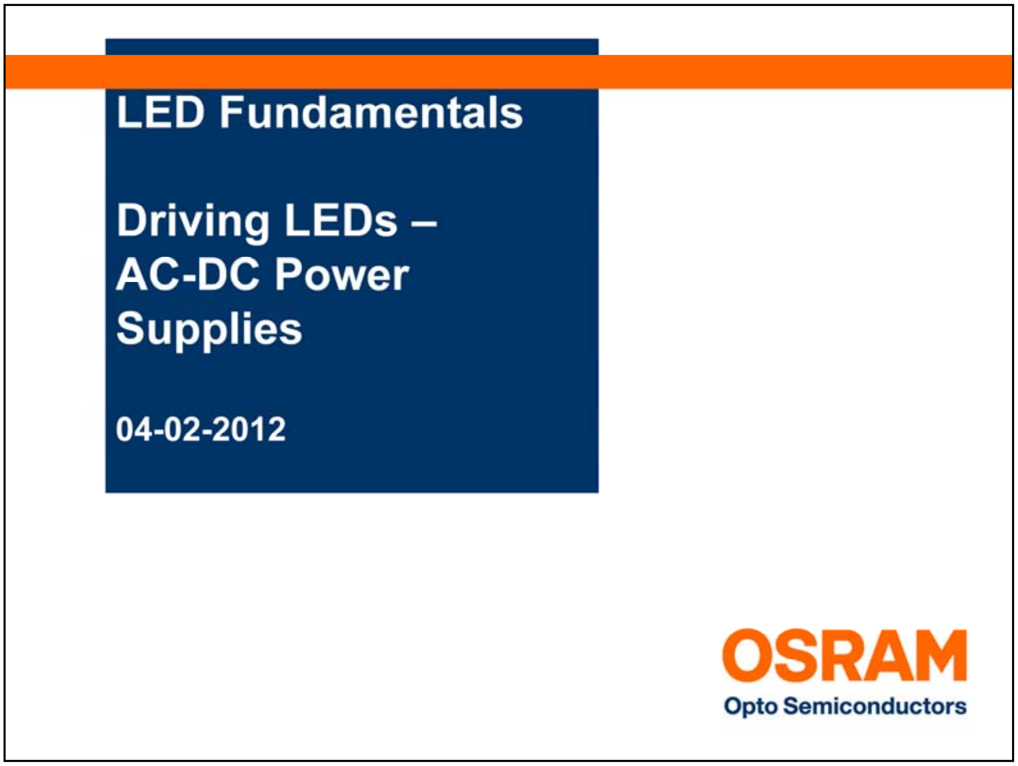


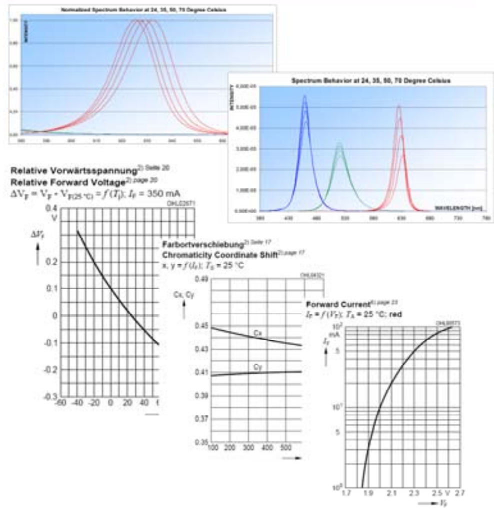
Welcome to this presentation on Driving LEDs – AC-DC Power Supplies, part of OSRAM Opto Semiconductors' LED Fundamentals series.

In this presentation we will look at:

- the typical circuit structure of AC-DC drivers
- the importance of TRIAC dimmability
- some of the standards covering drivers for LED systems

Introduction

- Proper driving of LEDs is required to address some of the fundamental variations that all LEDs may have due to manufacturing tolerances.
- There are different methods that are used to drive LEDs. These methods can be very simple or complicated depending on the application.
- Some of the key parameters needed to choose proper driving include, expected Tj (Junction Temperature), expected Vf mismatch between LEDs, color accuracy needed at the system level and if dimming of LEDs is required.



