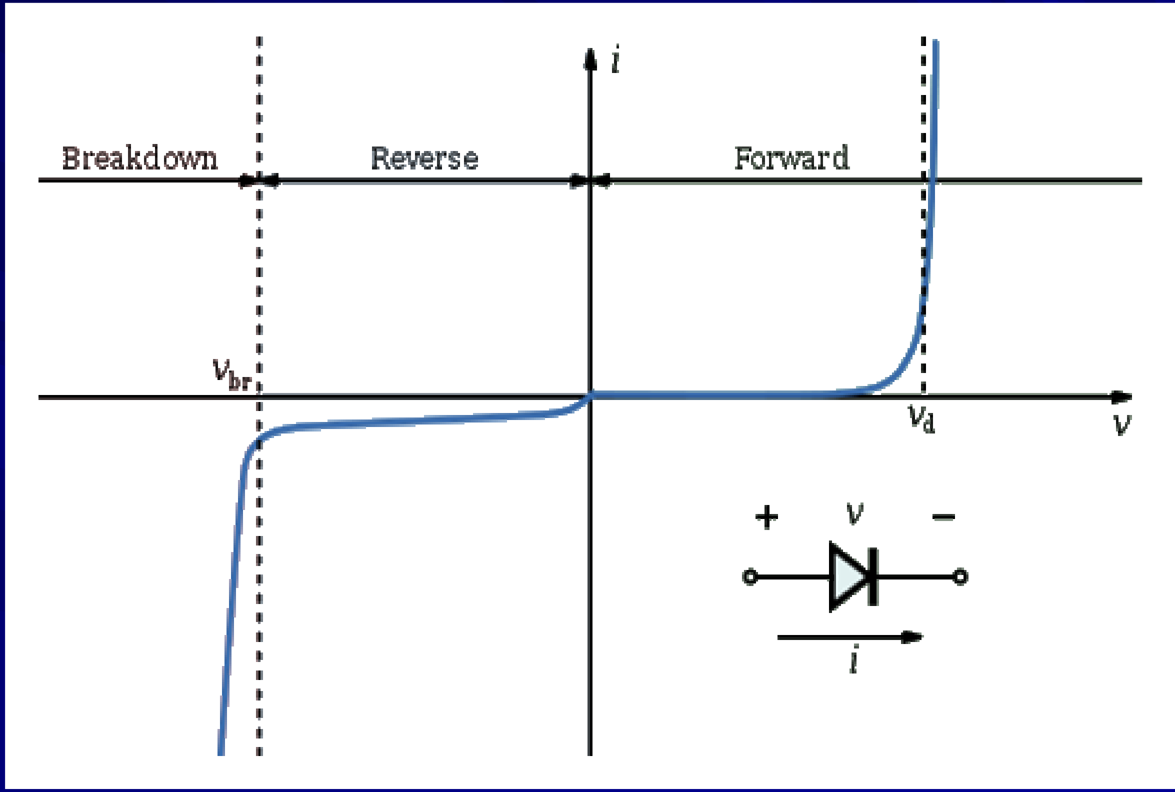
- A LED is a semiconductor diode.
- Its semiconducting materials create a P-N (positive-negative) junction
- When connected to a DC power source current flows from the P side (anode) to the N side (cathode) but not in the reverse direction .
- At the P-N junction a photon of Light is emitted for every electron that falls into a lower energy level.
- The color (wavelength) of the light is dependant on the semiconductor material .
- RED LEDs are Aluminum Gallium Arsenide (AlGaAs)
- BLUE LEDs are Indium Gallium Nitride (InGaN)
- GREEN LEDS are Aluminum Gallium Phosphide (AlGap)
- WHITE Light is created with a combination of Red Blue Green (RGB) LEDs or a Blue LED covered with yellow phosphor

Light Emitting Diodes (LED)



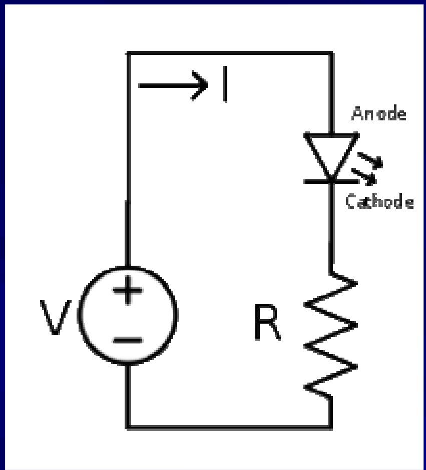
- Charge carriers (electrons and electron holes) flow into the junction from the positive and negative electrodes. When an electron meets a hole it falls into a lower energy level which releases the equivalent energy in the form of light (photons) .

Light Emitting Diodes (LED)



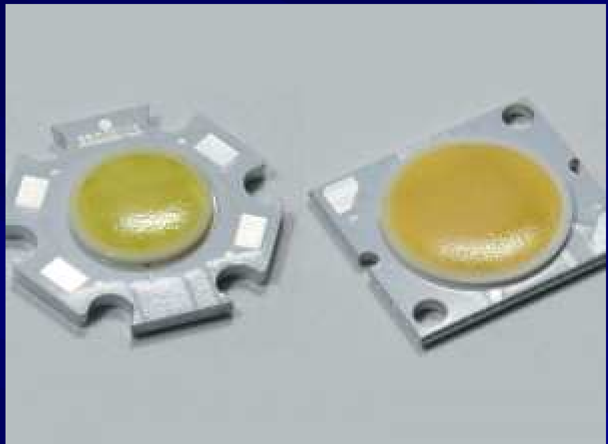
- The diodes are called light emitting because the energy given up by the electron as it relaxes is emitted as a photon.
- Above the threshold voltage (1.8V for Red to 3.3V blue LEDs), the current and light output increases exponentially with the bias voltage across the diode.

Powering Light Emitting Diodes



- The basic LED circuit consists of a DC voltage source powering two components connected in series. A current limiting resistor (sometimes called the ballast resistor), and the LED . The current limit can range from 20mA to 3A depending on the power of the LED used.
- R Ohms = Power Supply Voltage V - (Voltage drop across LED) / LED current , I
- Example R= (6V- 1.8V) / 0.02 = 210 Ohm
- LED power = 0.02*1.8=36mW
- However wasted power W watts =I^2 * R
- Example W= (0.02 *0.02*210) = 84mW which is 2.3 times the LED power !
- Therefore the need for Efficient Power supply Designs

