LED Fundamentals

Driving LEDs – Resistors and Linear Drivers

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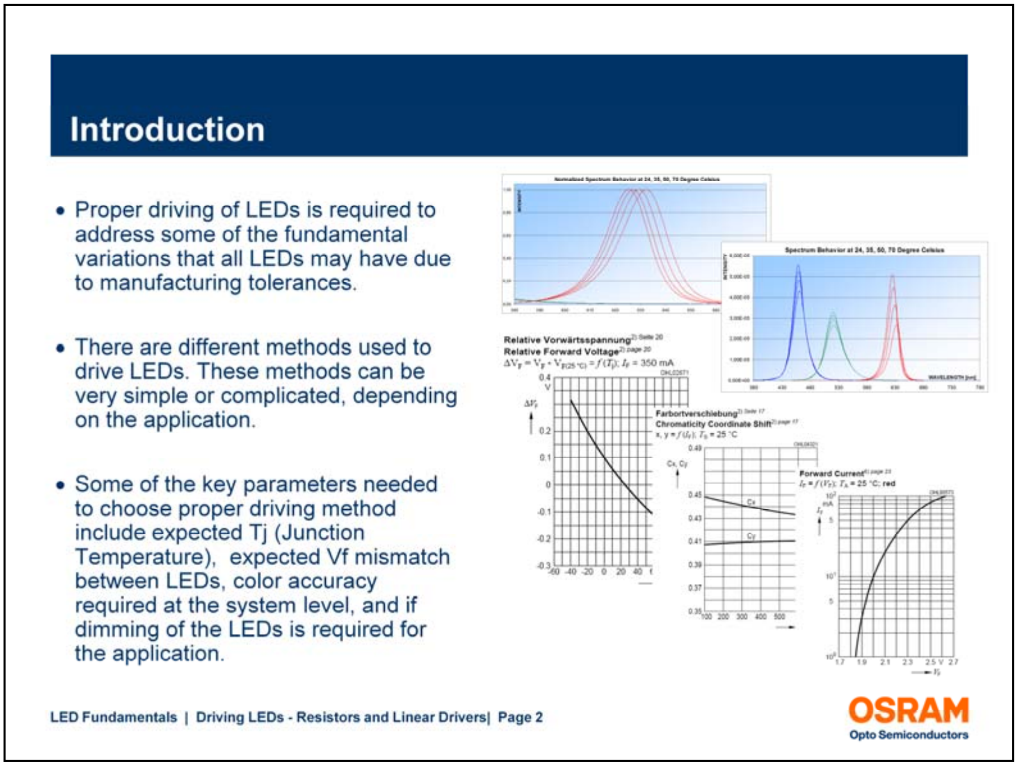
Welcome to this presentation on Driving LEDs – Resistors and Linear Drivers, part of OSRAM Opto Semiconductors' LED Fundamentals series.

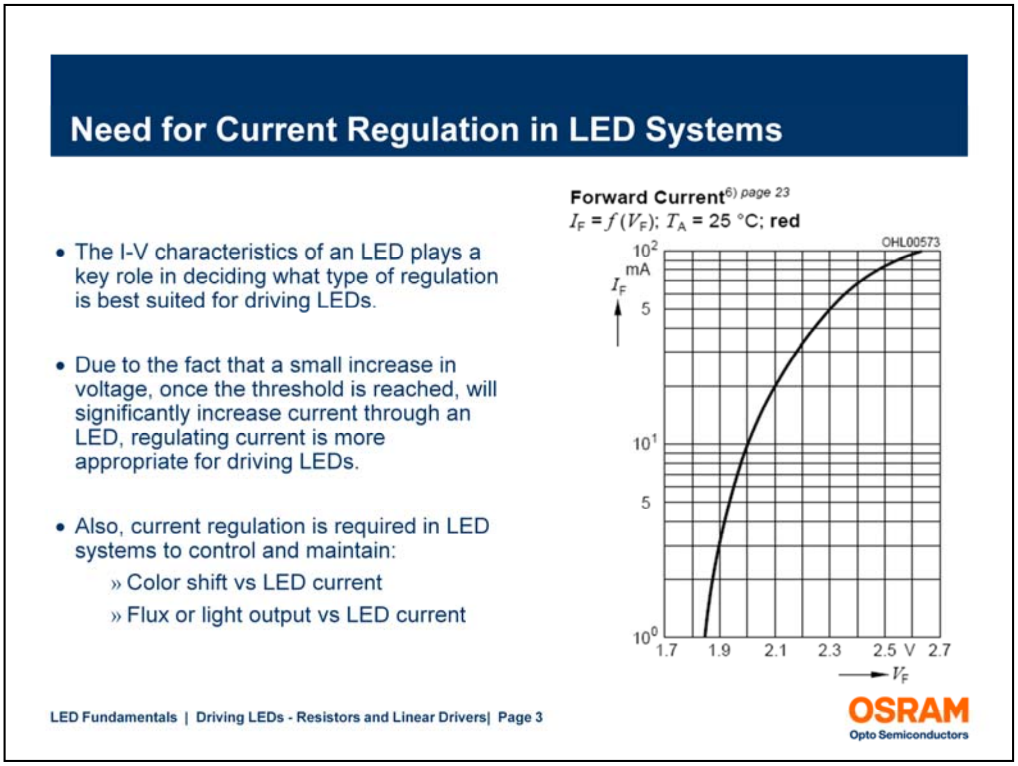
In this presentation we will look at:

- Simple resistor based current regulation for LED systems
- Use of linear drivers to regulate current in an LED system