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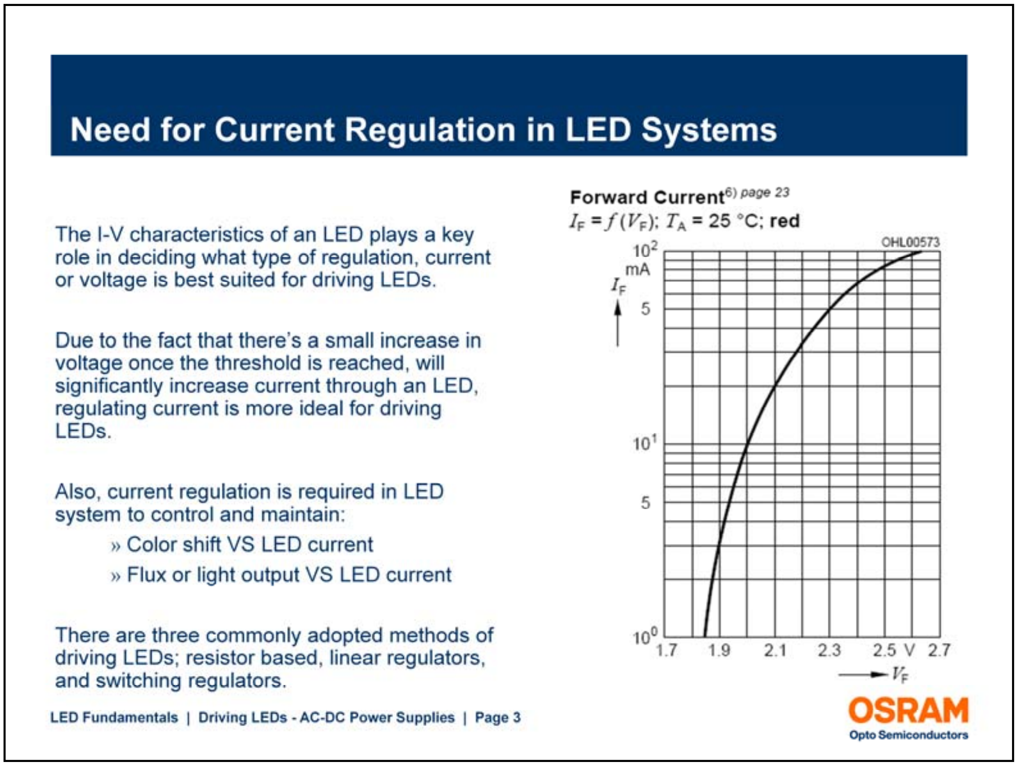
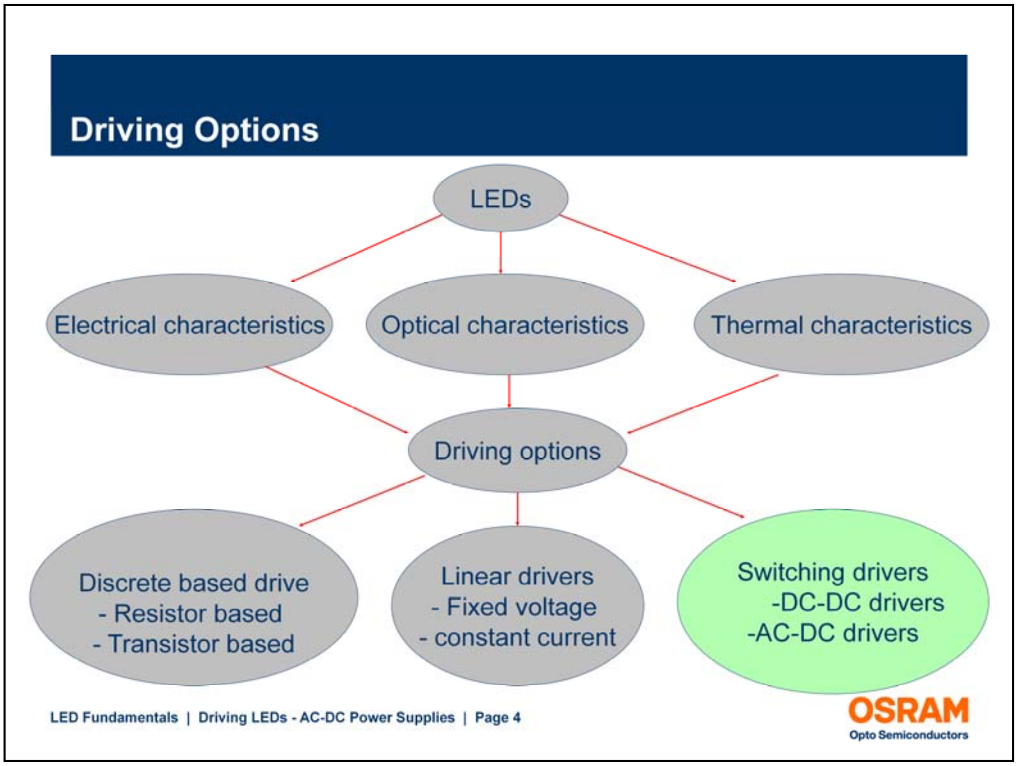
Just like any other electronic component, LEDs should be driven properly for improved efficacy, better reliability, and longer lifetime. Because of some of the fundamental variations, such as vf mismatch between LEDs and color variation within the same bin, even more care needs to be taken when deciding what type of driving method is suitable for LEDs in a particular application.

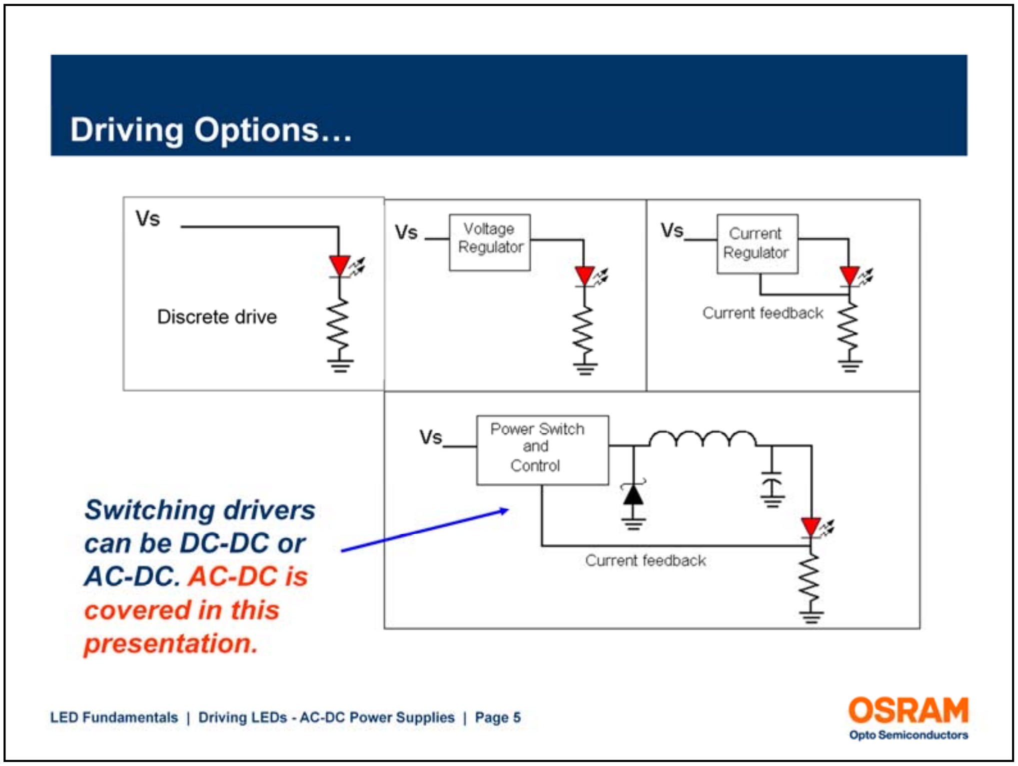
Some of the key parameters that play a major role in selecting a proper driving method are: expected junction temperature of the LED, expected Vf mismatch between LEDs and/or LED strings, color accuracy required, and whether dimming is required.