Powering LED s



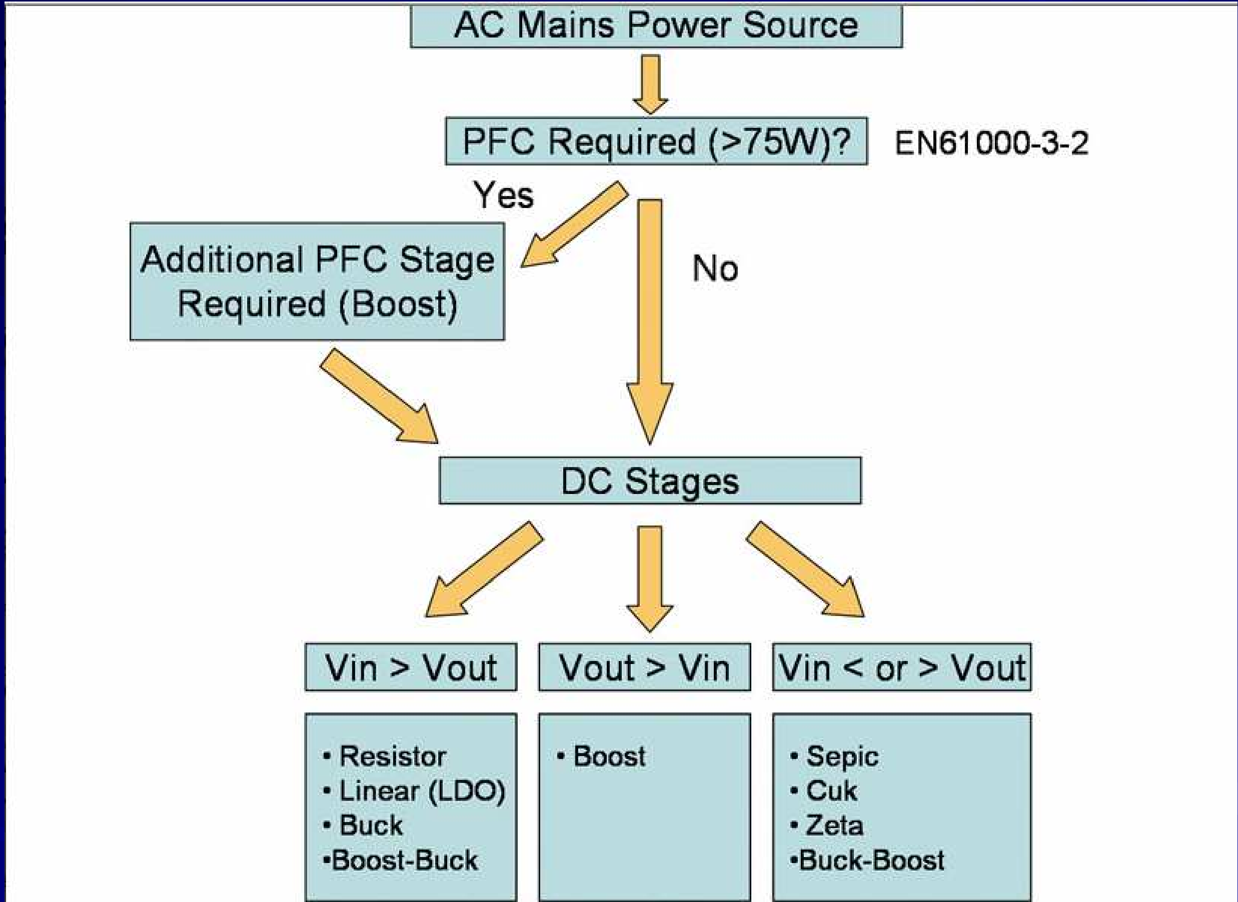
The high performance Cool, Neutral and Warm white LED arrays from Bridgelux in Star and Square package formats

- LED electronic driver design is an area of emerging importance in LED product development. Implementation of simple voltage control LED driver circuitry is disappearing in favor of current control, pulse width modulation,

  and energy efficient switching power supply designs. In many applications, temperature sensing and feedback are essential. In advanced lighting and display system applications, LED flux and color control

  feedback circuitry have become essential

LED Driver Topologies



The driver topology will depend upon the factors shown in above flow chart. However the function of the driver is convert the 115-230 V 50/60Hz mains power into a controlled dc current to light the LED lamps and at same time complying to Harmonic and efficiency standards.

LED Driver Topologies

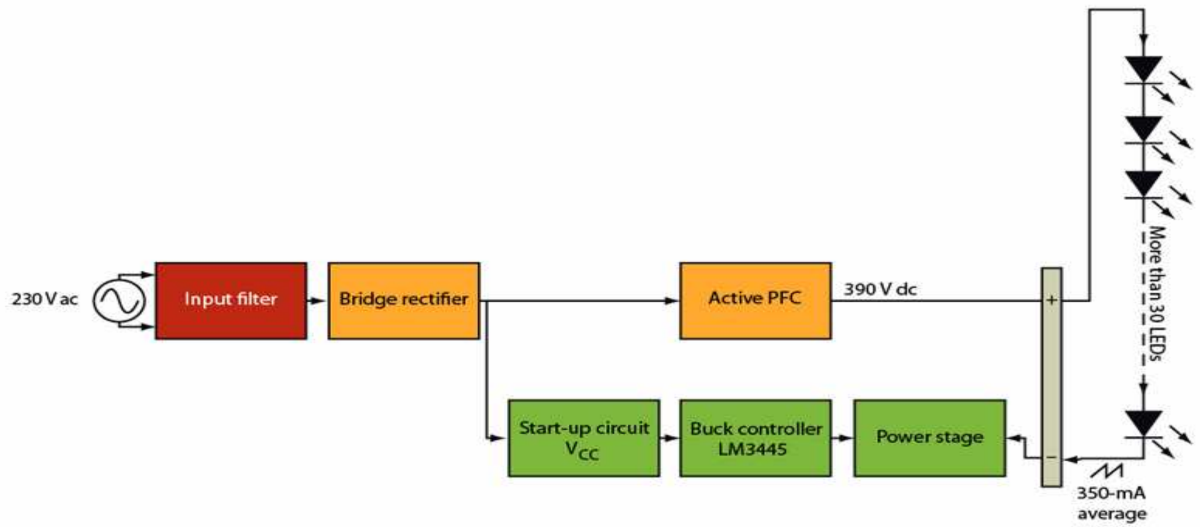
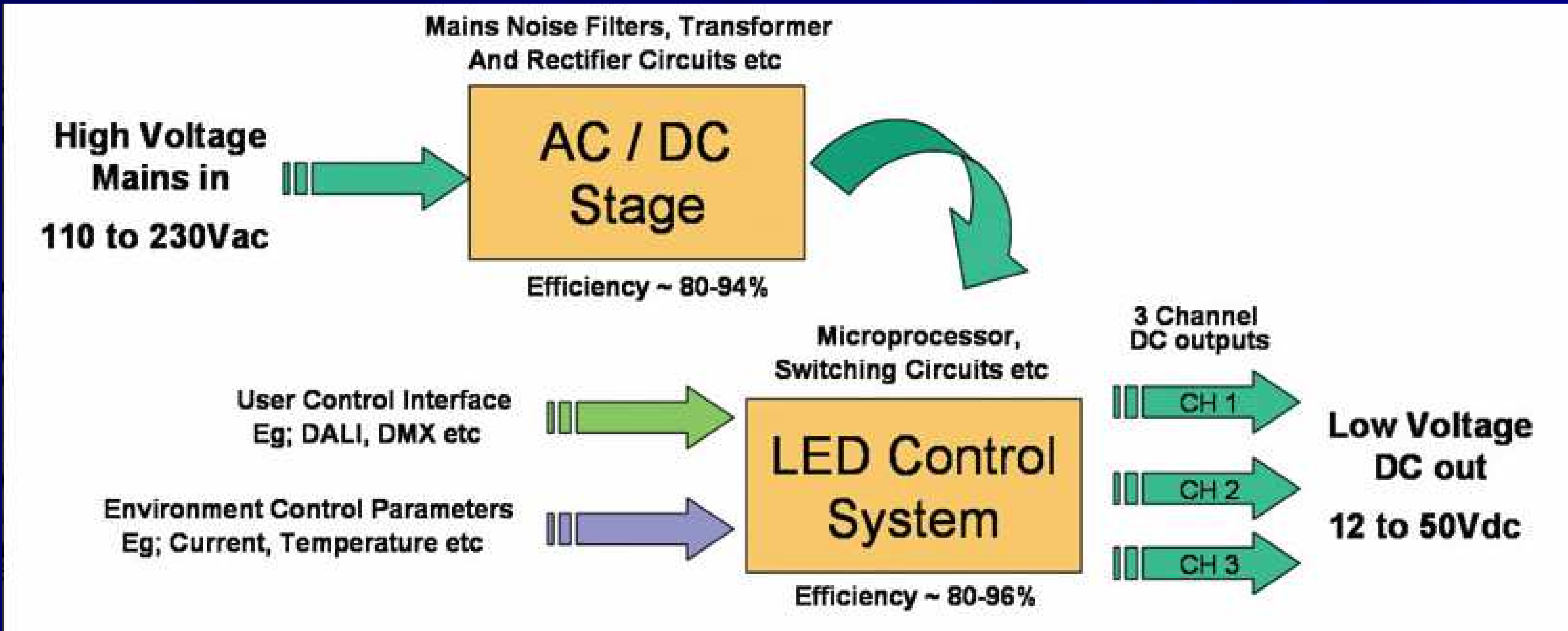


