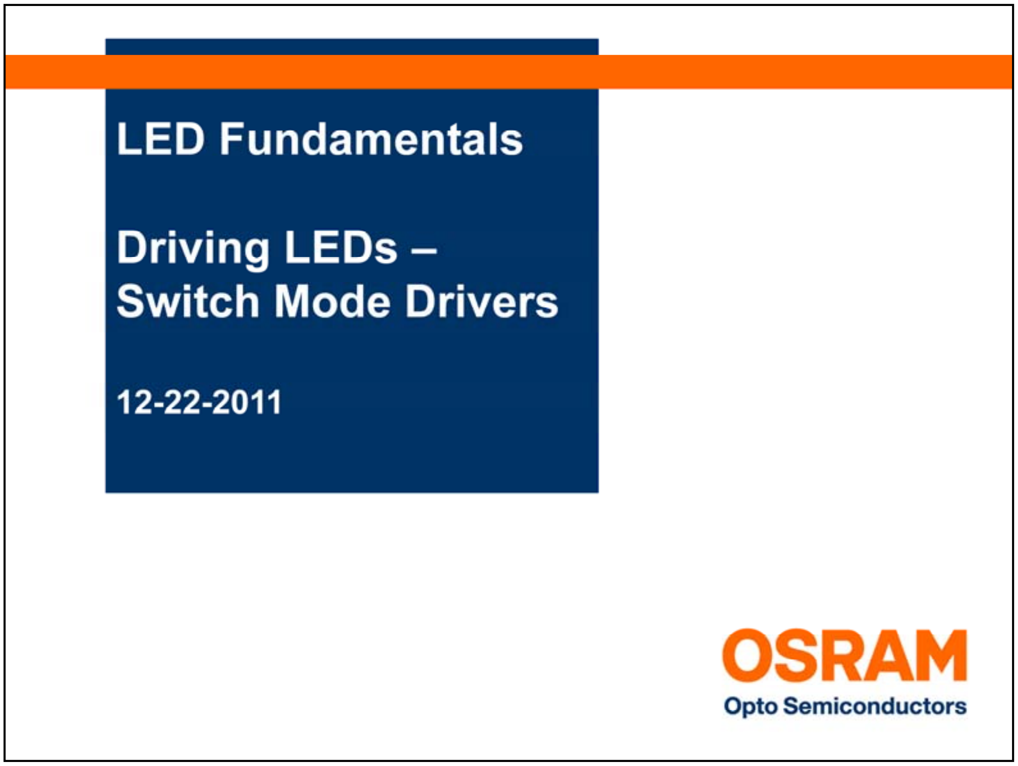
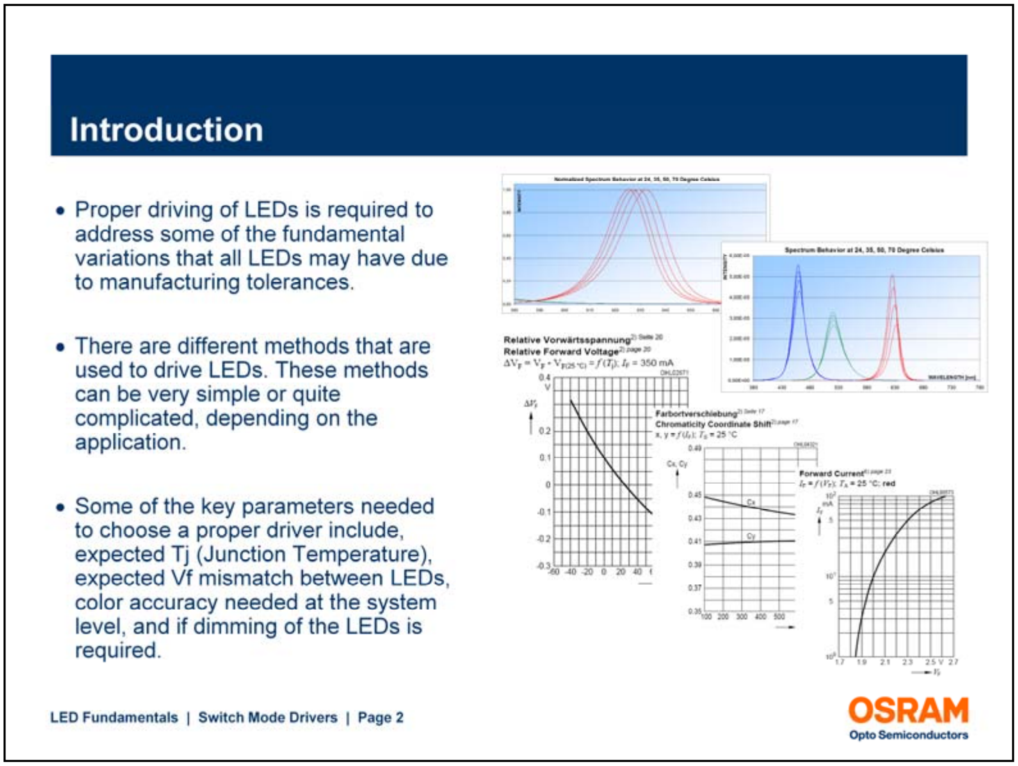


Welcome to this presentation on Switch Mode Drivers, part of OSRAM Opto Semiconductors‘ LED Fundamentals series.

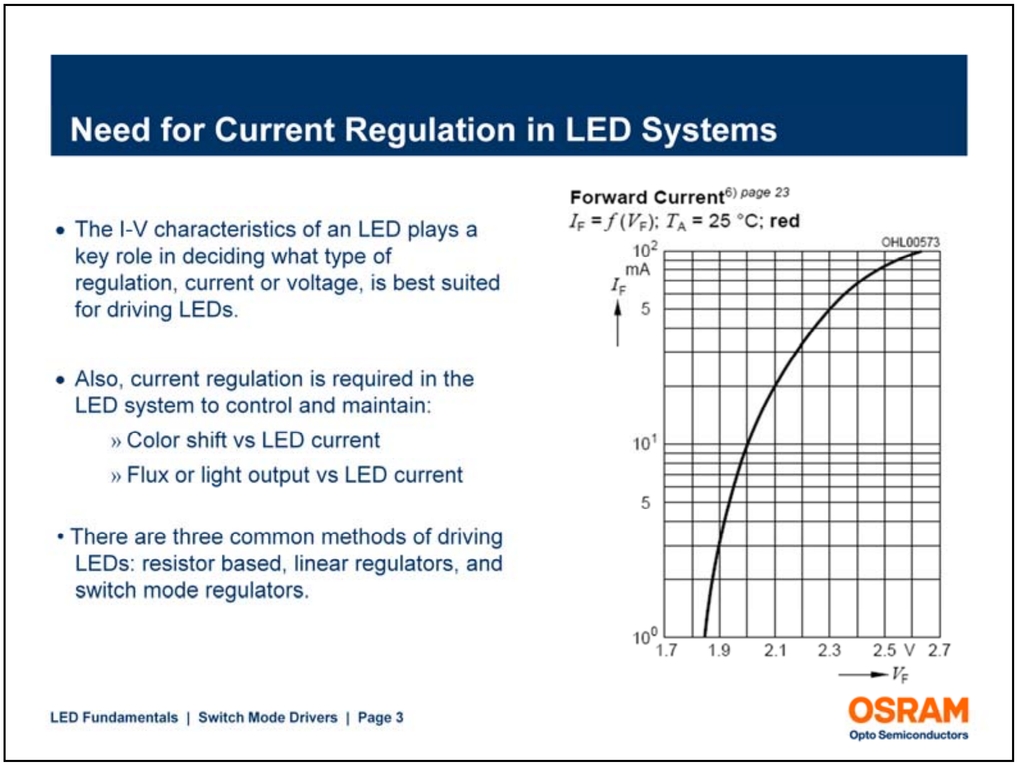
In this presentation we will look at:

How switch mode drivers work, switch mode driver topologies, and benefits of switch mode drivers in LED circuits and systems.