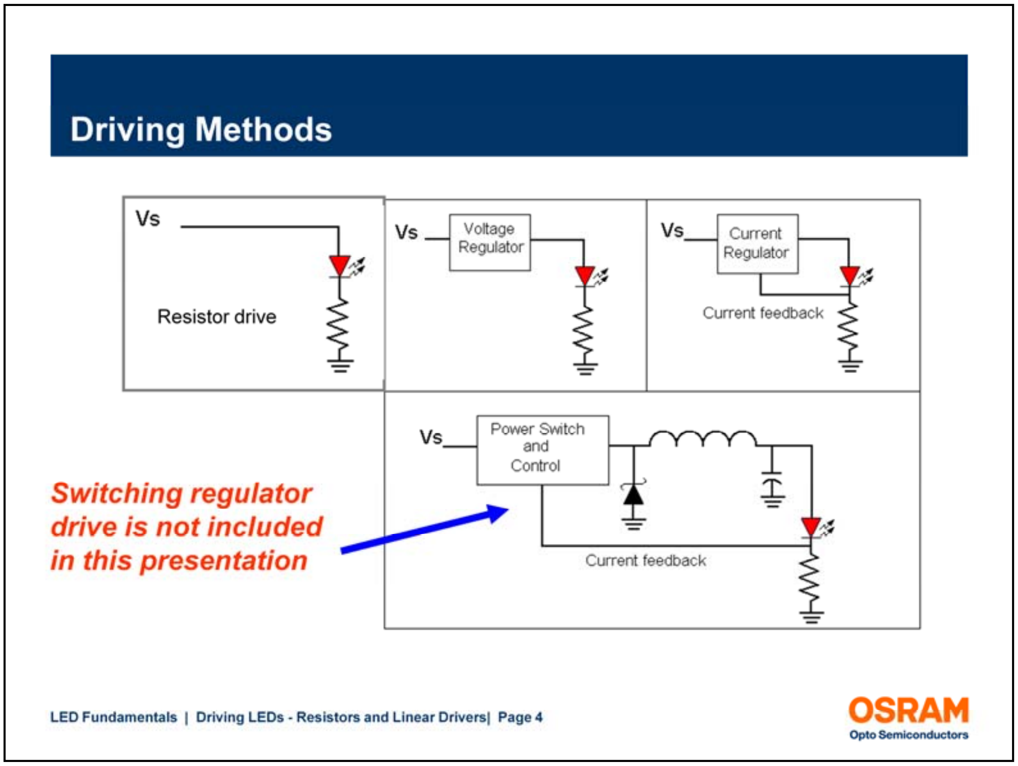


Just like any other electronic component, LEDs should be driven properly for improved efficacy, better reliability, and longer lifetime. Because of some of the fundamental variations, such as Vf mismatch between LEDs and color variation within the same bin, even more care needs to be taken when deciding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

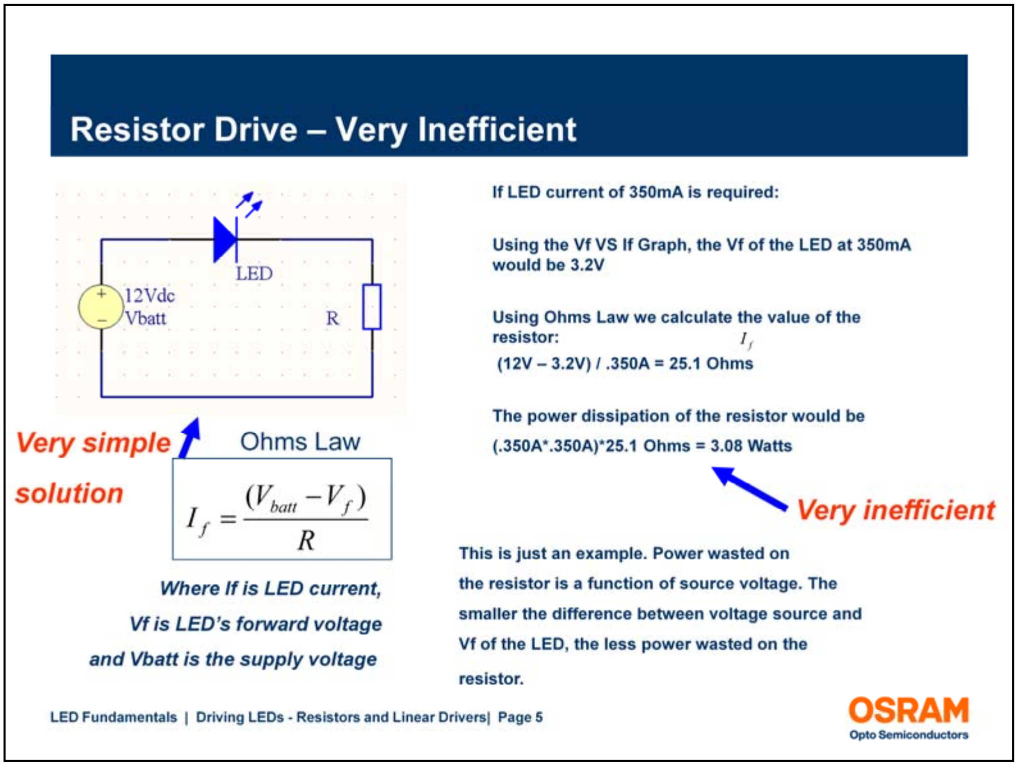
Some of the key parameters that play a major role in selecting the proper driving method are: expected junction temperature of the LED, expected Vf mismatch between LEDs and/or LED strings, color accuracy required, and whether or not dimming is required.



As previously mentioned, an understanding of the electrical, optical, and thermal characteristics of an LED is required to properly select a driving method for an LED circuit or system. Because LEDs have an I-V characteristic that is similar to standard diodes, they are more effectively driven with a constant current source than with a fixed voltage 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 key role in selecting the proper driving method.