Figure 1. This design configuration doesn't require galvanic isolation, improving operating efficiency.

A Typical high Power LED Driver can deliver power to 30 LEDs with Power factor correction and filtering to meet international harmonic standards. *FIRST STAGE: PFC*

Many basic ac-dc power supplies generate harmonic distortion in the input line and have poor power factor, making it difficult to meet the European standard EN-61000-3-2. The solution is to use a PFC circuit to make the input current waveform appear sinusoidal, like the input voltage waveform.

LED Control

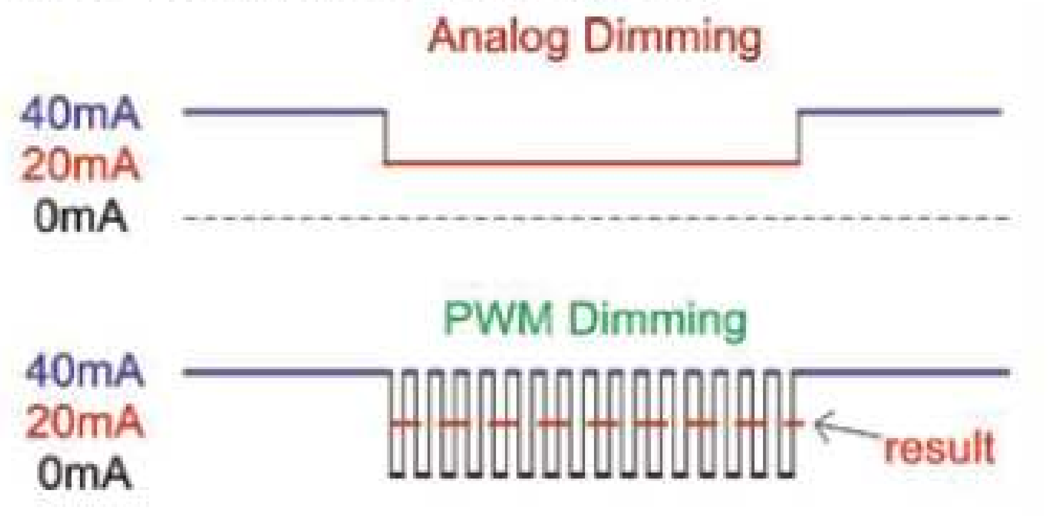


Adding Control systems will have the effect of reducing the overall driver efficiency

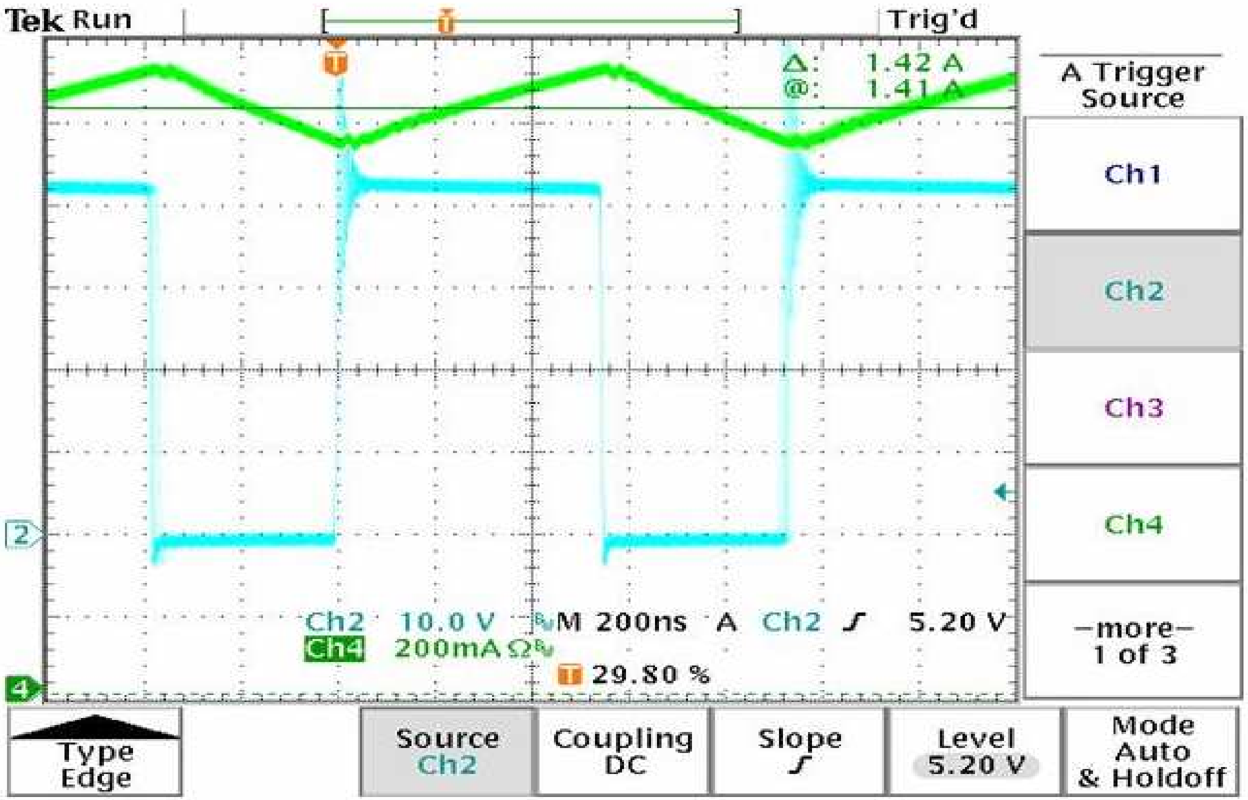
LED Brightness Control- Why Pulse Width Modulation?