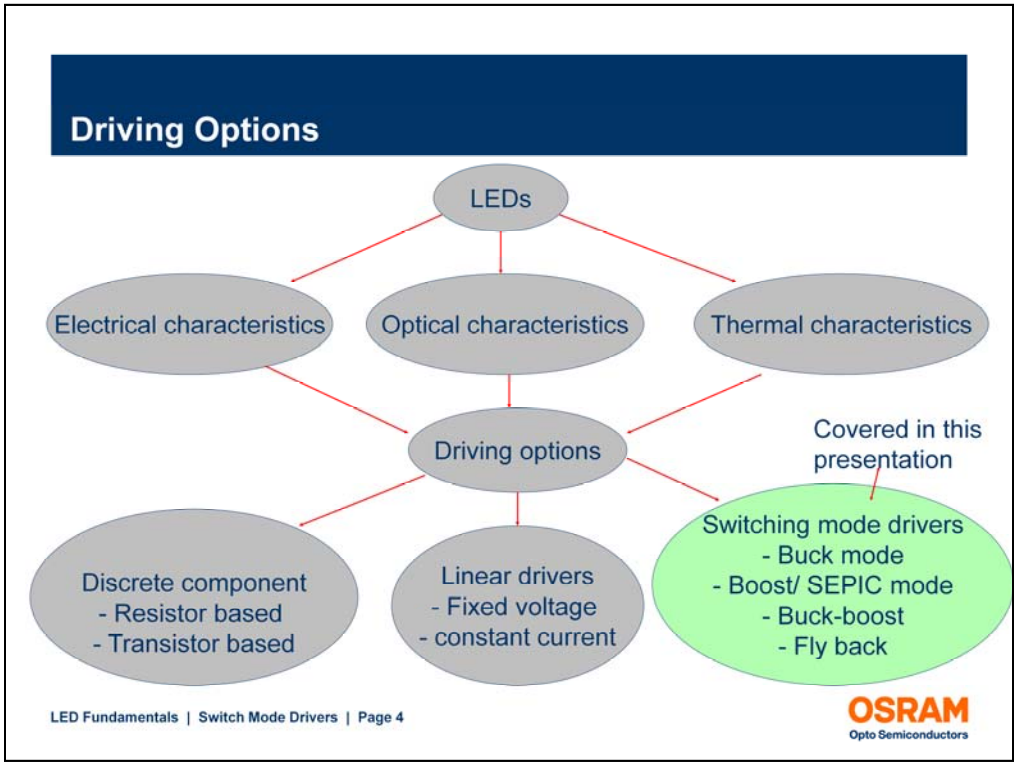


Like any electronic component, LEDs should also be driven properly for improved efficacy, better reliability, and longer lifetime. Because some of the fundamental variations, such as vf mismatch between LEDs and color variation within the same bin, more care needs to be taken when deciding what type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

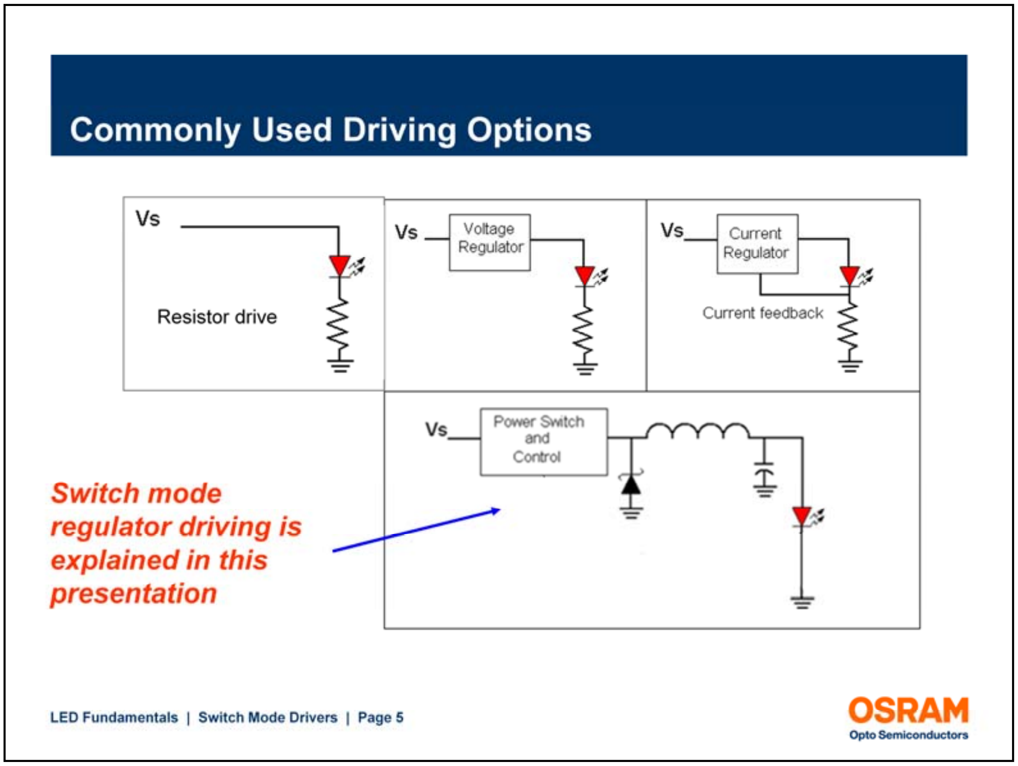
Some of the key parameters that play a major role in selecting the proper driving method are expected junction temperature of the LED, expected Vf mismatch between LEDs and/or LED strings, color accuracy required, and whether dimming is required.



As mentioned earlier, understanding the electrical, optical, and thermal characteristics of an LED is required to properly select the driving method for an LED circuit or system. An I-V characteristic of an LED is similar to that of a standard diode, meaning LEDs should be 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, play key roles in selecting the proper driving method.



When selecting the proper driving method for an LED application, only 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 typical methods for driving LEDs.



Commonly used driving options are: discrete component based drive, linear driver based drive, and switch mode driver based drive. This presentation covers switch mode driver based drive.

Advantages and Disadvantages of Each Driving Method

Before choosing a switch mode driver, refer to this table that outlines some of the advantages and disadvantages of each driving option.

	Discrete based drive Resistor/ Transistor	Linear Regulator	Switch Mode Regulator
Vf mismatch between LEDs addressed	NO/ YES	YES	YES
Vf change due to temperature addressed	NO/ YES	YES	YES
Source voltage variation addressed	NO/ YES	YES	YES
Tight current regulation	NO/ NO	YES	YES
Simple solution	YES/ YES	YES	NO
Costly solution	NO/ NO	YES (compared to resistor driver)	YES
Efficient solution	NO/ NO	NO	YES
Stable over wide-range of temperature	NO/ YES	YES	YES