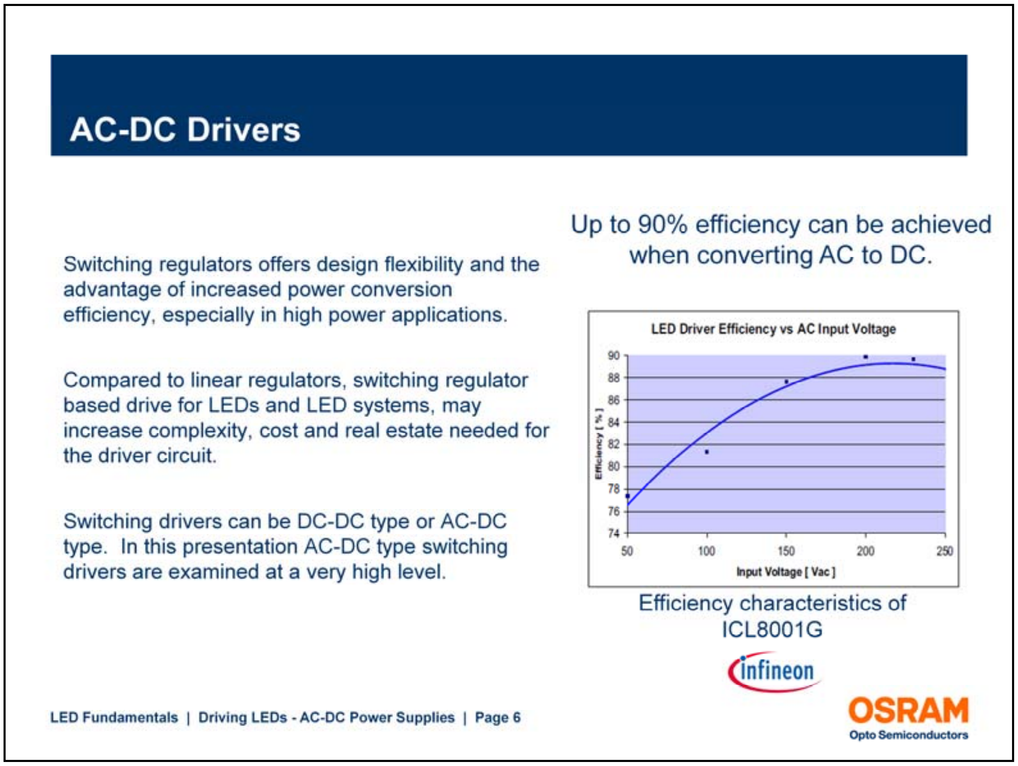
As mentioned earlier, understanding some of the electrical, optical, and thermal characteristics of an LED is required to properly select a driving method for an LED circuit or system. An I-V characteristic that is similar to standard diodes makes LEDs better driven with a constant current source. Also, optical characteristics such as color shift vs LED current and thermal characteristics such as Vf and color shift vs junction temperature of an LED, also play a key role in selecting a proper driving method.



When selecting a proper driving method for an LED application, just considering electrical characteristics of an LED is not sufficient. Electrical, optical, and thermal characteristics should be considered to select the appropriate driving method for an LED system. There are three commonly used methods of driving LEDs.



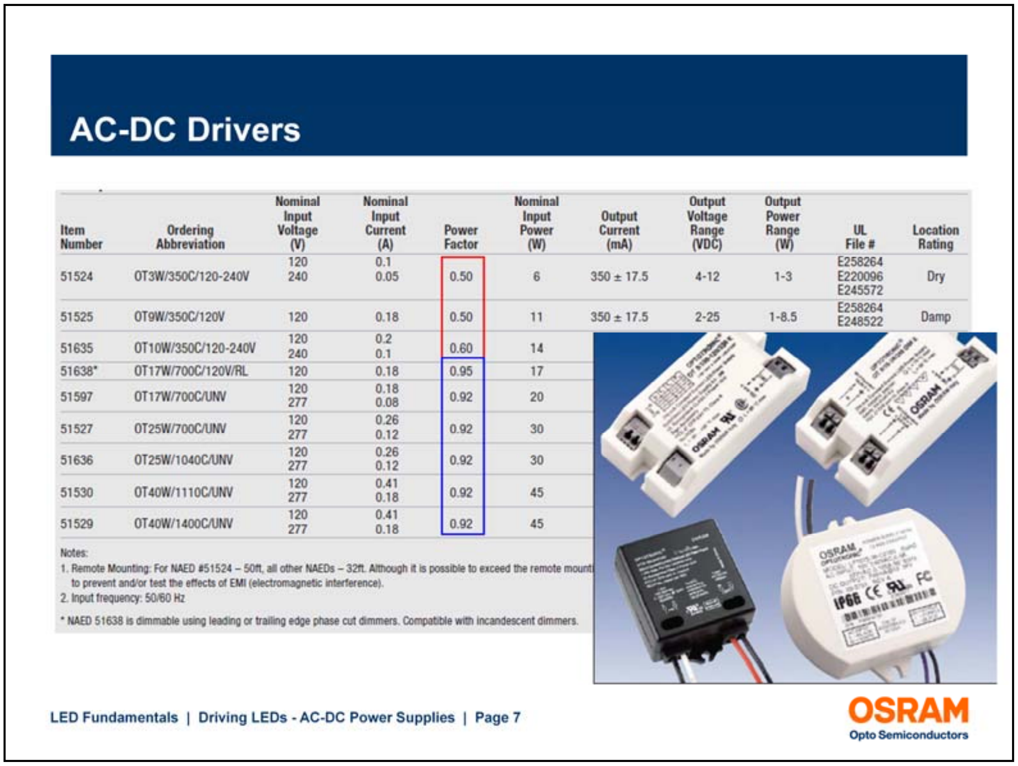
Resistor/discrete based driving, linear driver based driving, and switching driver based driving. This presentation covers switching driver based AC-DC driver/power supplies.