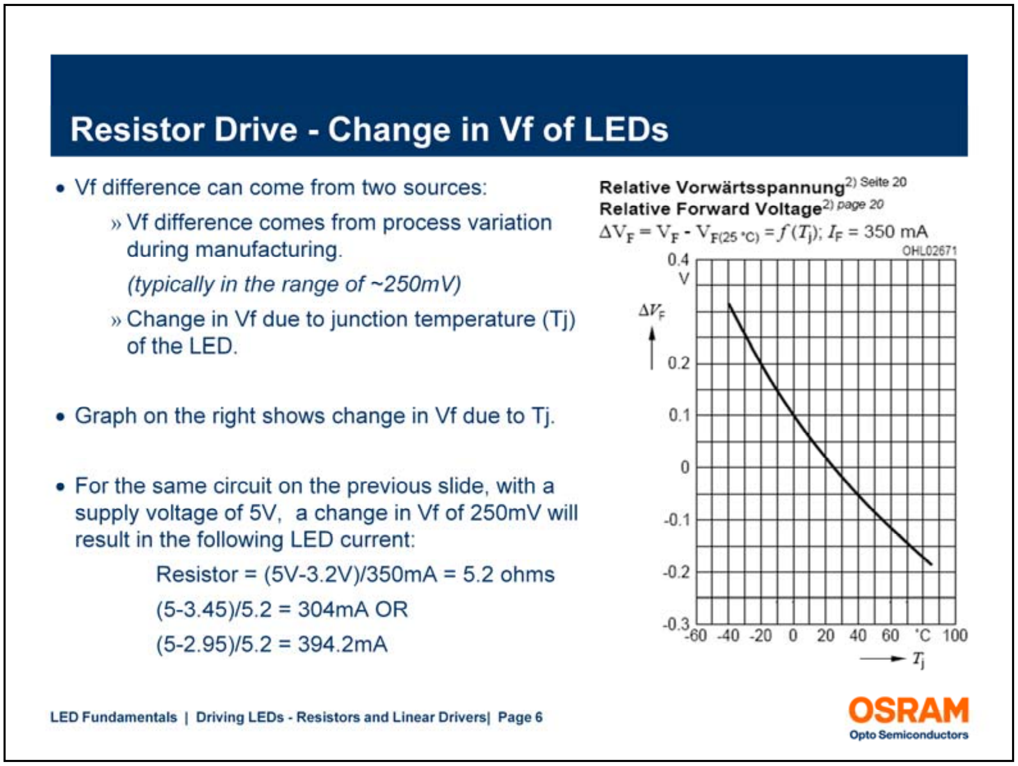
There are at least three different ways of driving LEDs that can provide constant current to LED circuits and systems. They are resistor or discrete based driving, linear regulator based driving, and switching regulator based driving. In this presentation, discrete based driving and linear regulator based driving are examined.



Discrete based driving can either be a simple resistor to regulate LED current or it can be based on a transistor.

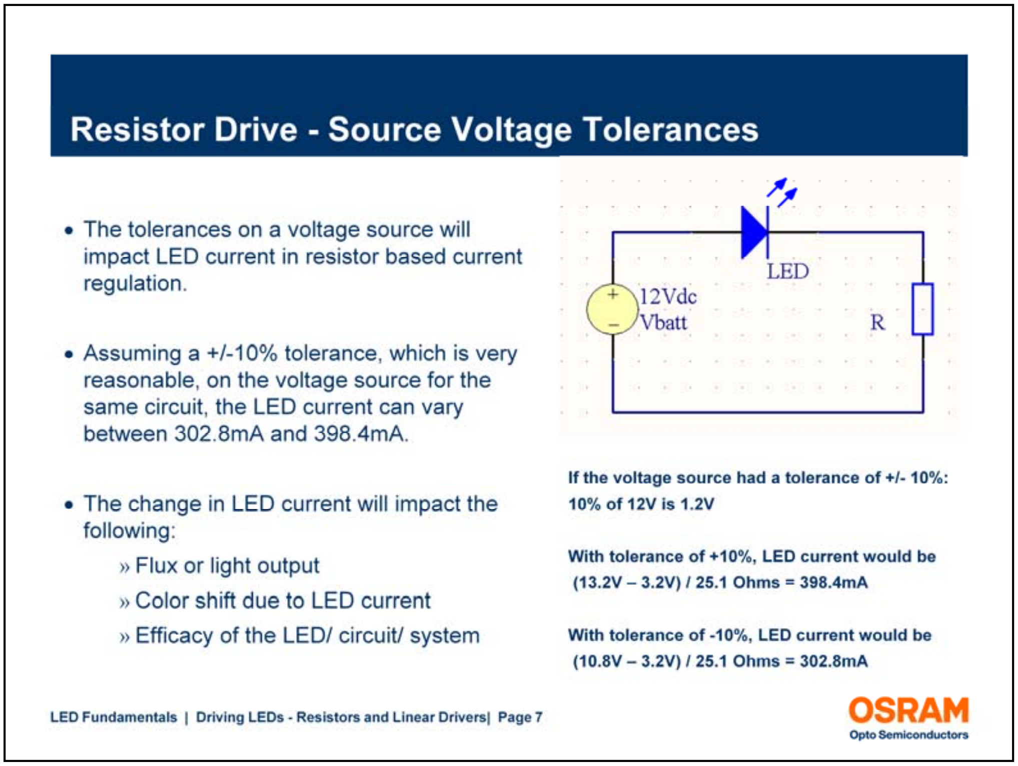
In this example, simply applying ohm's law will give the resistor value for a specific current, which is 350mA in this case. Also, the power dissipated in the resistor can be calculated by using the I^2 equation.

Even though this is the simplest way of driving LEDs, this is also a less efficient way of driving LEDs. As seen in this example, depending on the source voltage, the power wasted on the resistor can be significant.



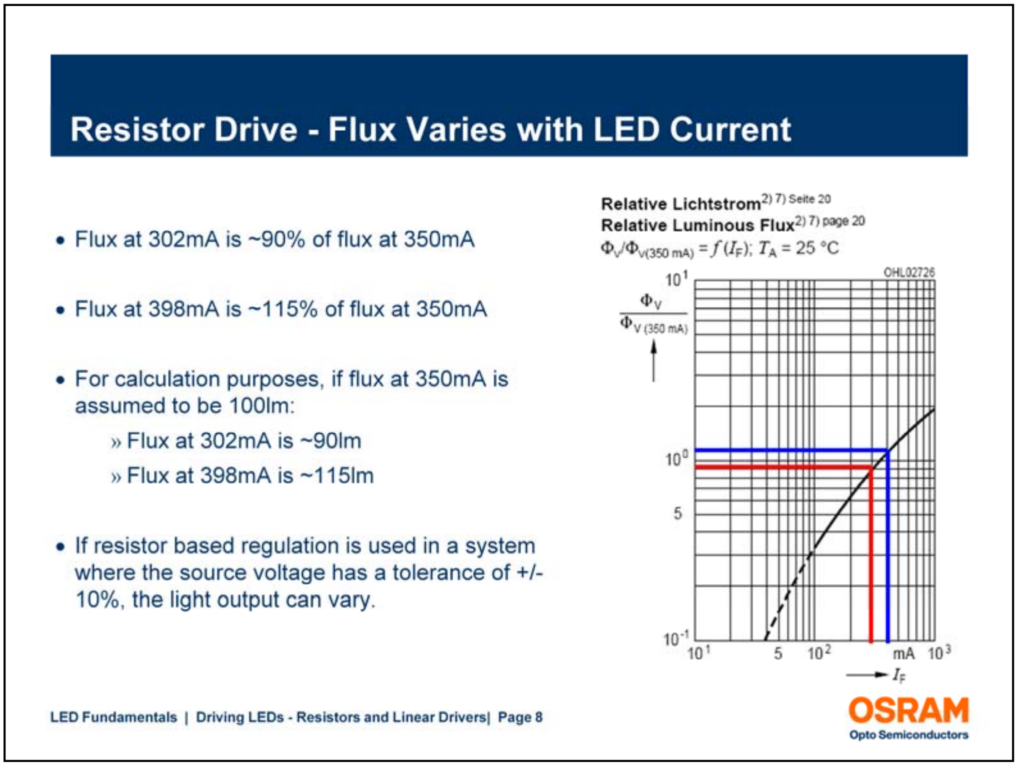
When a resistor is used to regulate LED current, the current can vary depending on the Vf of the LED. The change in current due to Vf variation may or may not be significant and is highly dependant on the application. For instance, this may be significant when multiple color LEDs are mixed to achieve a target color point.