- From the driver IC perspective, analog dimming presents a serious challenge to the output current accuracy. Almost every LED driver uses a resistor of some type in series with the output to sense current. The current-sense voltage, *VSNS*, is selected as a compromise to maintain low power dissipation while keeping a high signal-to-noise ratio (SNR). Tolerances, offsets, and delays in the driver introduce an error that remains relatively fixed. To reduce output current in a closed-loop system, *VSNS*, must be reduced. That in turn reduces the output current accuracy and ultimately the output current cannot be specified, controlled, or guaranteed. In general, dimming with PWM (Pulse Width Modulation) allows more accurate, linear control over the light output down to much lower levels than analog dimming.

Figure 1. Analog vs. PWM Dimming



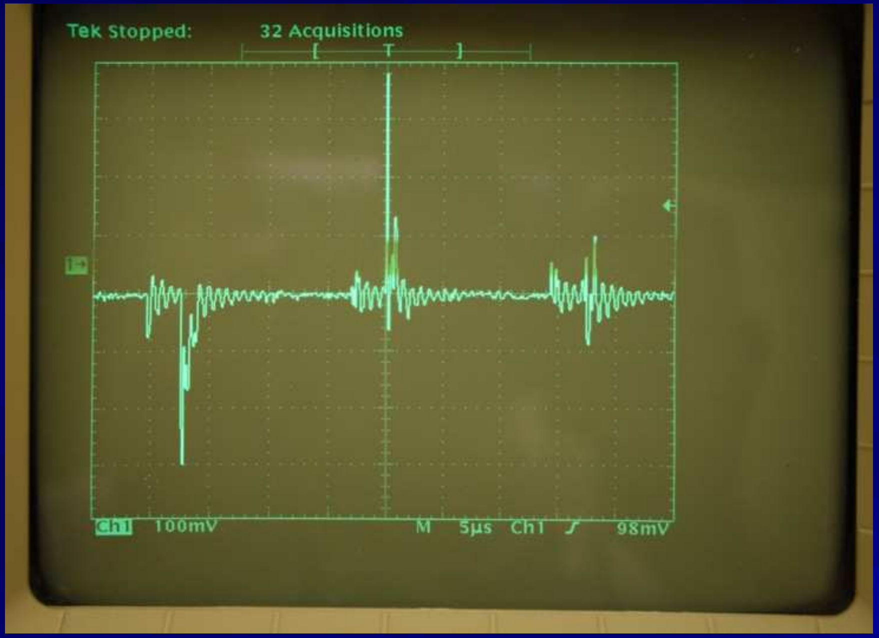
LED Driver Output



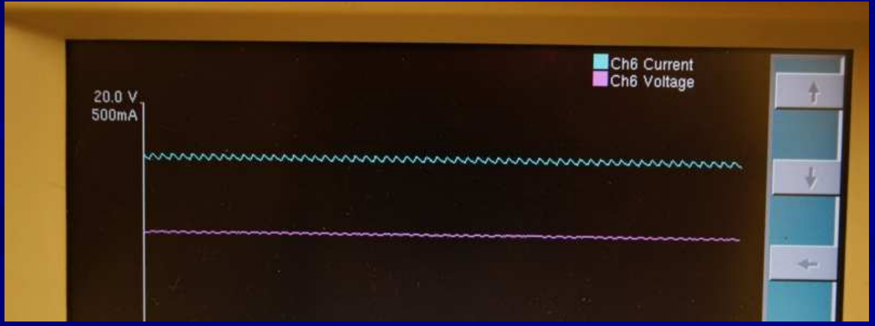
Ch2 is the main switching voltage waveform on the LX pin. Ch4 is the HB-LED current.

The pulse width modulation (CH2) will produce a AC ripple current through the LED String at the switching frequency (CH4) .In general higher switching Frequencies improve driver efficiency

LED Driver Output Measurements



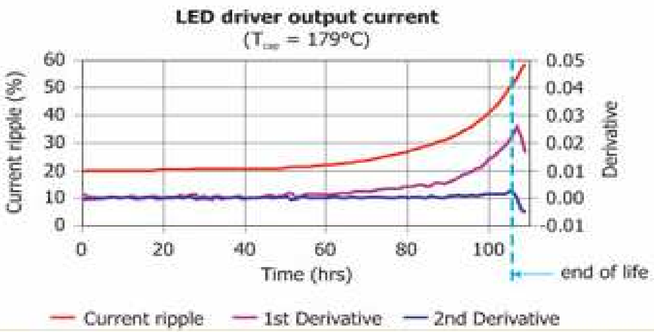
The driver output will have high frequency (30kHz) voltage transients produced by the PWM as seen on the Tektronix scope



These can be seen as ripple on the DC output current wave form as shown on the Voltech PM6000 Power analyzer which has a 5MHz sampling rate, there by measuring accurately the total output power of the LED driver

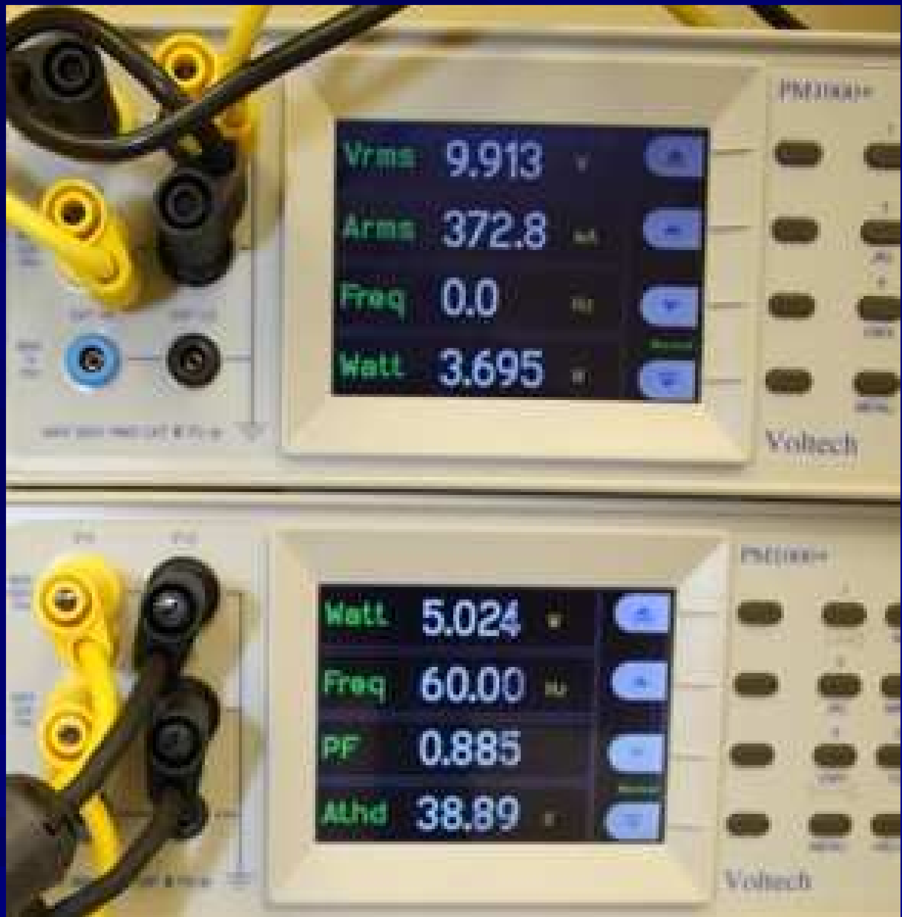
LED Driver Testing

An electrolytic capacitor.