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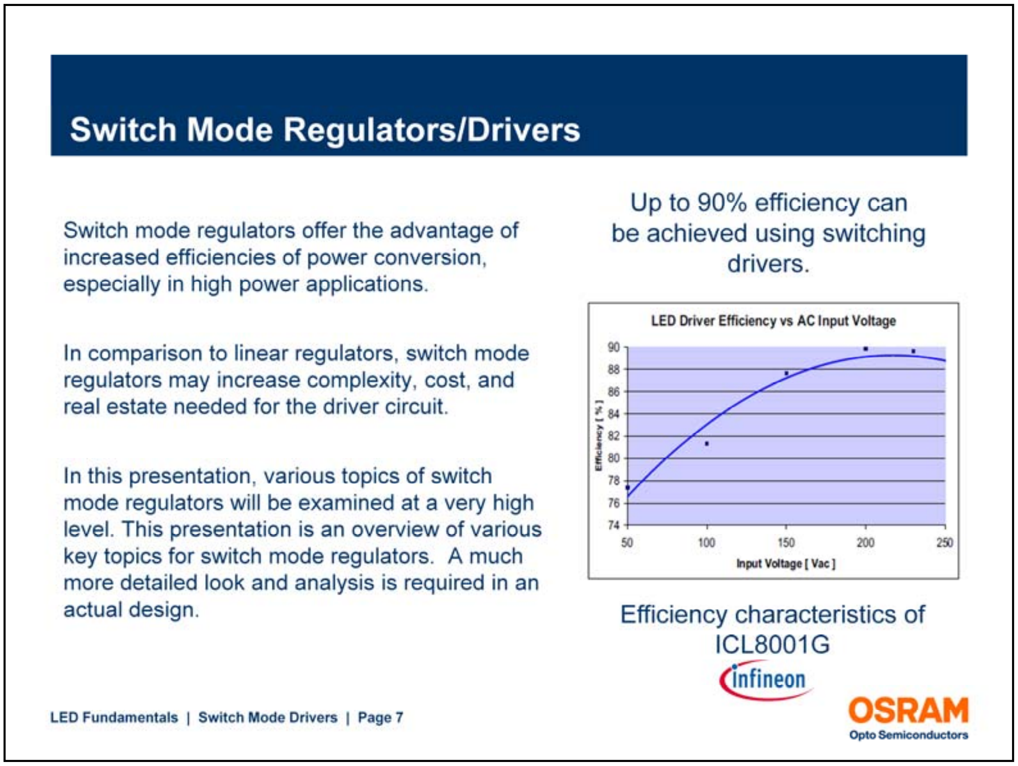
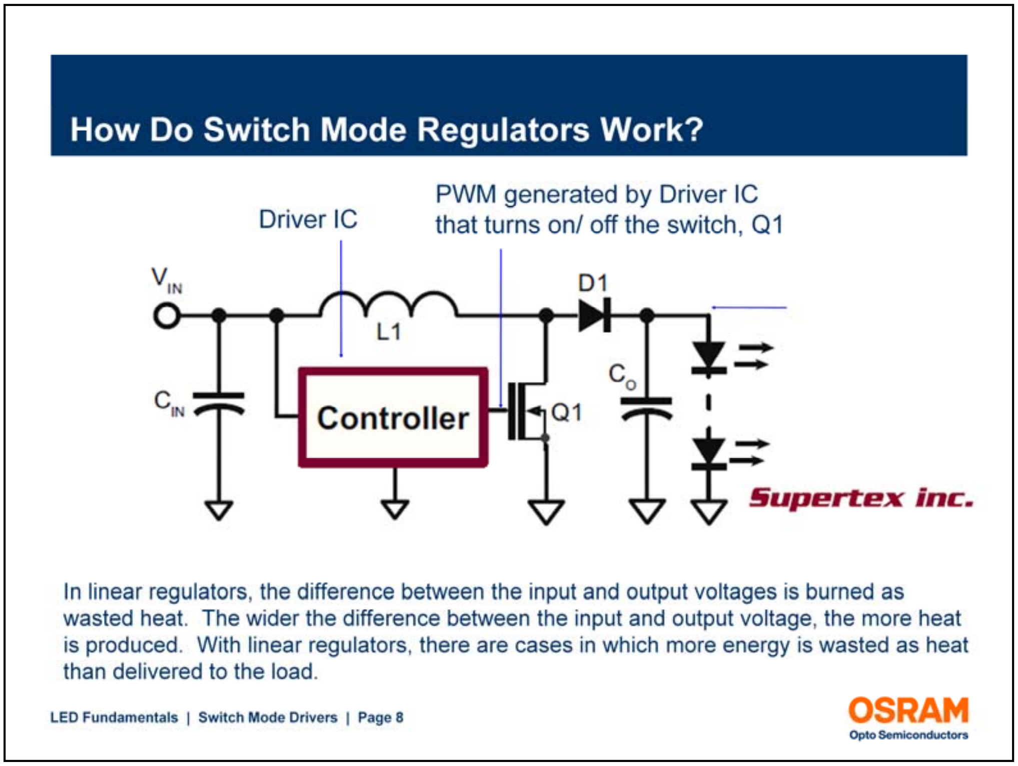
Before starting with a switch mode regulator, please take a look at the table on this slide to understand the advantages and disadvantages of each driving option. The biggest advantages of a discrete based drive are low cost and simplicity, where the major disadvantages of a switch mode based driver is the complexity of the design and the cost associated with it.



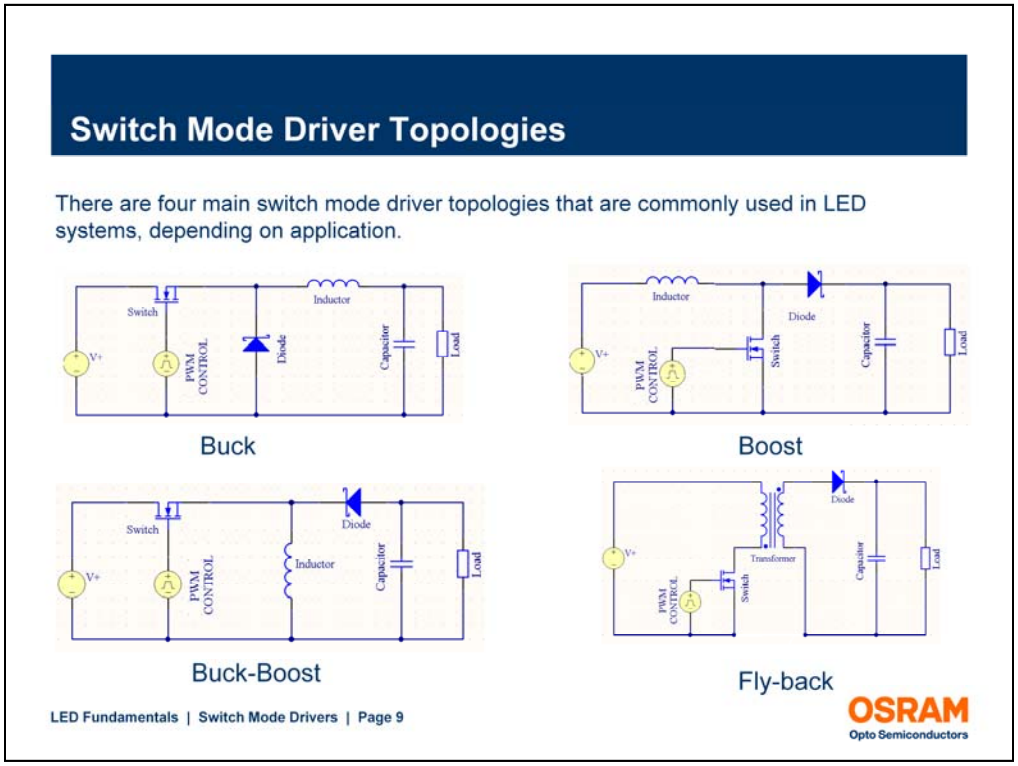
At present, when it comes to LED systems, efficacy (lm/W) is one of the key measures that make LED systems more attractive compared to traditional lighting systems. The efficacy of an LED system can be improved by optimizing electrical, thermal, and optical efficiencies of the overall system.

This presentation reviews how an optimized driver can be used to help improve the electrical efficiency of an LED system.

Switch mode regulators offer the advantage of more efficient power conversion, especially in high power applications.