Even with a Vf difference of 250mV, which is typical for LEDs, the LED current can vary between 304mA and 394mA for the same resistor.



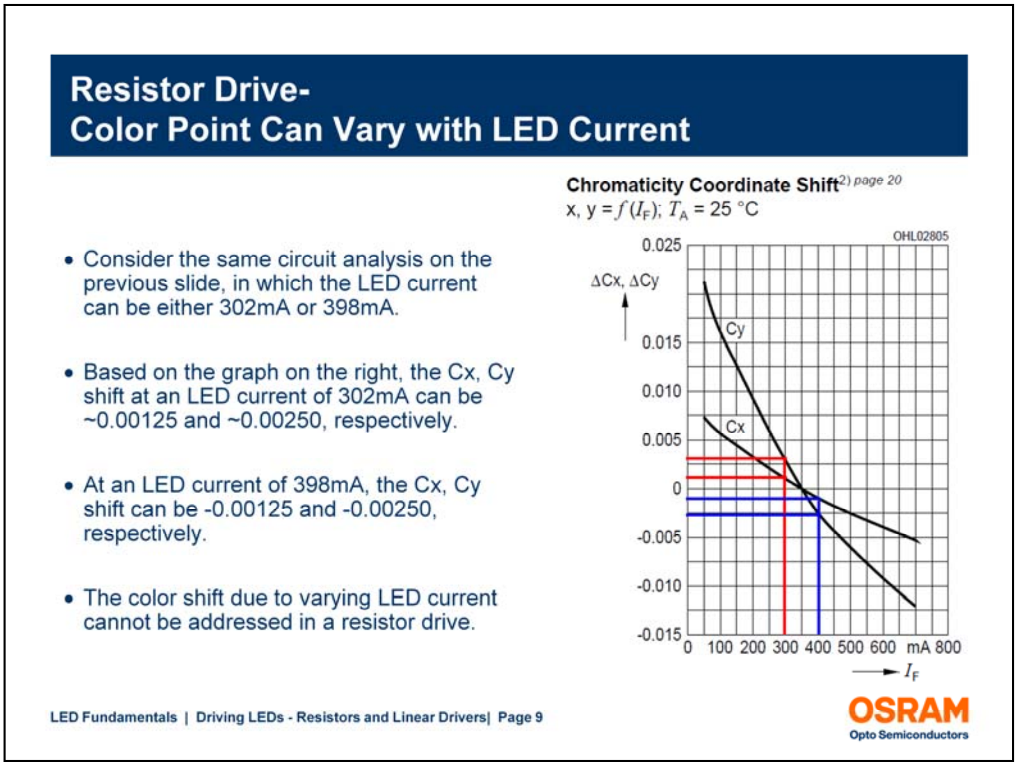
One of the key issues with resistor based driving is the variation in source voltage. Changes in source voltage will directly impact LED current. Any source voltage will have some tolerances and having a +/-10% tolerance is very common. A 10% tolerance can change the LED current to be between 300mA and 400mA where the actual calculated LED current should be 350mA.

Any change in LED current is not desired. A change in LED current will have an impact on flux output, which may increase or decrease total light output of a system.

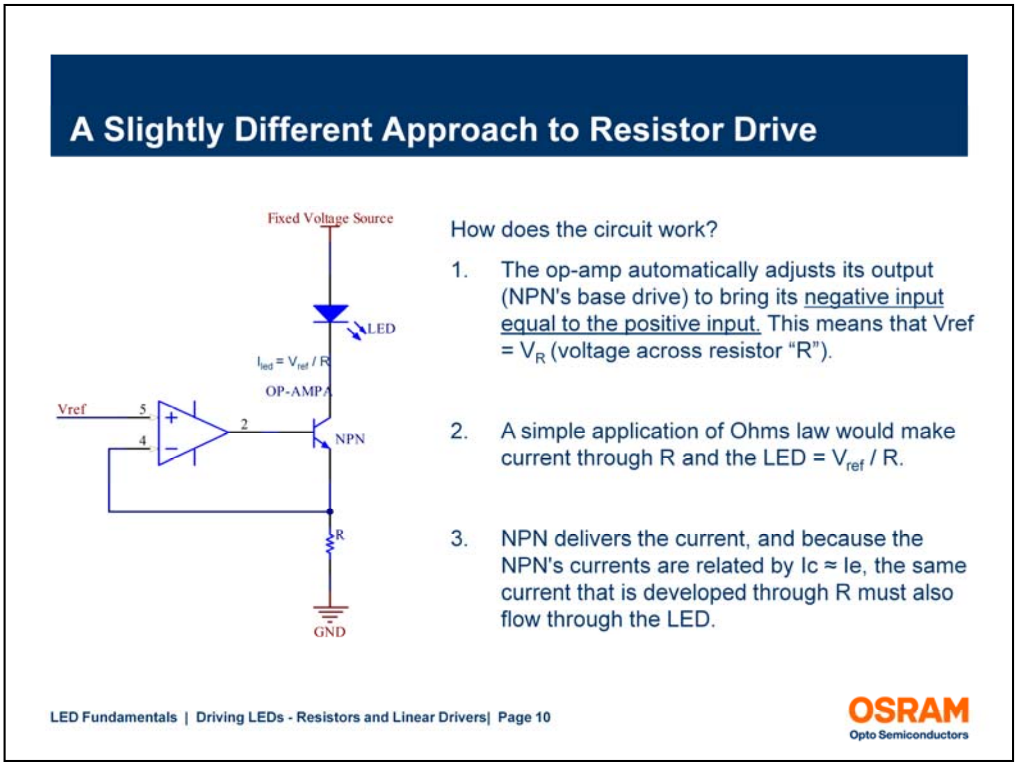


To explain impact on flux at different LED currents, an example is shown in this slide. Flux output at 300mA is only 90% of that at 350mA and at 400mA, it is 115% of that of 350mA.