When it comes to LED systems, efficacy (lm/W) is one of the measures that makes LED systems more attractive when compared to traditional lighting systems. The efficacy of an LED system can be improved by optimizing electrical, thermal, and optical efficiencies of the overall system.

This presentation covers the optimized driver, one of the key areas that should be considered to improve electrical efficiency of an LED system.

Switching regulators offer flexibility in the design and the advantage of increased power conversion efficiency, especially in high power applications.



AC-DC Drivers

Item Number	Ordering Abbreviation	Nominal Input Voltage (V)	Nominal Input Current (A)	Power Factor	Nominal Input Power (W)	Output Current (mA)	Output Voltage Range (VDC)	Output Power Range (W)	UL File #	Location Rating
51524	OT3W/350C/120-240V	120 240	0.1 0.05	0.50	6	350 ± 17.5	4-12	1-3	E258264 E220096 E245572	Dry
51525	OT9W/350C/120V	120	0.18	0.50	11	350 ± 17.5	2-25	1-8.5	E258264 E248522	Damp
51635	OT10W/350C/120-240V	120 240	0.2 0.1	0.60	14					
51638*	OT17W/700C/120V/RL	120	0.18	0.95	17					
51597	OT17W/700C/UNV	120 277	0.18 0.08	0.92	20					
51527	OT25W/700C/UNV	120 277	0.26 0.12	0.92	30					
51636	OT25W/1040C/UNV	120 277	0.26 0.12	0.92	30					
51530	OT40W/1110C/UNV	120 277	0.41 0.18	0.92	45					
51529	OT40W/1400C/UNV	120 277	0.41 0.18	0.92	45					

Notes:
1. Remote Mounting: For NAED #51524 – 50ft, all other NAEDs – 32ft. Although it is possible to exceed the remote mount
to prevent and/or test the effects of EMI (electromagnetic interference).
2. Input frequency: 50/60 Hz

* NAED 51638 is dimmable using leading or trailing edge phase cut dimmers. Compatible with incandescent dimmers.

An AC-DC driver would take an AC voltage from the mains and convert it into either fixed DC voltage or constant DC current. A switching driver IC within an AC-DC driver, acts as the brain of the driver. For more information on switching drivers, please refer to LED Fundamentals **"Driving LEDs – Switching Drivers"**. The output of an AC-DC driver can be fixed voltage or constant current. Since LED circuits and systems are better operated with fixed current, constant current type AC-DC drivers are explained in this presentation. The intention of this presentation is to provide the viewer with the basic understanding of AC-DC drivers. Therefore, the information in this presentation is very basic in nature.

An AC-DC driver can have the following constructions:

1. An AC-DC Driver without Power Factor Correction (PFC)
2. An AC-DC driver with Power Factor Correction
3. An AC-DC driver can be TRIAC dimmable, non-dimmable, or dimmed by other means such as 0-10V dimming

Importance of Power Factor Correction (PFC)

Power Supplies

Power Supply Requirements	
Power Factor	Residential ≥ 0.70 Commercial ≥ 0.90
Minimum Operating Temperature	Power Supply shall have a minimum operating temperature of -20°C or below when used in luminaires intended for outdoor applications.
Maximum Measured Power Supply Case or Manufacturer Designated Temperature Measurement Point (TMP_{PS})Temperature	Not to exceed the power supply manufacturer maximum recommended case temperature or TMP when measured during in-situ operation. **Note:** This performance characteristic is separate and distinct from thermal requirements established by UL which governs safety rather than longevity of the power supply. All qualified luminaires are expected to meet this requirement, including linear, suspended, close-to-ceiling, IC, ICAT and Non-IC recessed canisters, etc. as well as those luminaires that may be exempt from UL1598.
Output Operating Frequency	≥ 120 Hz