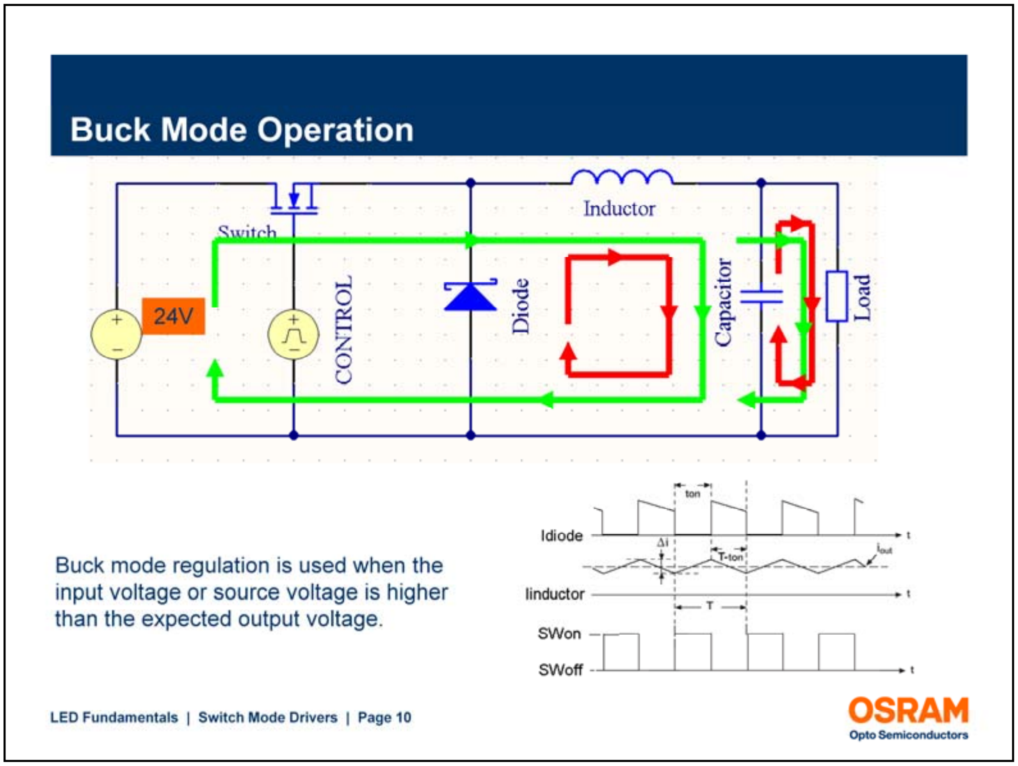


A switch mode regulator takes a small portion of energy at a time from the input voltage source and transfers it to the load or device being driven. An electrical switch, such as a transistor, is used along with a controller that regulates the rate at which the switch is turned on and off. In a switch mode driver, the driver IC is the brain of the power supply. Basically, it generates the PWM signal that turns the switch on and off so the output is maintained at a specified value.



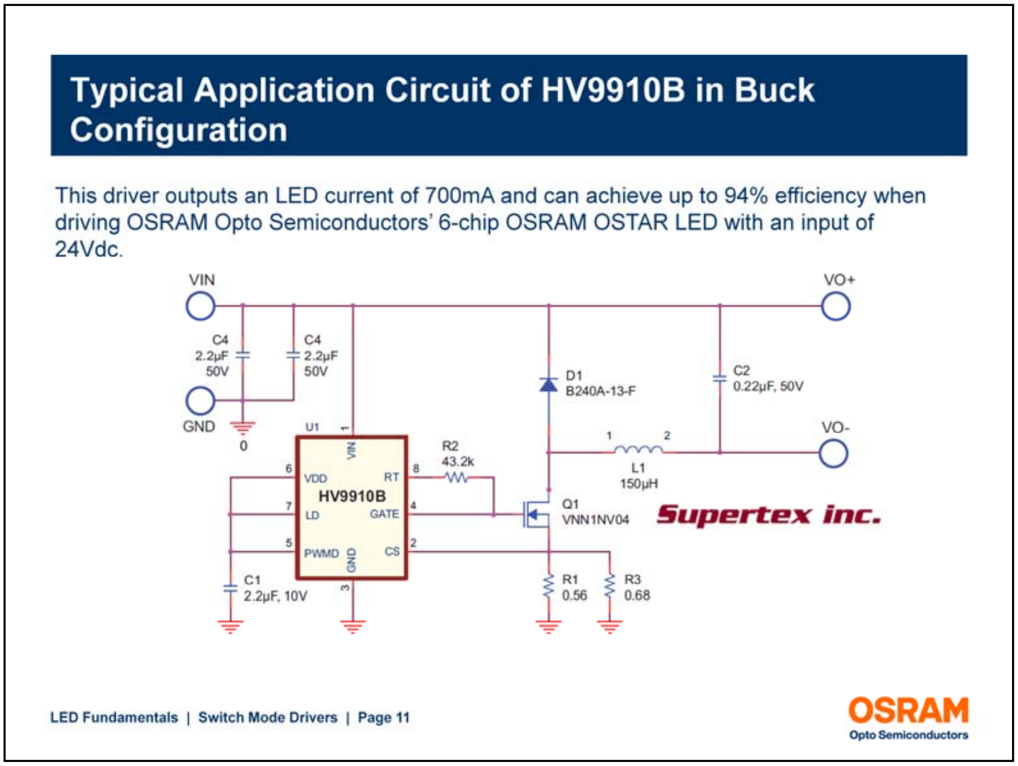
There are four different topologies in which a switch mode driver can be operated. They are buck mode, boost mode, buck-boost mode, and fly back mode.

Next we will analyze each topology in greater detail.



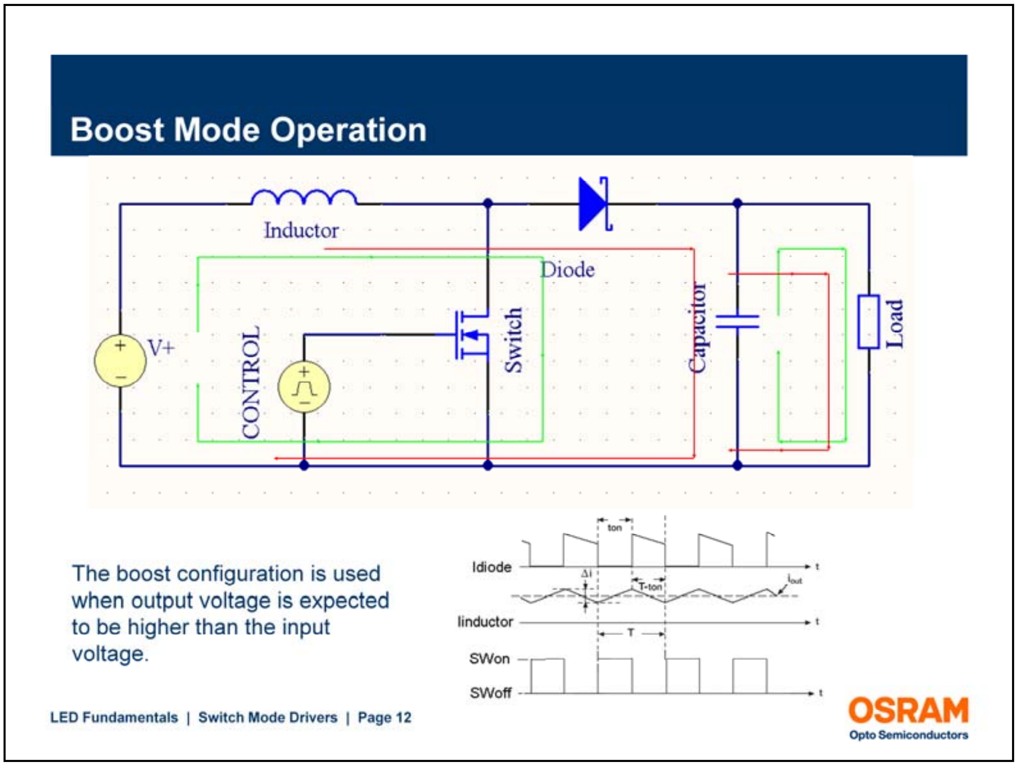
This example illustrates the simple circuit diagram of a buck type switch mode regulator design. The primary function of the driver IC is to generate the control signal which turns the switch on and off. When the switch is closed, there will be two current loops (shown in green). When the switch is open, current flows in the direction (shown in red).