Some LED Drivers use electrolytic capacitors on their outputs to reduce the AC ripple . However electrolytic capacitors have a defined life. It has shown that by measuring the percentage of ripple on this output is a good indication of the life of the product .

LED Driver Measurements



Typical Output measurements

Using a Voltech PM1000+

DC Volts 9.913 RMS

DC current 372.8 mA

Watts 3.695 W

Typical Input measurements

Watts 5.024 W

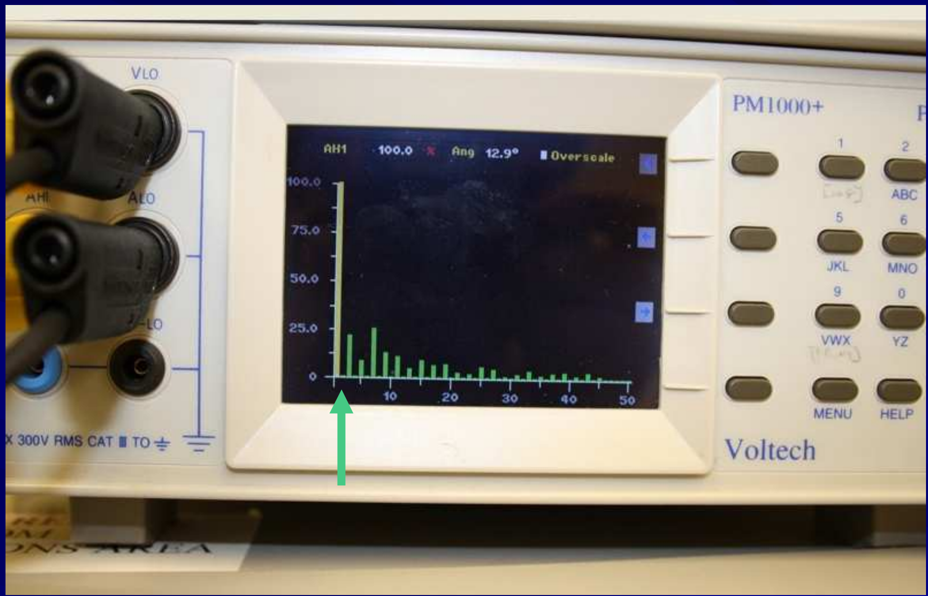
Frequency 60.00Hz

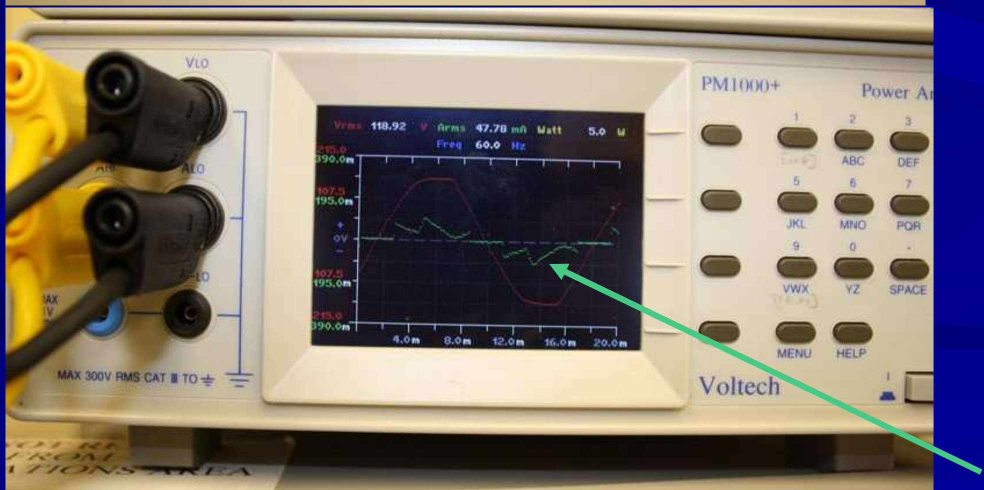
Power factor 0.885

Current distortion 38.89% ATHD

Calculated Efficiency of this Driver = 3.695/5.024 = 73.55%

LED Driver Measurements





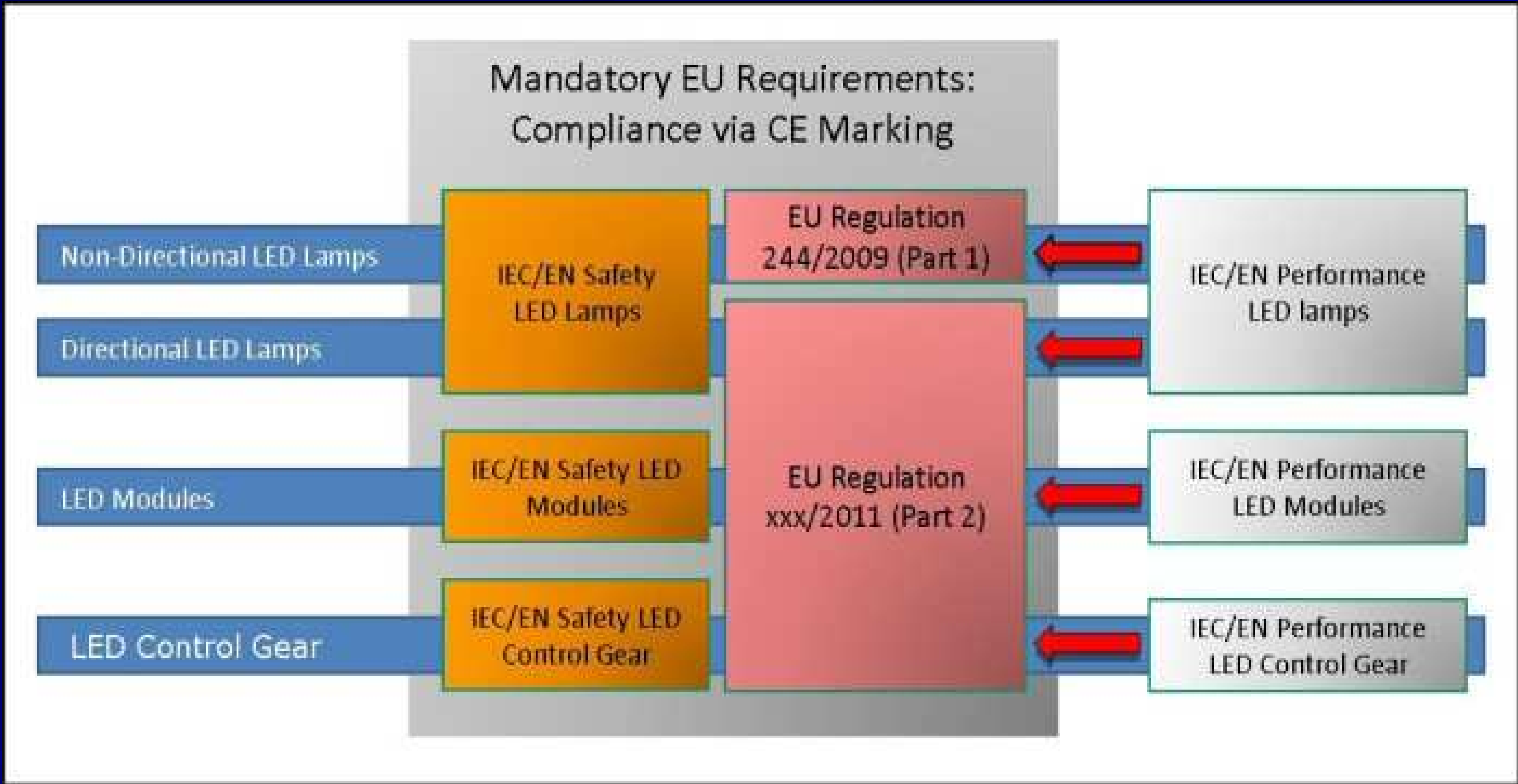
The Mains Input current Harmonics can be measured individually as an absolute value or as a percentage of fundamental as shown here on the Voltech PM1000+Power Analyzer.