The calculation of flux variation reveals that with just one LED, the flux can vary up to 25lm. In a system with multiple LEDs, the change in flux can be significant.



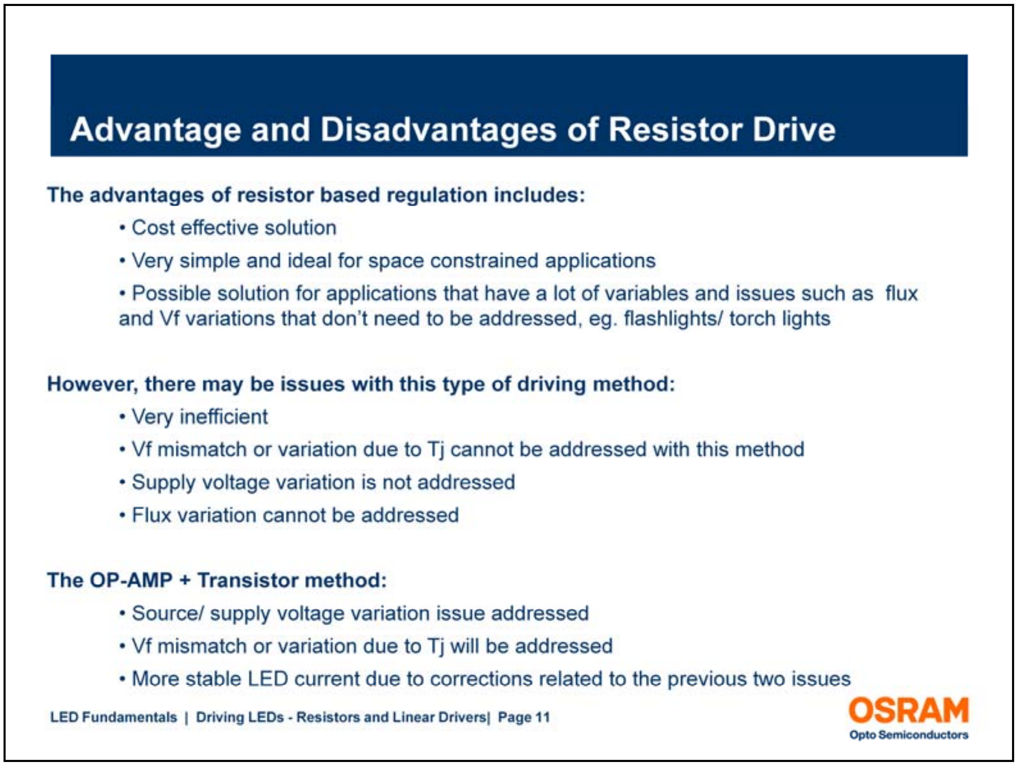
Also, there will be a slight color shift when LED current is changed. Depending on the application, this should be taken into account when selecting the correct driving method for an LED application. The color shift for two different currents is shown on this slide.



This slide shows a different approach to resistor based driving using a transistor and an OP-AMP. In this way of driving, the Vf mismatch and source variations will not change the LED current.

The LED current in this circuit will be Vref divided by Resistor R.

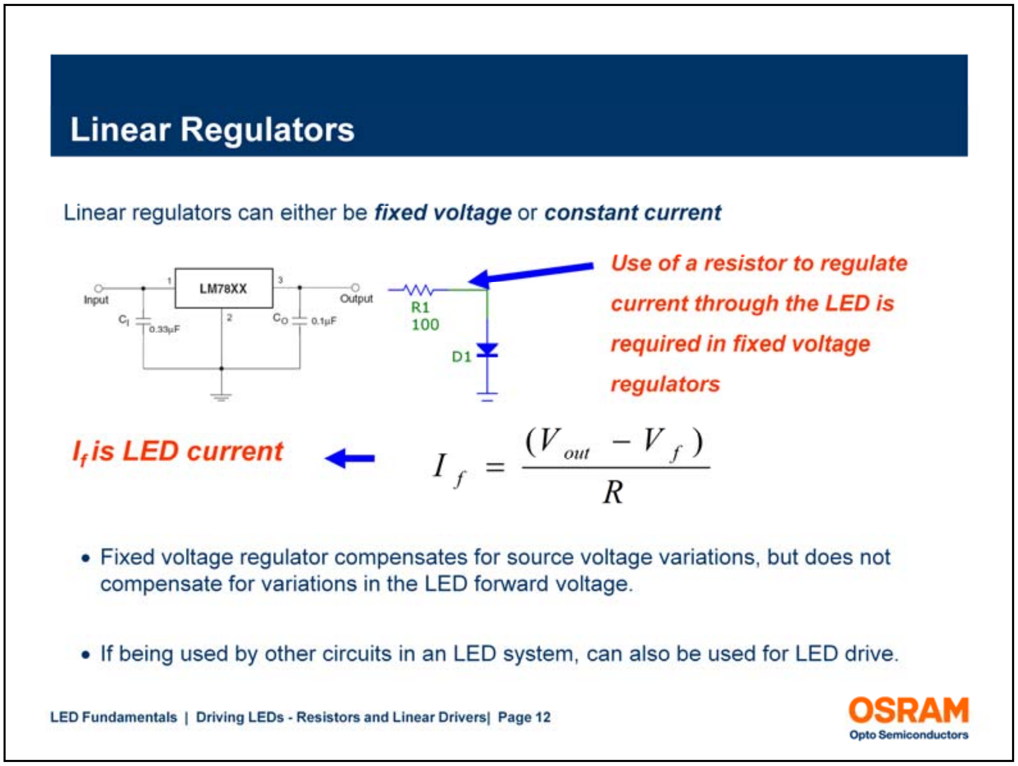
The addition of a transistor and an op-amp can be justified in an application where impacts of Vf mismatch and source variation cannot be tolerated.