ENERGY STAR® Program Requirements for Solid-State Lighting Luminaires

Eligibility Criteria – Version 1.1

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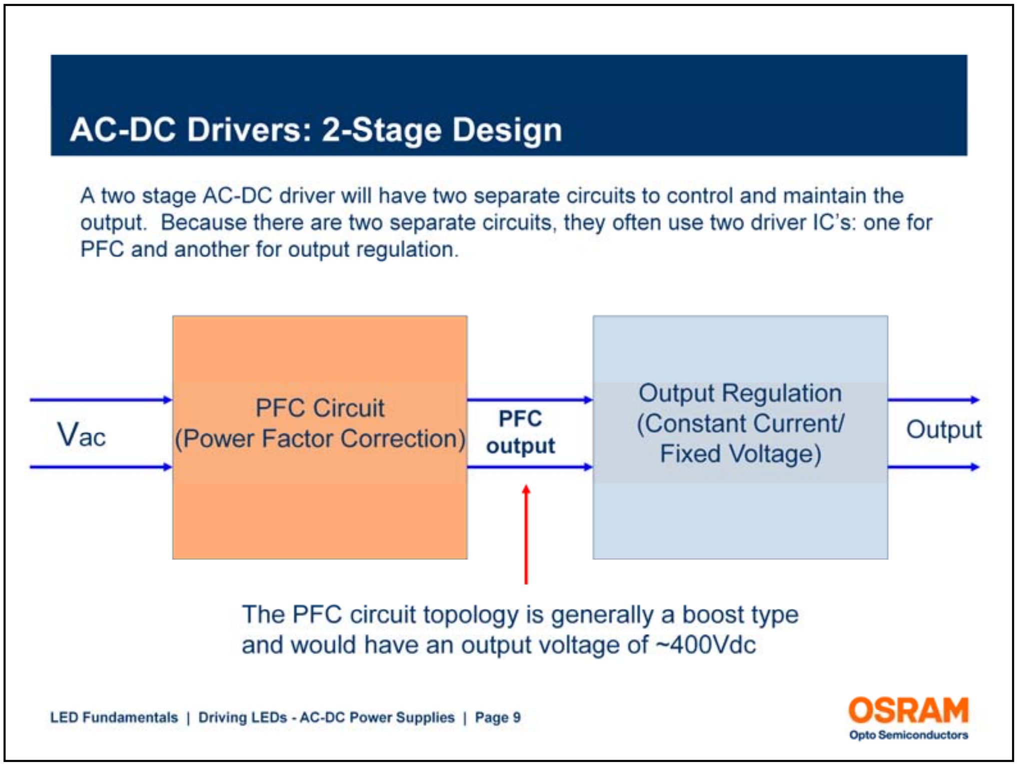
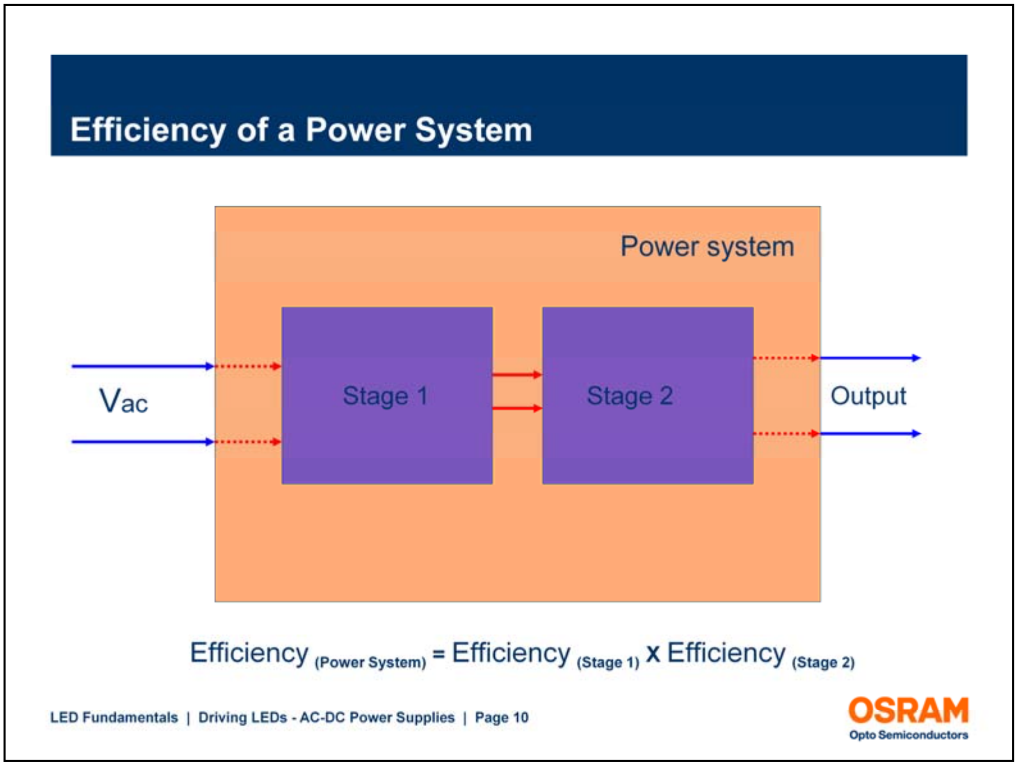
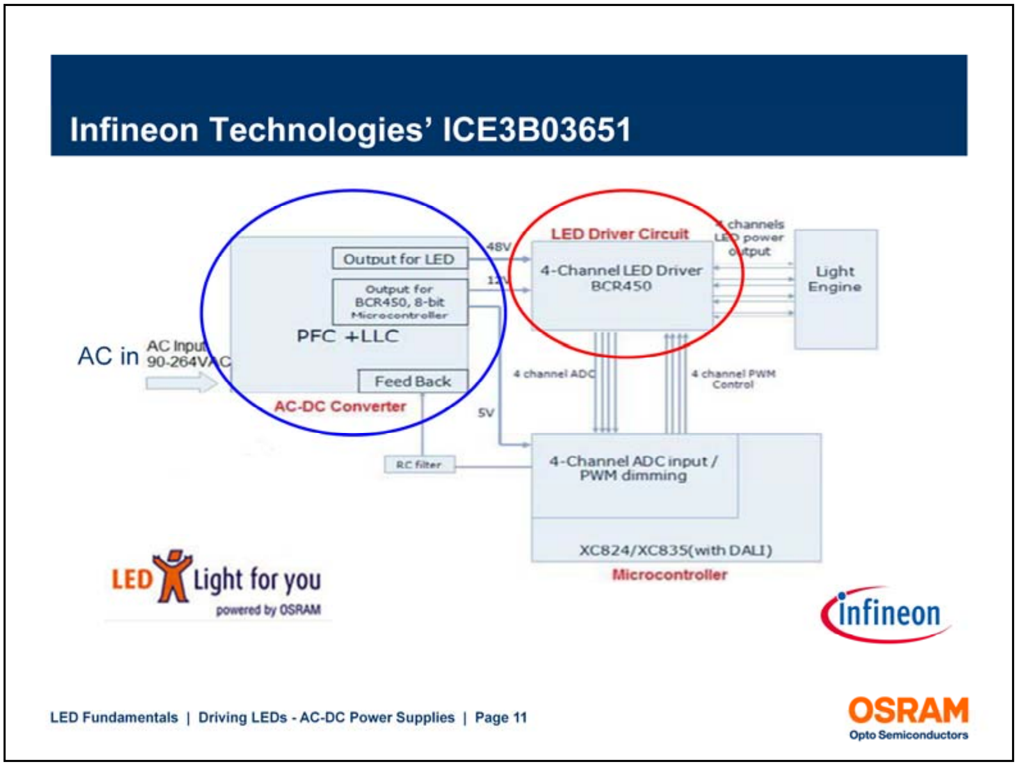
For regulatory reasons, such as Energy Star, a Power Factor of greater than .90 is required for commercial applications and a Power Factor of greater than .7 is required for residential applications. For more information on Power Factor, please consult the application guide **"Power Factor Correction (PFC) Basics"** on the Tools tab under Technical Papers and Presentations on this website.