Buck mode regulation is used when the input voltage or source voltage is higher than the expected output voltage. For instance, if a standard 24V supply is used to drive an LED system in which four 1W high power LEDs are connected in series, there needs to be a buck mode constant current driver in place to drive the LEDs.

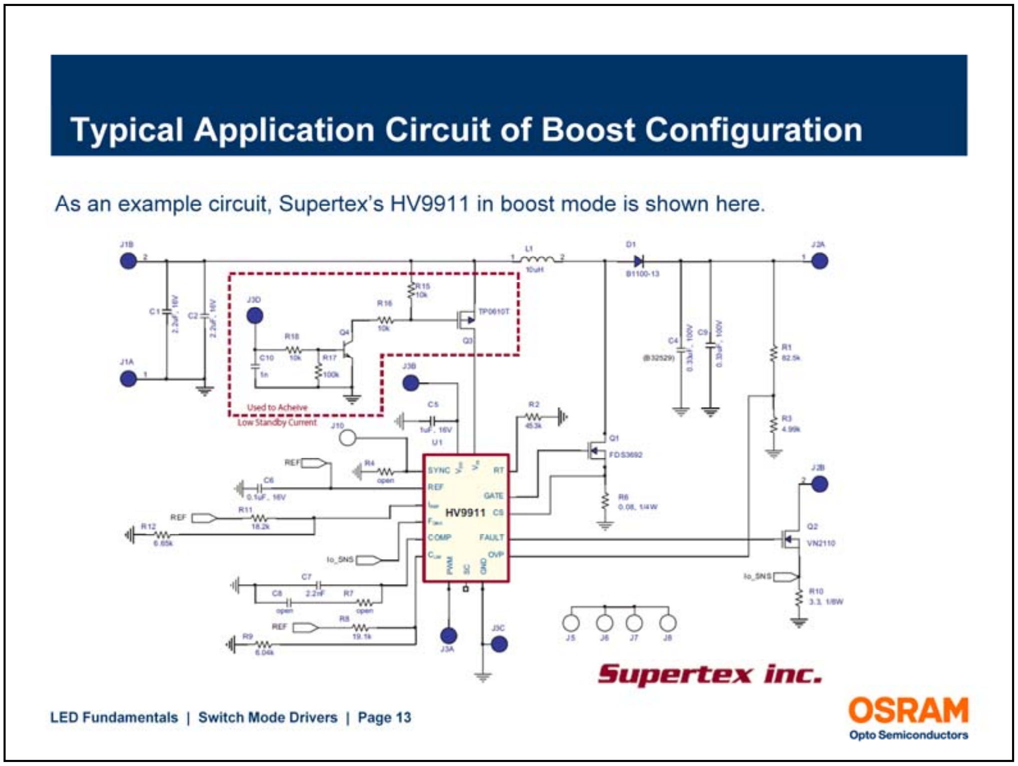


There are a number of IC manufacturers that focus on LED drivers. The brain of a power supply is the driver IC.

Shown on the right, is the schematic of a typical application circuit using Supertex's HV9910B, a buck driver IC. In many cases, the same driver IC can be configured to be operated in buck, boost, or Single Ended Primary Inductance Converter (SEPIC) configurations. The arrangement of the components is what changes in these different configurations. The basic components for all modes stay the same.



The boost topology is the second most commonly used configuration. In boost mode operation, when the switch is closed, current flows through the inductor while the capacitor supplies the load. When the switch opens, stored energy in the inductor releases, the capacitor charges, and the load is supplied.



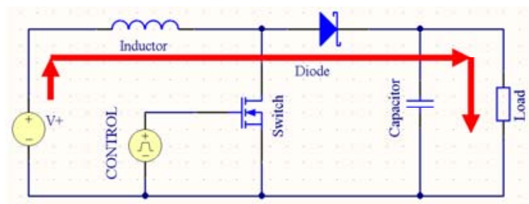
Shown here is a simple boost topology schematic using a Supertex's HV9911. Please note that the circuit enclosed in dotted lines is not part of the boost topology.

Shortcoming of Boost Mode Operation

In a boost topology, the input is less than the output. However, what will happen if the input goes above the output?

Due to circuit arrangement in a boost topology, there will be current flow (shown in red) when input goes higher than the output and the output will not be regulated. This may cause damage to the load and should be prevented.

In a situation similar to the above, the SEPIC configuration helps and maintains a regulated positive output when the input is higher or lower than the output.