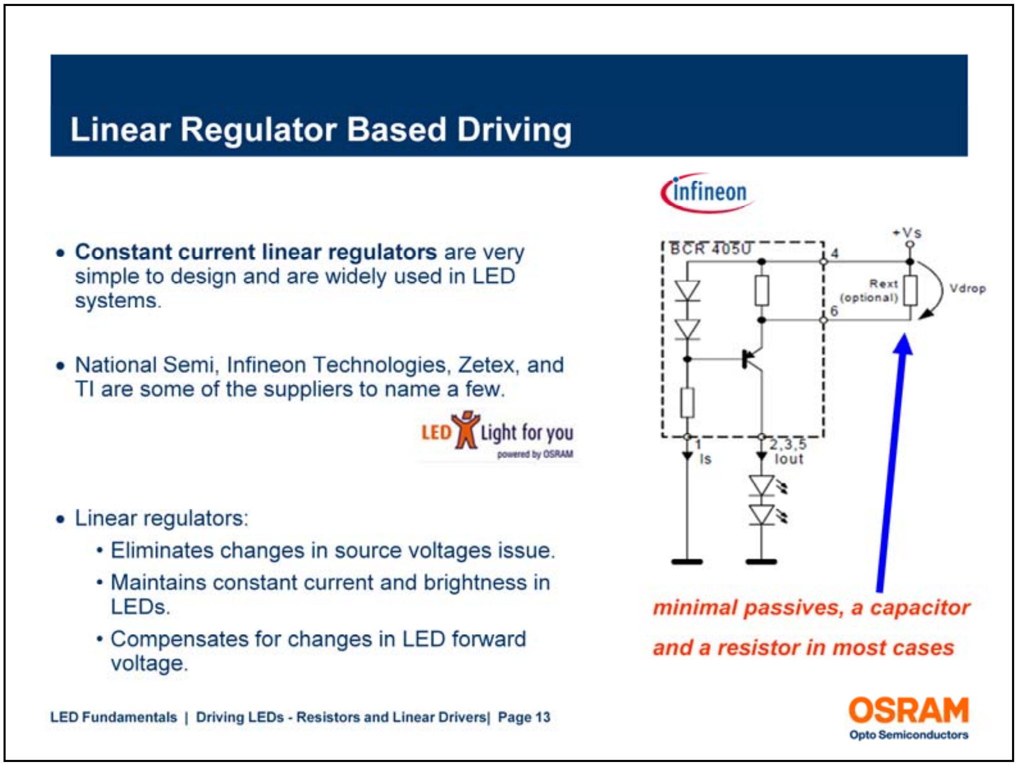
In this slide the advantages and disadvantages of methods discussed so far are analyzed.

A resistor based current regulation is very cost effective and very simple for space constrained application, and ideal for applications where color, flux, and Vf mismatch are not a significant concern, such as flashlights or torch lights. However, with a resistor based solution, Vf mismatch, variation in supply voltage and flux, and color shift cannot be addressed. It is also very inefficient.

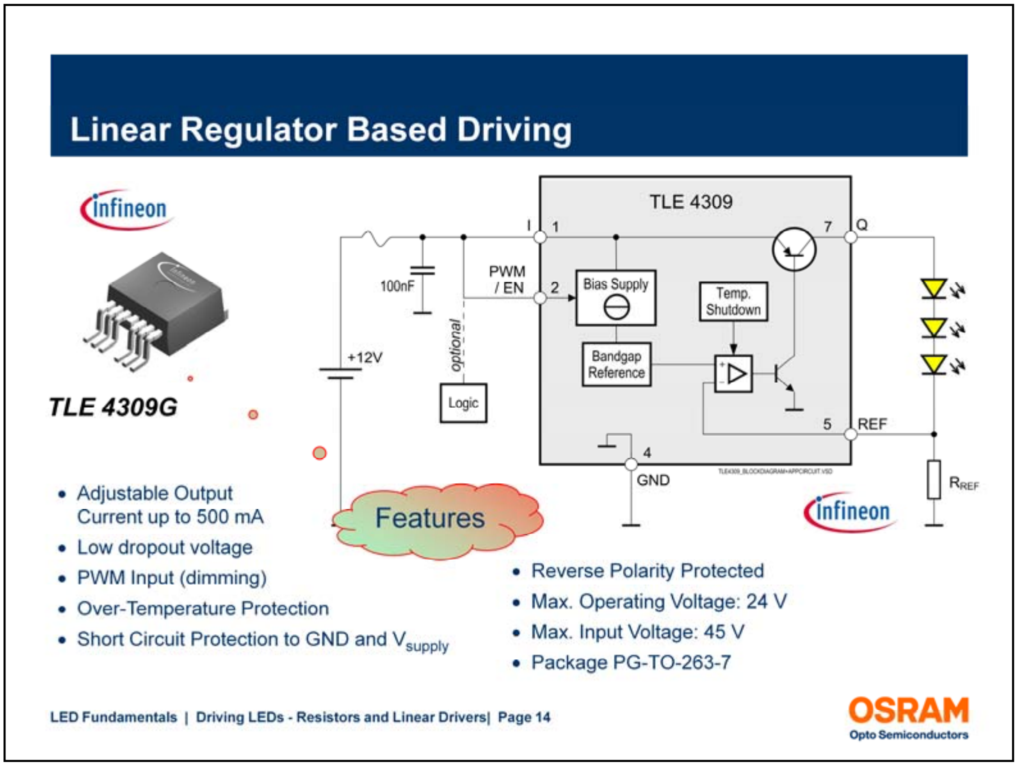
With the OP-AMP + transistor method, source variation and Vf mismatch are addressed.