Note the harmonic spread of this driver is typical .

Also Input measurements of Watts , Current, Voltage, Frequency and “scope” waveforms of Voltage , Current and Power can be displayed in real time on the PM1000+

Note the non linear current waveform (Green) is the cause of the Harmonics

Evolving Standards for LEDs



- *Current and future EU Regulations (parts 1 and 2), in combination with safety standards, specify mandatory requirements for LED products placed on the EU market, guided by performance standards. Source: ELC/CELMA/P.Besting.*

European LED Standards

TABLE 1 list of standards related to LED products

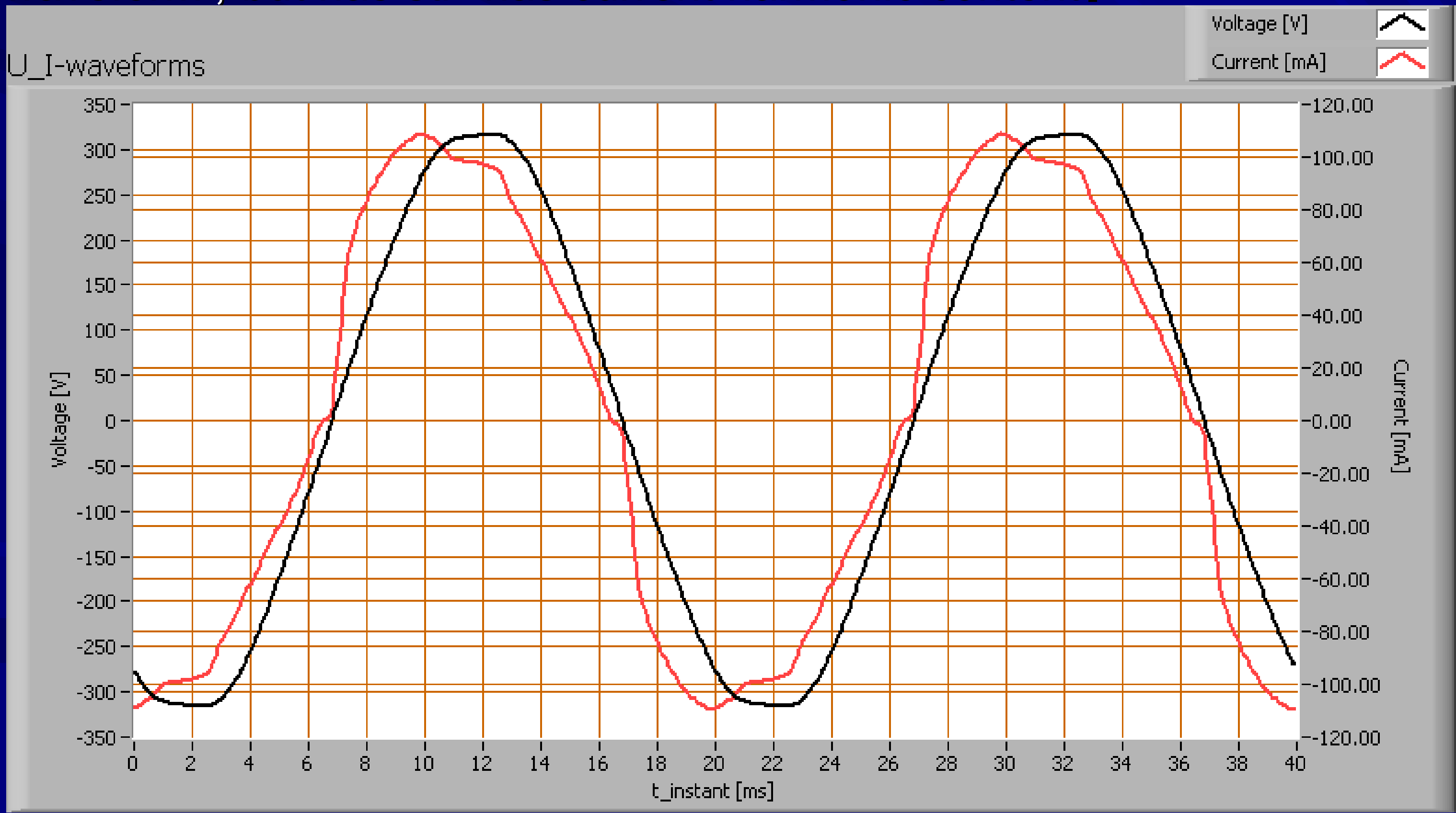
IEC/EN 60598	Luminaire requirements
IEC/EN 62031	LED Modules for General Lighting – Safety Specifications
IEC XXXXX	LED Module for General Lighting - Performance
Pr. IEC 62560	Lamps - Self-ballasted LED-lamps for general lighting services by voltage > 50 V - Safety specifications 34A/1354/CDV
Pr. IEC 62612	Lamps – Self-ballasted LED-lamps for general lighting services >50 V - Performance requirements 34A/1343/CD
IEC/TR 61341 ed. 2	Method of measurement of centre beam intensity and beam angle(s) of reflector lamps
IEC 61231	International lamp coding system (ILCOS)
Pr. IEC 62504	LED Terms & Definitions - 34A/1355/DTS
IEC/EN 60061	Lamp Caps and holders
IEC/EN 60838-2-2	Connectors for LED-modules
IEC/EN 61347-1	Lamp control gear - Part 1: General and safety requirements
IEC/EN 61347-2-13	Lamp control gear - Part 2-13: Particular requirements for d.c. or a.c. supplied electronic controlgear for LED modules
IEC/EN 62384 + A1	DC or AC supplied electronic control gear for LED modules - Performance requirements
IEC 62386-207	Digital addressable lighting interface - Part 207: Particular requirements for control gears; led modules (device type 6):
IEC/EN 60825-1	Safety of laser products (see Annex A)
IEC/EN 61000-3-2:	EMC - Limits for harmonic current emissions
IEC/EN 61000-3-3:	EMC - Limitation of voltage changes, voltage fluctuations and flicker
IEC/EN 61547:	EMC - Immunity requirements
EN 55015:	EMC - Radio disturbance characteristics
EN 62471: 2008 (IEC 62471:2006 modified) (CIE S 009:2002)	Photobiological safety of lamps and lamp systems (see Annex A to the Guide)
IEC TR 62471-2	Photobiological safety of lamps and lamp systems - Part 2: guidance on manufacturing requirements relating to non-laser optical radiation safety (see Annex A to the Guide)