Boost Topology

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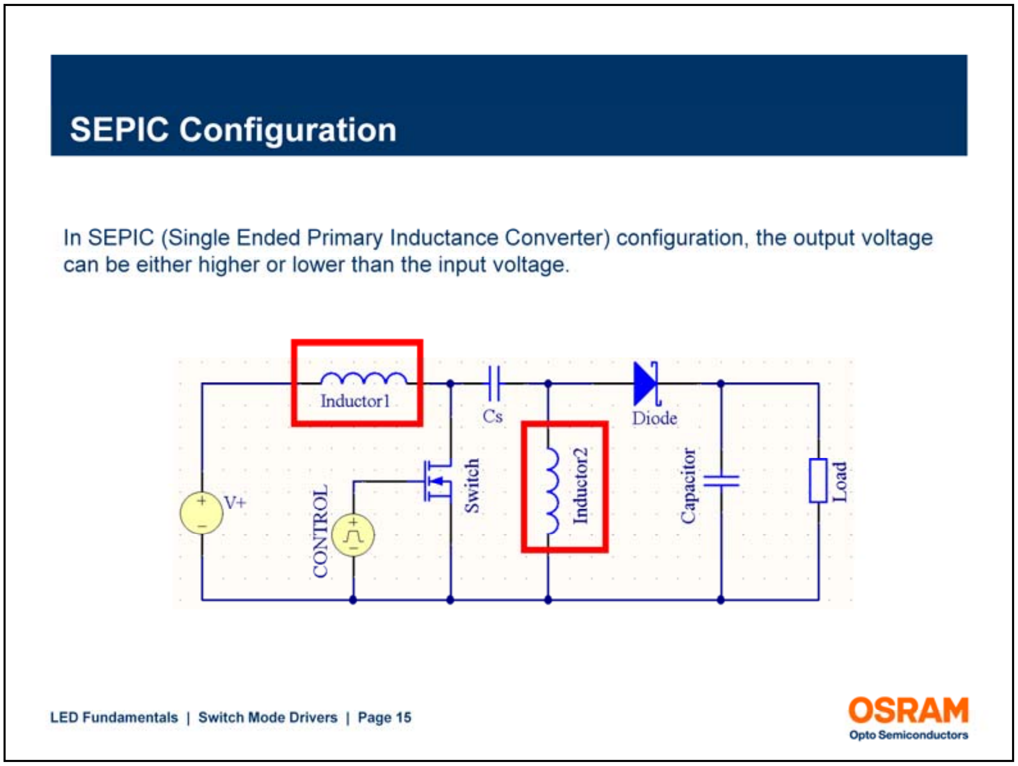
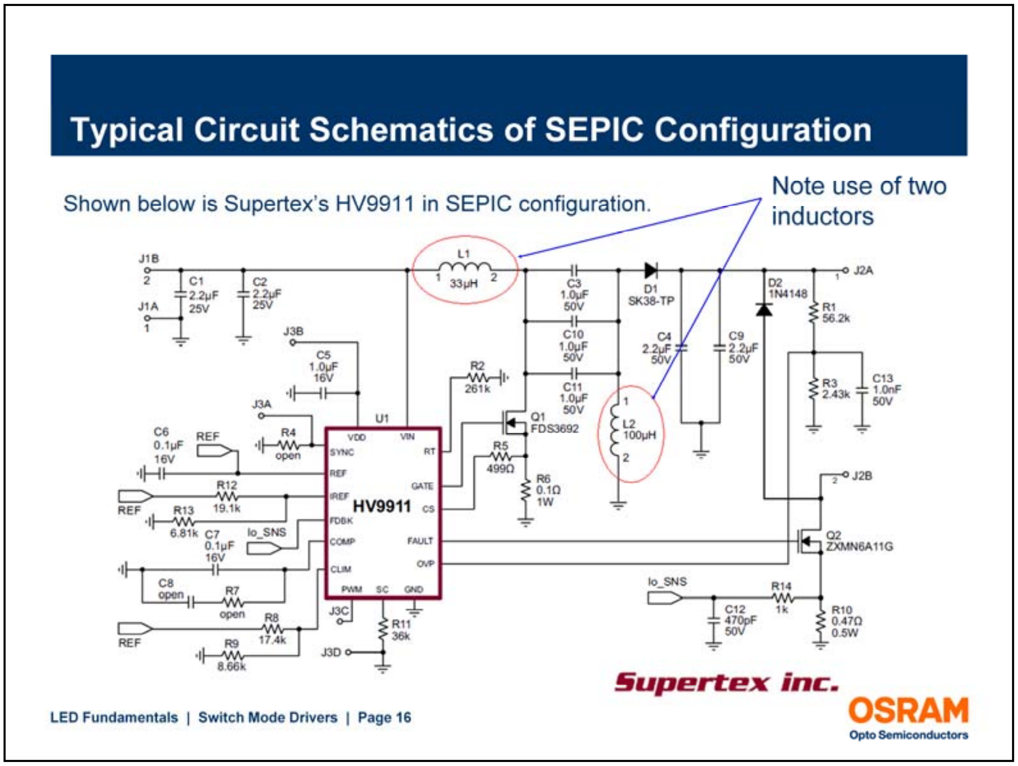
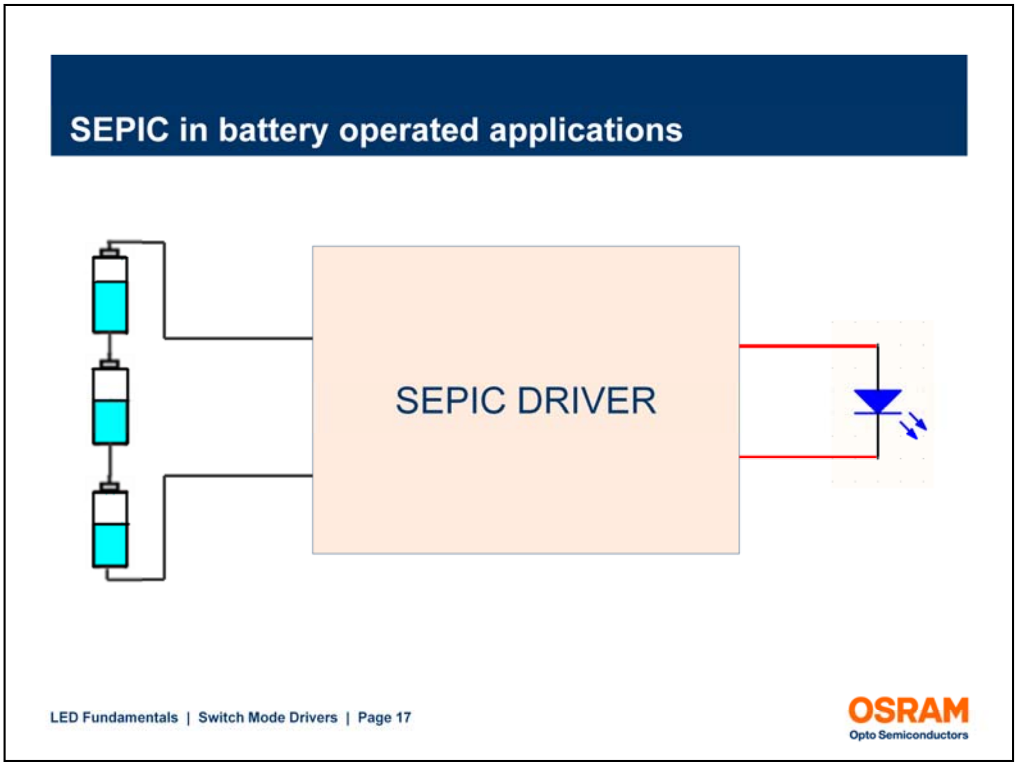
Ideally, boost topology is used when input voltage is lower than the output voltage. However, due to the circuit component arrangement in boost topology, there will be a direct current flow into the load when the input goes above the output voltage. This is not desired, as there will be no current regulation in this situation.



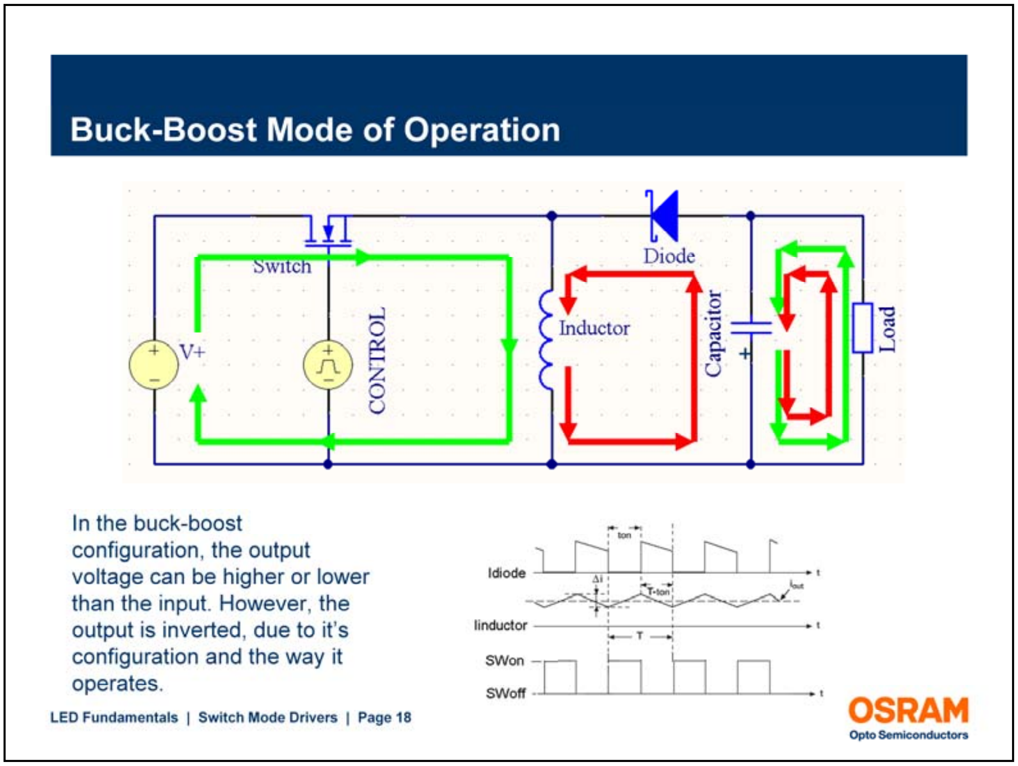
To address this loop hole in boost configuration, SEPIC configuration is used. In a SEPIC configuration, the input voltage can either be higher or lower than the output voltage. Please note that there are two inductors in this configuration compared to only one inductor on the three previously explained modes. The addition of the inductor may slightly increase the cost of the driver.