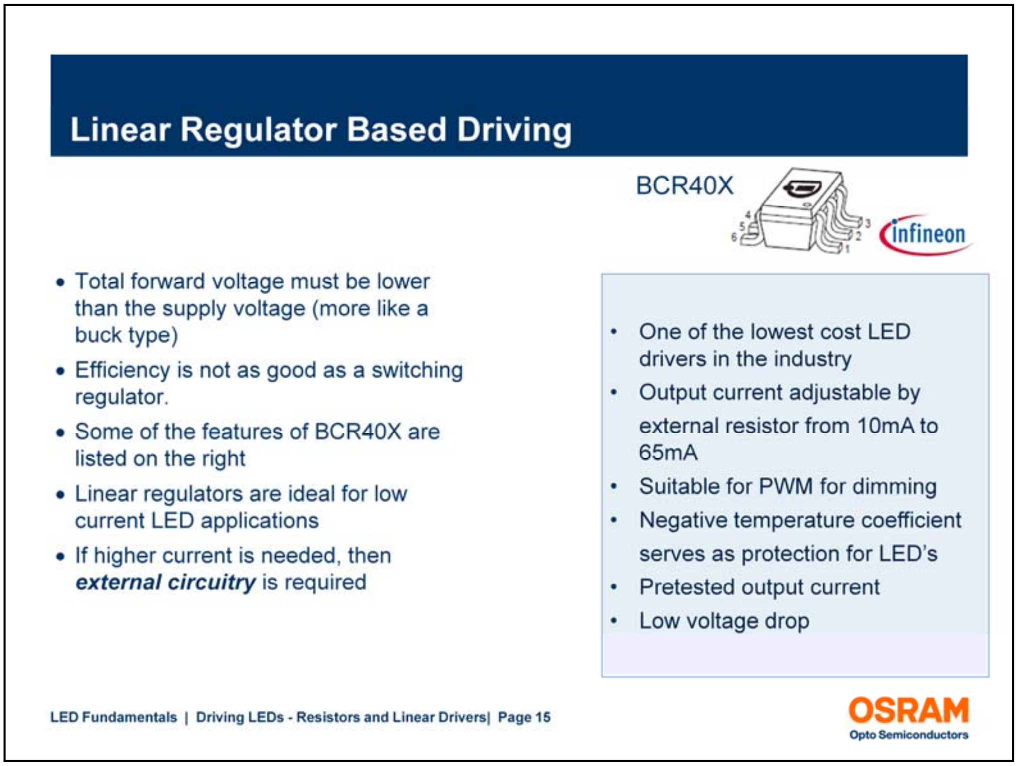
Aside from resistor based regulation, LEDs can also be driven using linear regulators. Linear regulators can either be fixed voltage or constant current. In fixed voltage linear regulators, a resistor is also required to set proper LED current.



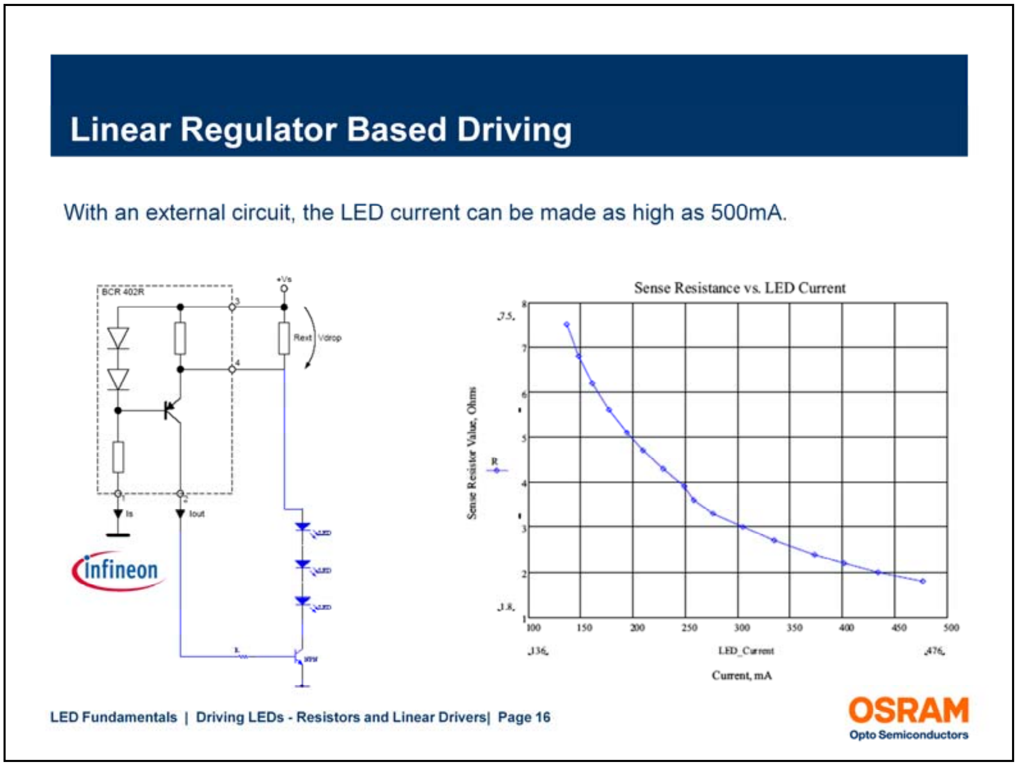
A constant current linear regulator is preferred over fixed voltage linear regulator because it can take a wide range of voltage and output with a set constant current, ideal for driving LEDs. Because the output is constant current, Vf mismatch between LEDs is not a concern with constant current linear regulators. Also, a linear driver requires very few passive components, in many cases only a resistor and/or a capacitor.



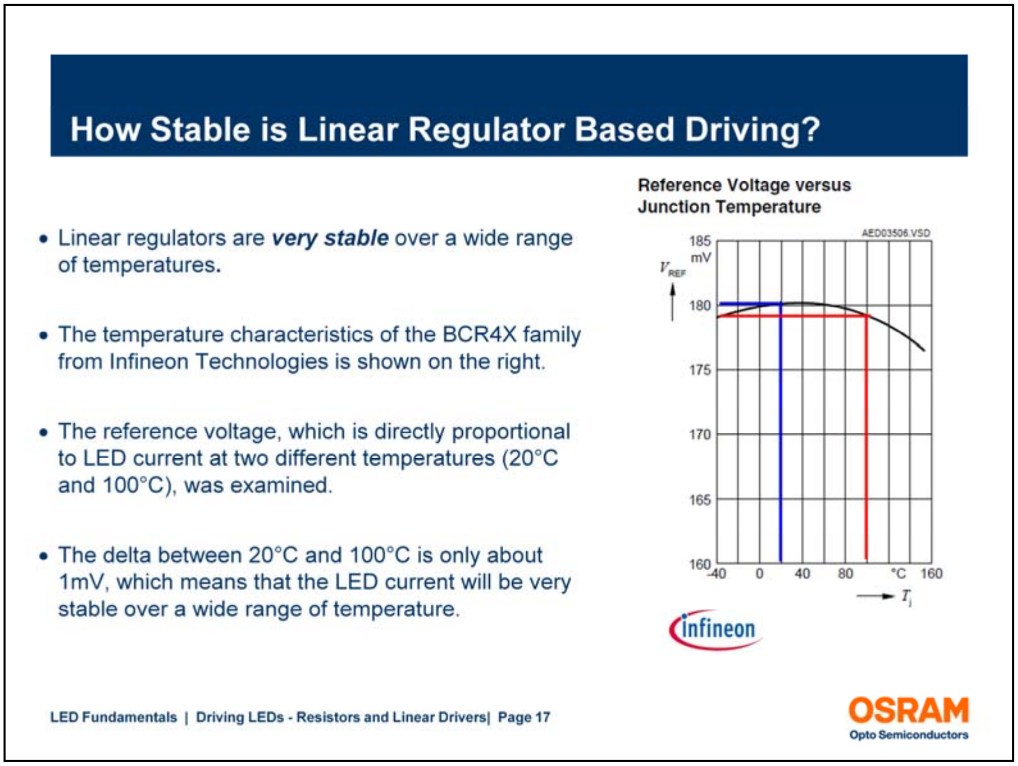
There are many different constant current linear regulators on the market. In many cases, the passive components that are required to complete the linear driver circuit are very minimal. A picture of Infineon's TLE4309 and its features are shown here for reference.