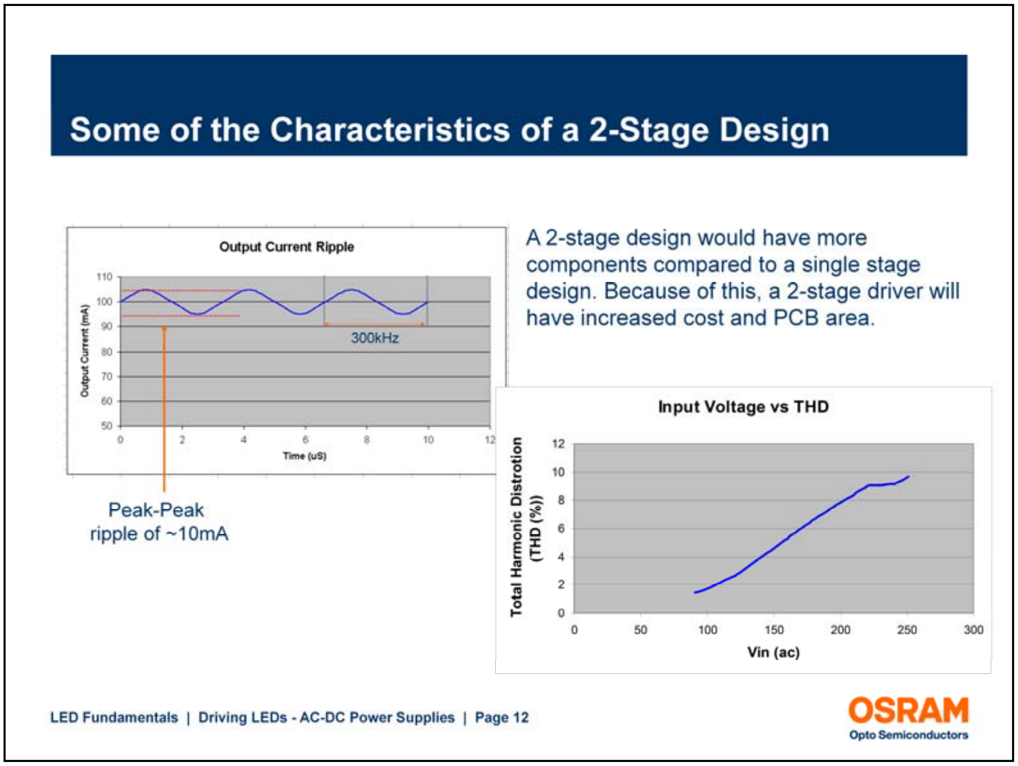
There are two widely used configurations of AC-DC drivers. The first is called a "2-stage" design, in which there are two sets of circuits used to regulate output. The PFC circuit is the first part of the circuit. This circuit generally employs a boost type topology and would have a fixed DC voltage output. The second part of the circuit is generally a buck type topology to convert the PFC output of ~400Vdc into fixed voltage or constant current. For more information on boost or buck topologies, please refer to LED Fundamental **"Driving LEDs – Switching Drivers".** The second widely used configuration is called single stage design, in which both stages of a 2-stage design are combined.



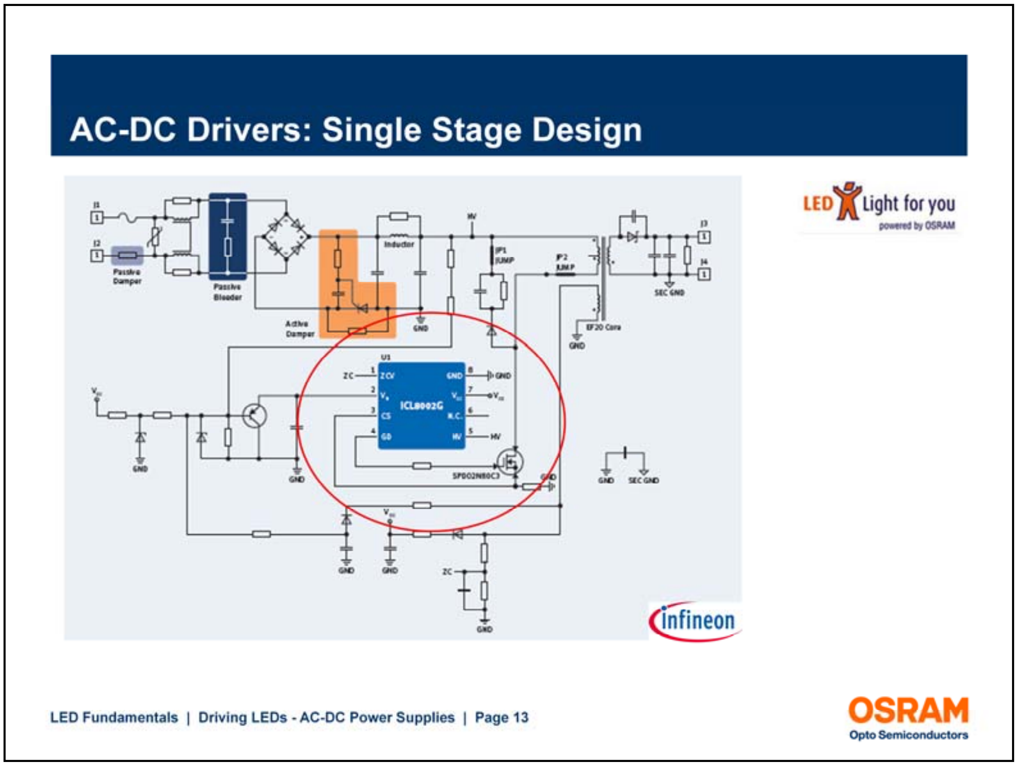
Efficiency of an overall power system, in this case an AC-DC driver, is highly dependant on the number of stages for the overall system. This is due to the fact that the overall efficiency, is the product of all the stages. The higher the number of stages, the lower the overall efficiency. For example, if stages 1 and 2 each has an efficiency of 90%, the overall system efficiency would only be 81%.