Harmonic Standards

- IEC61000-3-2 Class C Mains Current Harmonic Limits. For European Markets
- ANSI C82.77-2002 Harmonic Emission Limits
- ANSI C82.XXX – LED Drivers For American Markets
  - Provides specifications/operating characteristics of electronic drivers (power supplies) for LED devices, arrays, or systems
  - Applies to drivers operating up to 600V and frequencies of 50 or 60 hertz as well as above 20 kHz

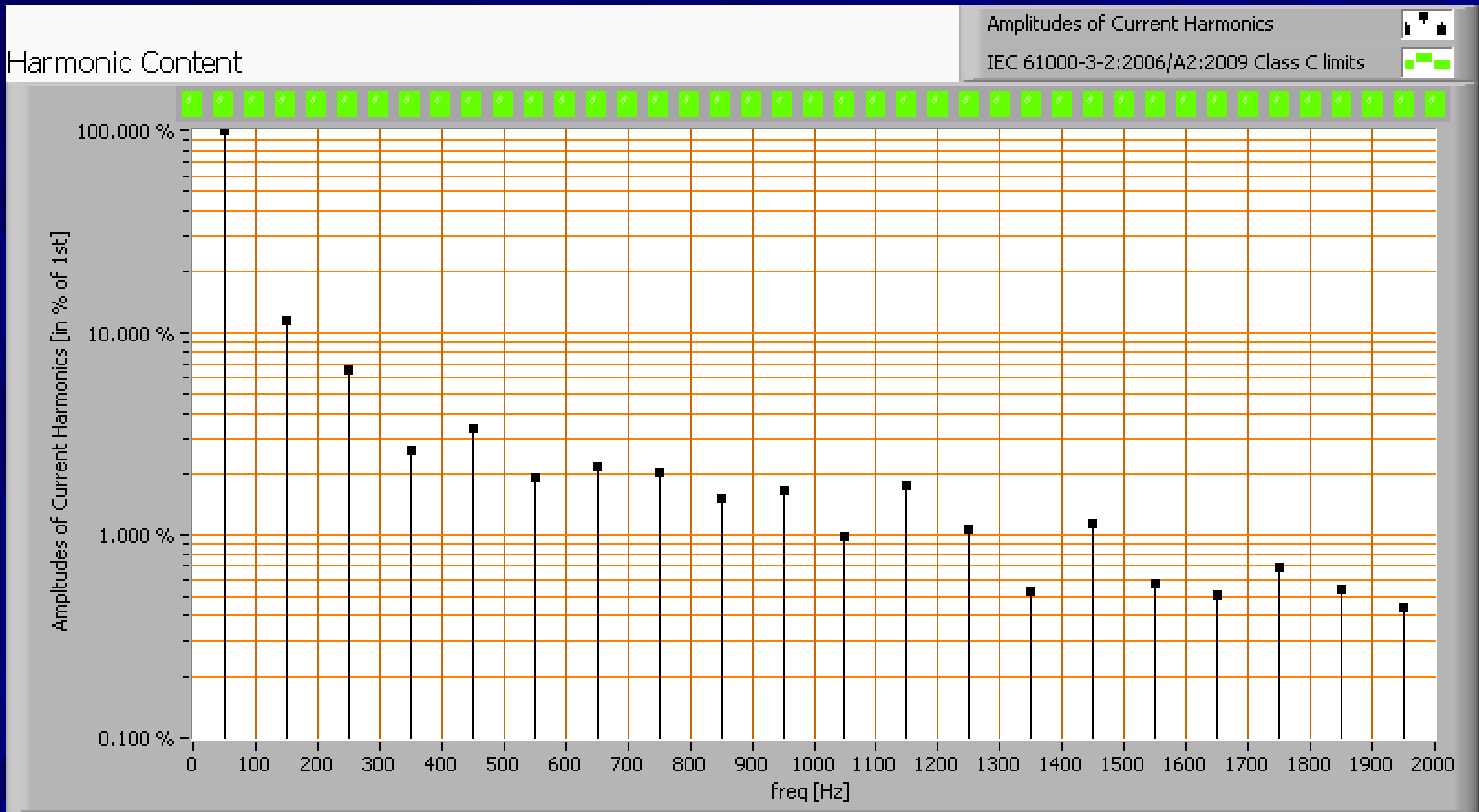
Harmonic Standards

- **EN61000-3-2 Class C .**
  - Shown here ,a 17 Watt LED Driver with Power Factor corrected Current waveform , but has still has current harmonic content.



Harmonic Standards

- EN61000-3-2 Class C
- Mains Current Harmonic Limits are % of Fundamental .
- LED Drivers are Rich in Harmonics



Limits are set for all 40 current harmonics The setting of the dimming device is varied in 5 equidistant steps between the minimum and the maximum power in order to obtain comprehensive results.

Harmonic Standards

- EN61000-3-2   Class C Mains Current Harmonic Limits are % of Fundamental .

Table 2. Limits for Class C Equipment

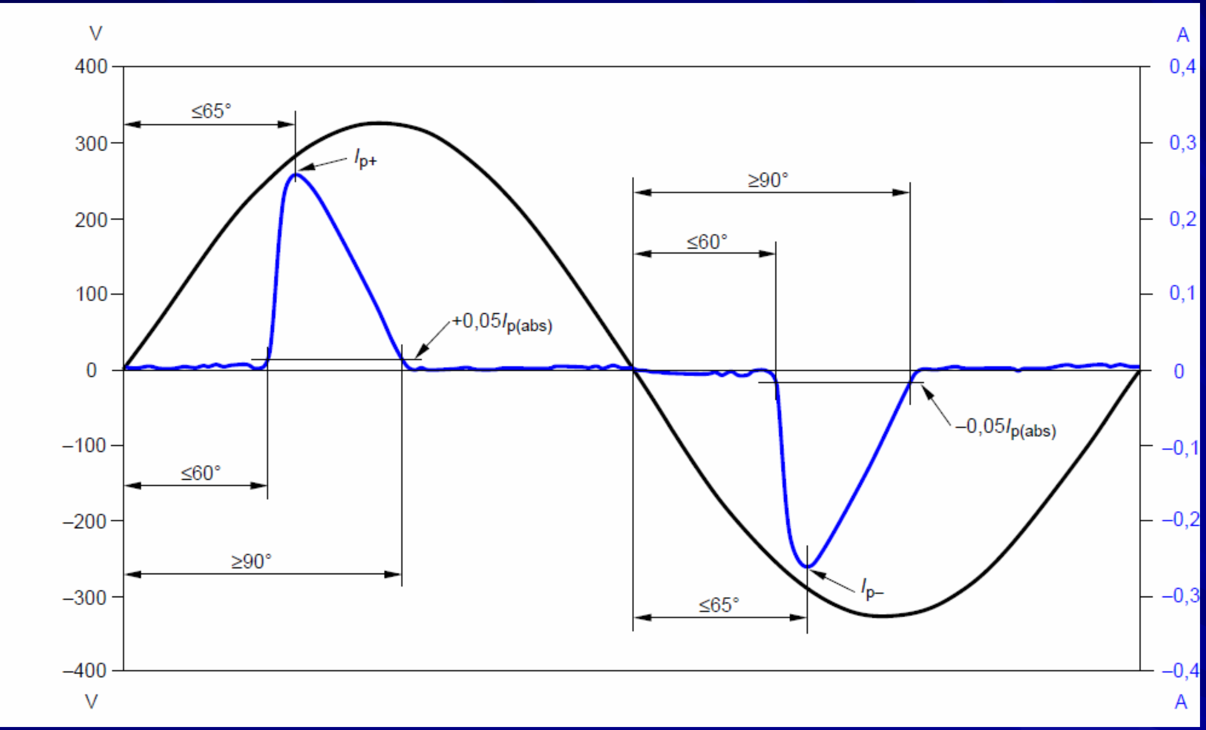
Harmonic order (n)	Maximum permissible harmonic current expressed as a percent of the input current at the fundamental frequency (%)
2	2
3	$30 \cdot \lambda^*$
5	10
7	7
9	5
$11 \le n \le 39$ (odd harmonics only)	3