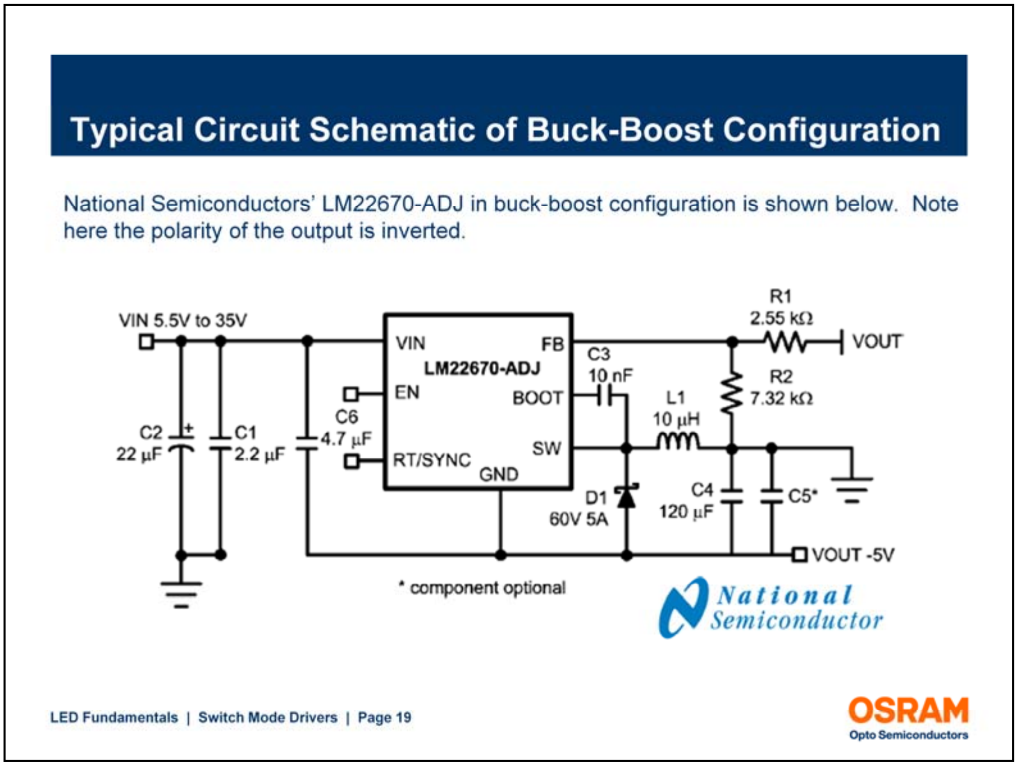
One of the key differences between boost and SEPIC is the use of two inductors, which may add cost to the system, but is very commonly used in portable battery operated applications.



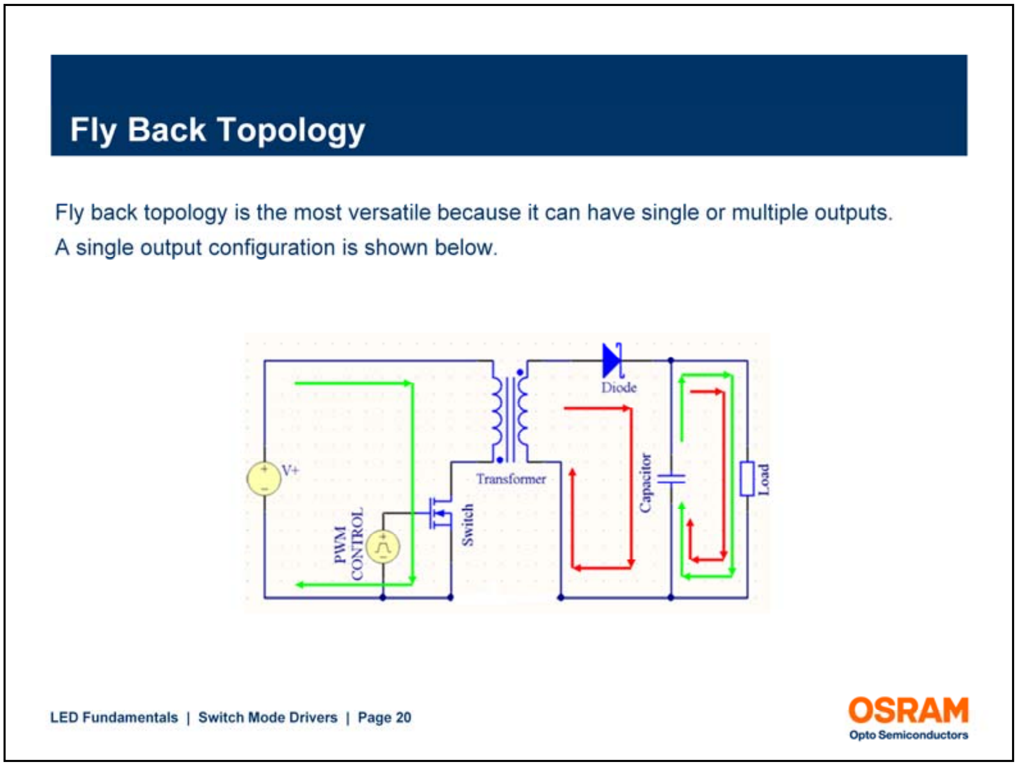
An ideal example for SEPIC configuration would be a device which has a single LED (Vf ~3.2V) and is operated with three AA or AAA batteries. When the batteries are new, a buck mode operation is required and when the batteries drain below 3.0V a boost mode operation is required.



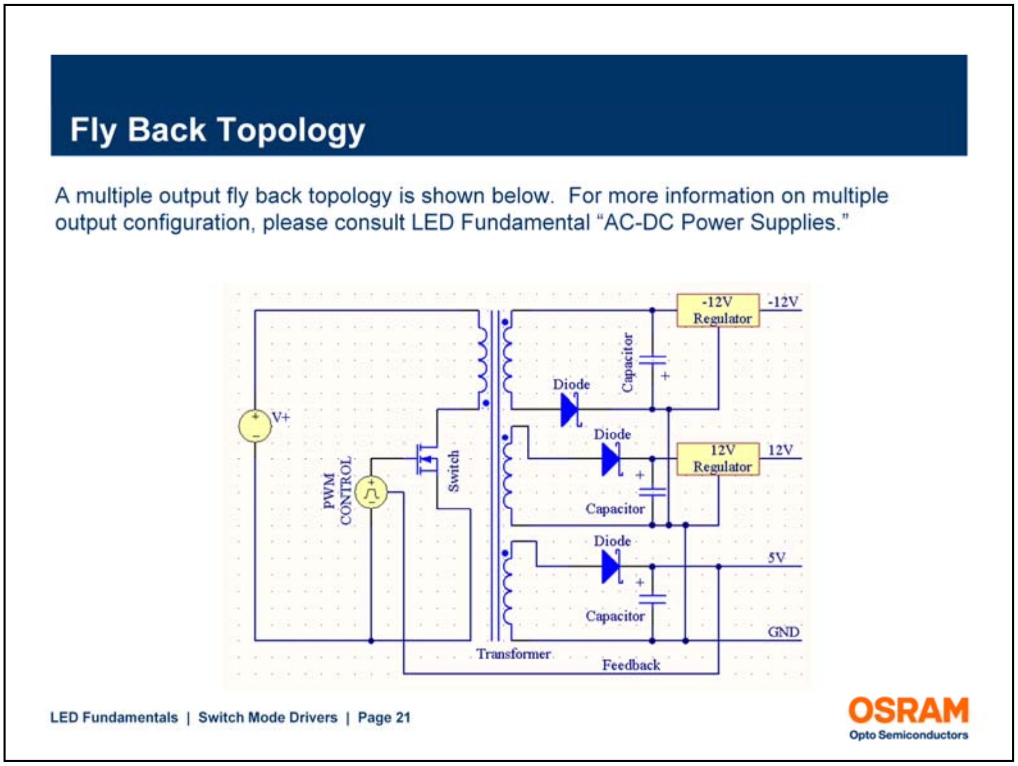
Buck-boost is the third commonly used topology. It is also called inverter topology because the output polarity is inverted. The operation is such that when the switch is on, current flows through the inductor and energy is stored in the inductor. During this period, the load is supplied by the capacitor. When the switch opens, stored energy in the inductor is released and the capacitor charges up while the load is also supplied.