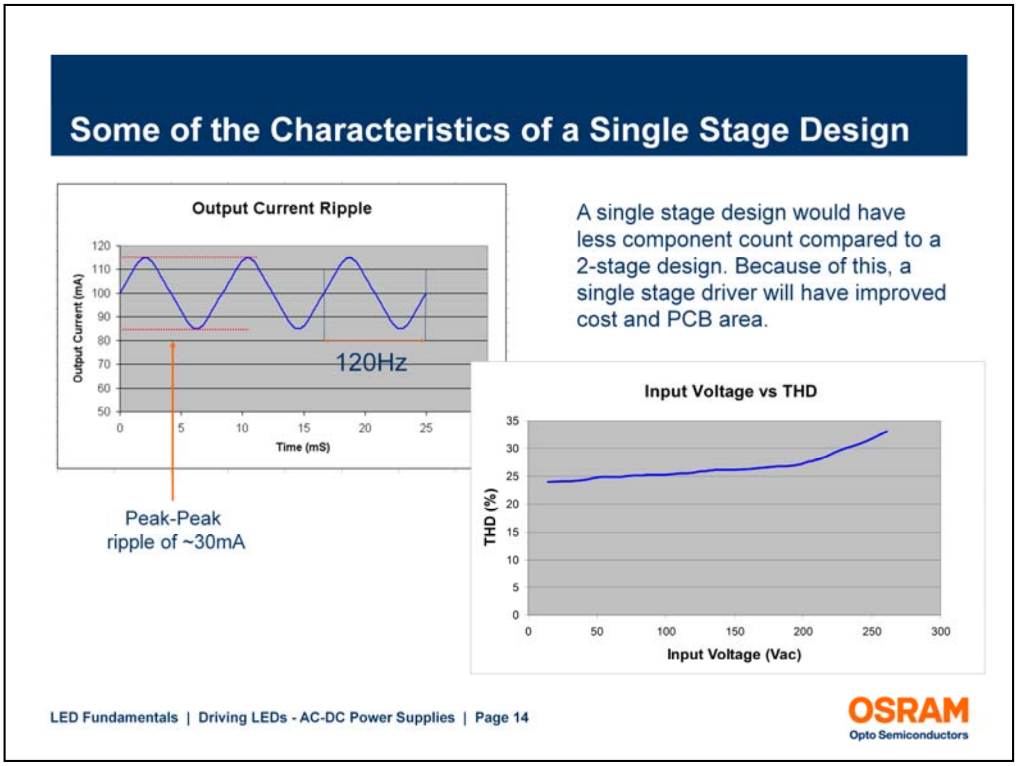
There are many driver IC's available on the market to design a 2-stage AC-DC driver. Shown in this slide is a block diagram of a 2-stage design from Infineon Technologies. The first stage is the AC to fixed DC voltage block with PFC. The second stage is the fixed DC to constant current conversion that is suitable to driver the LEDs. This stage can utilize a linear or switching driver. Infineon Technologies' BCR450 is one of the many drivers that are available in the market.



A two-stage AC-DC driver will have very low output ripple, generally in the range of 5-20%. The ripple frequency on a 2-stage design is equivalent to the switching frequency of the driver. Also, Total Harmonic Distortion (THD), can be kept below 15-20%. The Total Harmonic Distortion of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. One of the other advantages of a 2-stage design is that it exhibits better transient response compared to a single stage design. At a very high level view, any sudden change in a signal is regarded as transient. A better transient response from a system would ensure stable operation of the system due to transient events. As a draw back, a 2-stage design will cost more because of component count and PCB size.



In a single stage design, only one driver IC is used instead of two. Shown in this slide is Infineon Technologies' ICL8002G in single stage configuration. Compared to 2-stage design, a single stage design will have much lower component count.



A single stage AC-DC driver will have significantly higher output ripple, generally in the range of 20-50%. The ripple frequency on a single stage design is equivalent to two times the input voltage frequency. Also, Total Harmonic Distortion can be over 20%, which may not comply with some standards such as energy star. The advantages of a single stage design include more efficiency, lower cost, and reduced size.

Single Stage vs 2-Stage Design

This table compares 2-stage and single stage designs, if the specification for both were to be kept the same.

	Two-Stage Design	Single Stage Design
Efficiency	Good	Better
Component count	Higher	Lower
Output ripple	Lower (5-15%)	Higher (20-40%)
Transient response	Good	Poor
PCB area	Require more area	Less PCB area
Cost	Higher	Lower
THD	Lower (< 20%)	Higher (> 20%)