* λ is the circuit power factor.

As said before Limits are set for all 40 current harmonics . Note the third Harmonic limit is altered by the Power factor measured ,so having a “good” PF of 1.00 is an advantage.

Harmonic Standards

- EN61000-3-2 Class C Waveform check.



Rules: The value of the current reaches 5 % of the max value latest at 60º and value of the current reaches its maximum latest at 65º

The value of the current is decreased to 5 % of its maximum value not before 90º : Applies to Active input power ≤25 W .The third harmonic current, expressed as a percentage of the fundamental current, shall not exceed 86 % and the fifth harmonic current shall not exceed 61 %.

Harmonic Standards USA

- ANSI C82.77,

  Most recently revised in 2002, it recommends that all commercial indoor, hard wired ballasts meet a minimum power factor of 0.9 with a maximum of 32% THD.

  (21Harmonics measured) Note at the time of the ANSI standard publication most discharge lighting hard wired ballasts were 28 Watts or greater. The cost of correcting the power factor at this wattage level to ANSI commercial limits was considered acceptable for hard wired electronic ballasts. ANSI C82.77 requires residential hard wired luminaries below 120 Watts meet a minimum power factor of 0.5 with a maximum of 200% THD.

  The ANSI standard acknowledges that low density installations do not have same impact on the VA load and require less power factor and harmonic content control.

- ANSI C82.77 has special allocations for specific applications such as task, down lighting and modular office furniture.
- For these applications ANSI recommends a minimum power factor of 0.5 with maximum THD of 32% for products below 50 Watts. This gives an allowance for ballasts that have an increased displacement factor. ***By granting this allowance ANSI has permitted lower cost power factor appropriate solutions to be used.***

European LED Efficiency Standards

- Light output is measured in Lumens (lm)
- Electrical power input is measured in Watts
- ELC and CELMA are providing input on quality requirements to the Commission as it prepares part 2 of the EcoDesign Regulations. The current EU Regulation 244/2009 (EcoDesign part 1) is restricted to non-directional lamps.
- The recommendation is to include LED modules in part 2, and to require efficacy >50 lm/W in 2012, increasing to >60 lm/W by 2015.

Standards - Efficiency

LEDs in Title 24 2008 Lighting

Luminaire Power Rating for LED Lighting	Minimum Luminaire Efficacy for LED Lighting
15 watts or less	40 lumens per watt
15 watts to 40 watts	50 lumens per watt
Over 40 watts	60 lumens per watt

Title 24 is a local Californian US Standard for Promoting Lower Power consumption in lighting systems

The Efficiency of the LED Driver System will improve as the total power increases because the power lost in the driver circuit remains nearly constant and independent of the power supplied the LEDs.

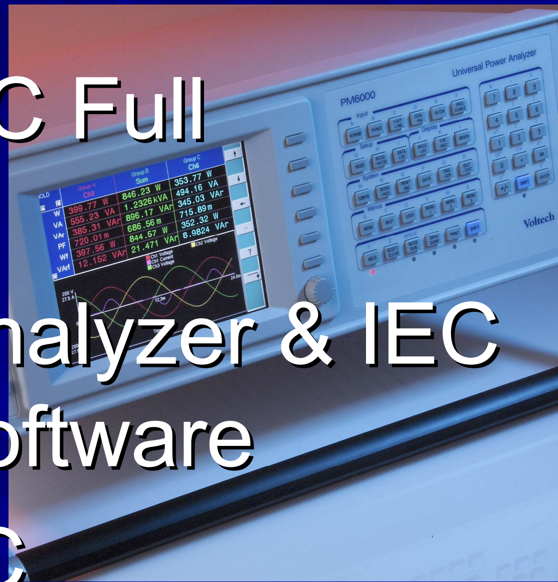
Safety Standards

- IEC SC 34C 62384 - DC or AC supplied electronic control gear for LED modules
- • IEC SC 34A - Performance Standard for LED Lamps
- • NEMA Premium SSL Standard (SSL-5)Tabled for the moment
- NEMA SSL-1 Power Supply
- IEC SC 34A 62031:2008 LED modules – Safety
- IEC SC 34C 61347-2-13:2006 - Lamp Control gear Part 2-13: DC or AC control gear for LED modules

- IEC SC 34A IEC 62560 Self-Ballasted LED Lamps
- IEC SC 34A <tbd> LED lamps > 50 V - Safety specs
- UL 8750 Standard for LED Equipment for Use in Lighting Products

Recommended Voltech Solutions

- LED IEC61000-3-2/3 Class C Full Compliance Testing
- Solution:- PM6000 Power Analyzer & IEC Network with Voltech IEC Software

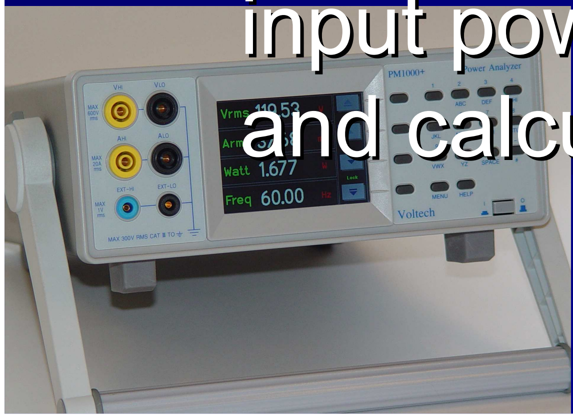


- LED IEC61000-3-2/3 class C Pre-Compliance Testing
- Solution PM1000+ and Pre-Compliance IEC Software.

Recommended Voltech Solutions

- Efficiency Measurements for 1 phase Input
- Solution (A) :- 2 channel PM6000 Power Analyzer with on board math Function or VPAS software
- Solution (B):- PM1000+ Power Analyzer .

  For Steady state conditions; measure input power and then the output power and calculate the efficiency .



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