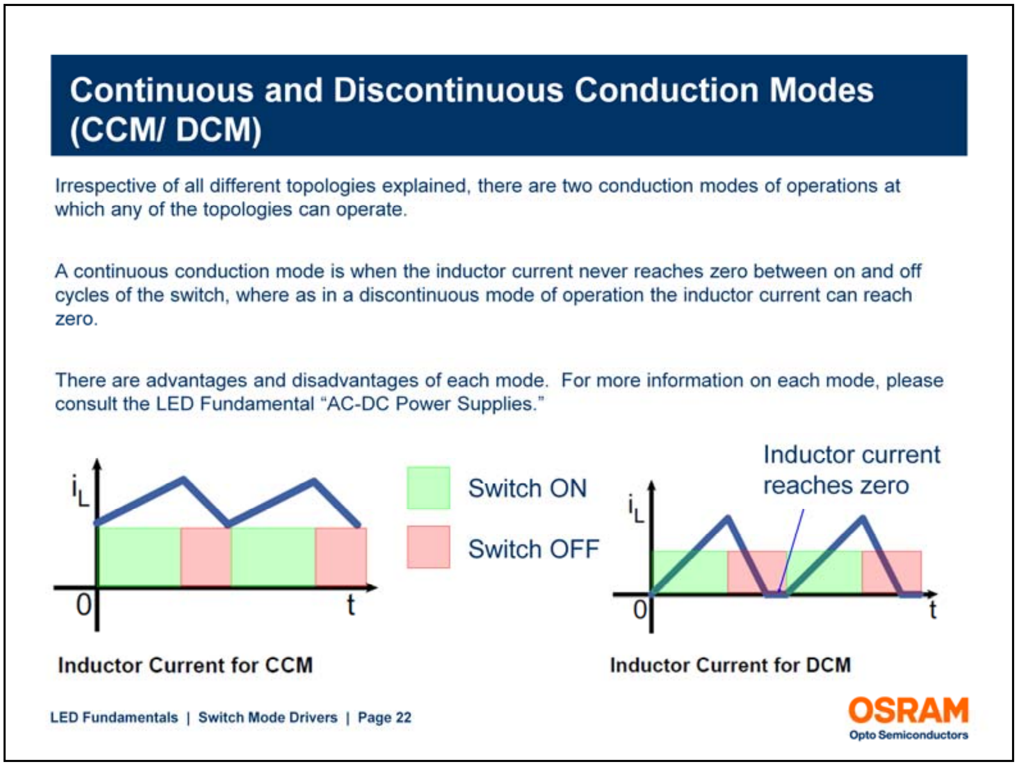
As an example, a National Semiconductor's LM22670-ADJ in buck-boost mode operation is shown.



The fly back is the fourth commonly used topology. It can be configured for single output or multiple outputs. In single output configuration, when the switch is on, the current flows through the primary side of the transformer. During this cycle, the load is supplied by the capacitor. When the switch is turned off, the voltage at the primary side is reflected on the secondary side, which causes the diode to conduct, supplying the load as well as charging the capacitor.



This slide shows the typical configuration of a multiple output fly back topology. For more information on multiple output configuration, please consult the LED Fundamental **"AC-DC Power Supplies."**



All four of the topologies explained can be operated in either continuous conduction mode or discontinuous conduction mode, depending on the current through the inductor. In continuous conduction mode, inductor current never reaches zero, but in a discontinuous conduction mode operation the inductor current does reach zero.

Summary

- There are four different switch mode driver topologies that are widely used:
  Buck, Boost, Buck-Boost, and Fly back
- All of the topologies can be operated in Continuous or Discontinuous mode (CCM/DCM).
- SEPIC can be considered a variation of Boost configuration.
- Fly back topology gives the designer freedom in the design and is considered the most versatile.
- Switch mode drivers are much more efficient than discrete component based drivers or linear drivers.

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In conclusion, there are four different switch mode driver topologies and the fly back topology is the most versatile and widely used because of the flexibility it offers. Irrespective of what topology is used, switch mode driver based current regulation is much more efficient than discrete or linear based regulation. On the negative side, switch mode drivers are more complex compared to a simple resistor or linear driver based designs and can also add costs to the overall system.

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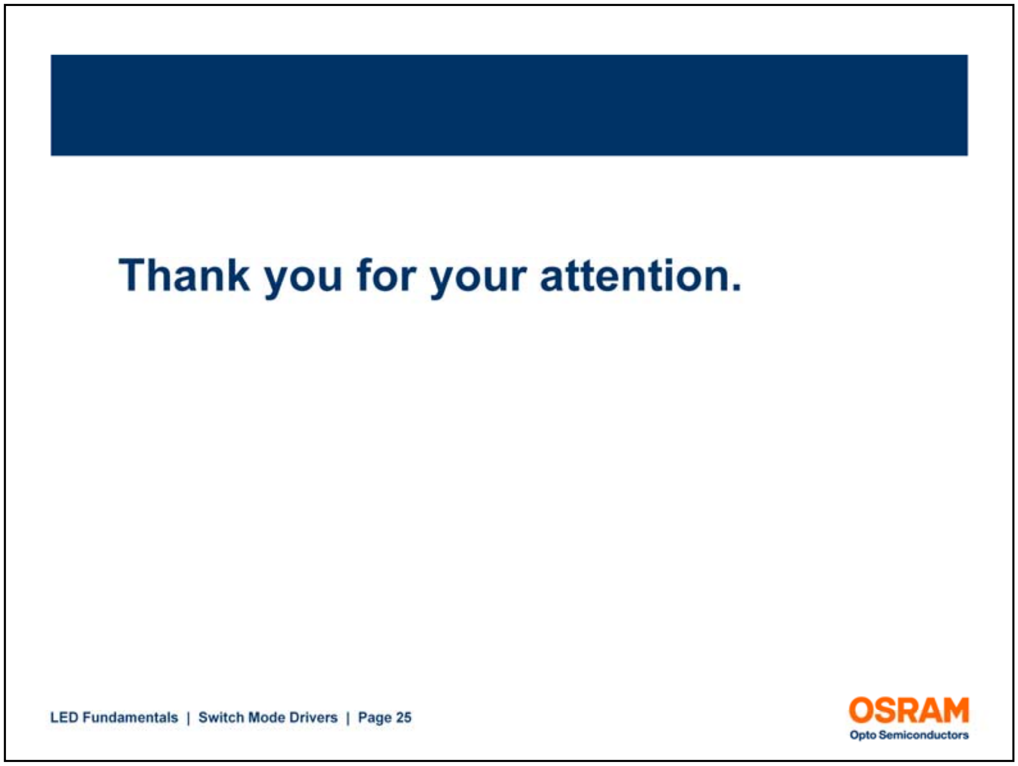

Please refer to the LED Fundamental **“AC-DC Power Supplies”** on this website for additional information.

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