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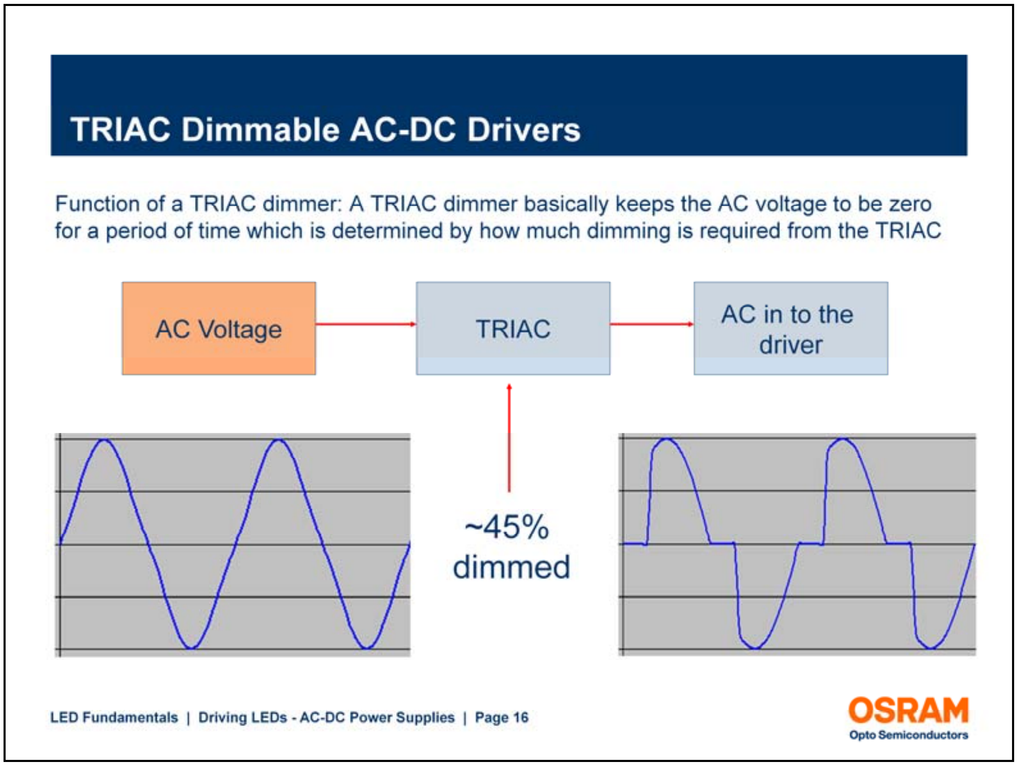
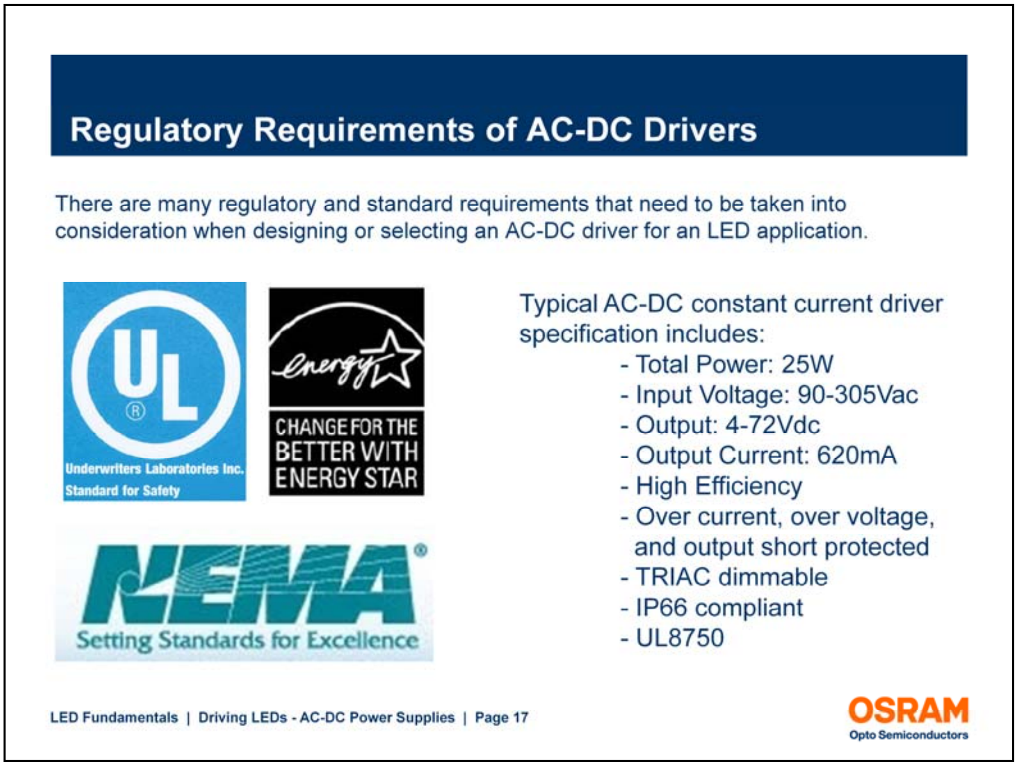
When designing or selecting a proper AC-DC driver for an LED circuit or system, it is always good to understand what type of design configuration is utilized with the AC-DC driver. Between the two commonly used designs of 2-stage and single stage, there are advantages and disadvantages of each design. A 2-stage design will have better output regulation with lower ripple, lower THD, and better transient response while a single stage design would offer better efficiency, lower cost, less PCB area for the driver, and less overall component count.



TRIAC dimming is widely accepted in the lighting industry for various reasons. When a traditional lighting source, such as incandescent or fluorescent, is replaced with an LED system, it is always expected that the TRIAC dimmer should work with the LED system as well. The function of a TRIAC is to chop the AC voltage and keep it at zero for a period of time that depends on the setting of the dimmer. When selecting an AC-DC driver for an LED system, be sure that the driver will operate with a TRIAC dimmer.



In many cases, an AC-DC driver designed for LED systems needs to be in compliance with some of the industry standards such as UL, NEMA, and Energy Star. The applicable standards depend on the application and geographical region. For more information on standards, please refer to Dr. Jianzhong Jiao's training videos "**LED and SSL Standardization Regulations"** on the Knowledge section of this website.

Summary

- AC-DC drivers can be single stage or 2-stage design.
- AC-DC drivers can be Power Factor Corrected or not.
- A TRIAC dimmable, Power Factor Corrected, AC-DC constant current driver is preferred for LED circuits and systems.
- AC-DC drivers should be in compliance with some of the standards, such as UL and Energy Star.
- When designing or selecting a proper AC-DC driver for an LED system, one has to consider what the target LED application is, in order to make an advised selection.

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In conclusion, there are two widely used designs of AC-DC drivers. One is the 2-stage design and the other is the single stage design. AC-DC drivers can be Power Factor corrected or not. For regulatory requirements, such as Energy Star, Power Factor correction in LED drivers are required. A driver with TRIAC compatibility is also expected as most of the traditional lighting sources are presently dimmed using TRIAC dimmers. To select the appropriate driver solution, a deep understanding of the application and its' requirements at system level is required.

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Please refer to the LED Fundamental **“Driving LEDs – Resistors and Linear Drivers”** on this website for additional information.

Thank you for viewing this presentation by OSRAM Opto Semiconductors.