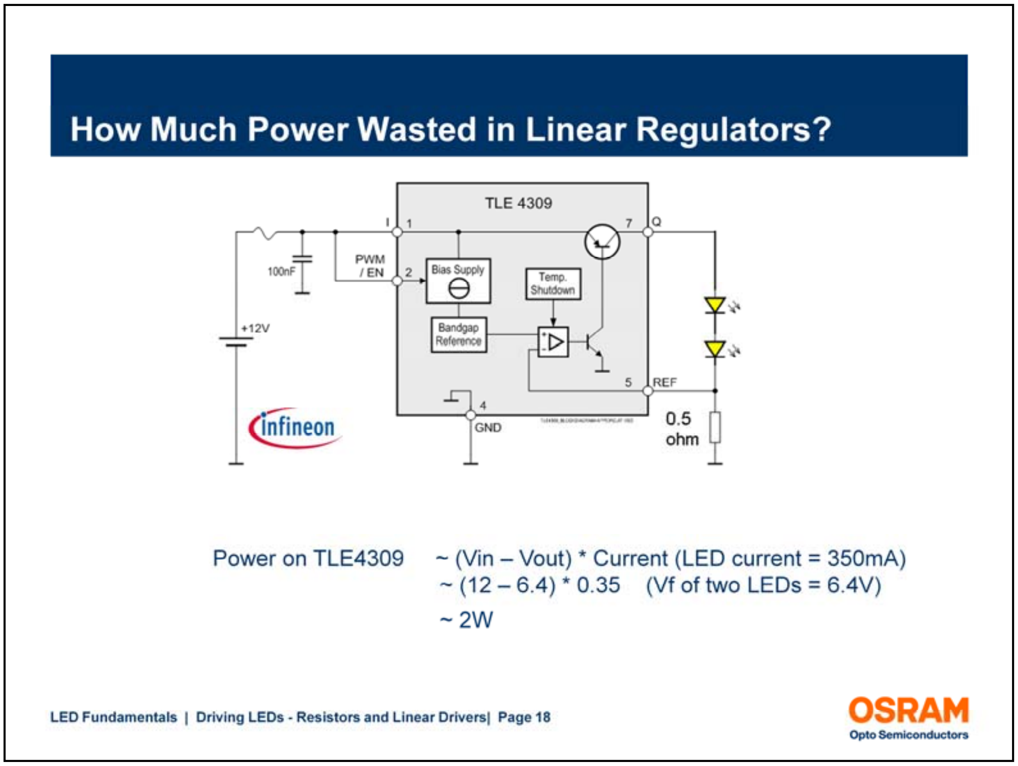
One of the issues with linear regulators is that the LED current is limited to tens of mA due to the maximum power rating on the regulator itself. If higher current LEDs are required, external circuitry should be in place.



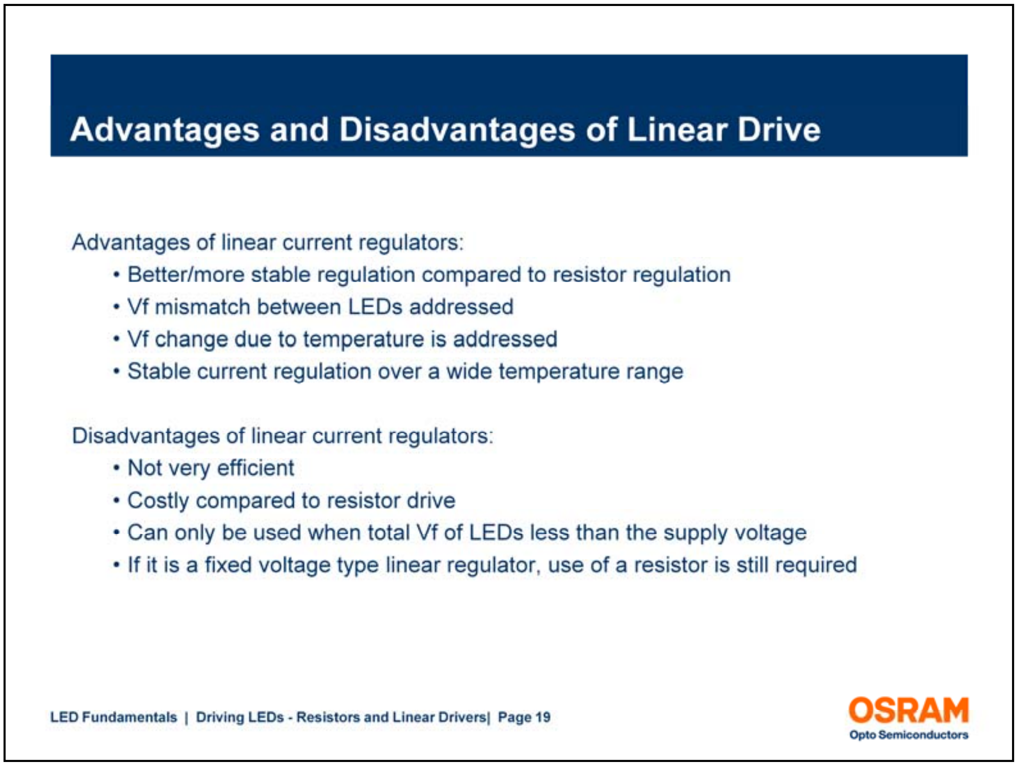
Pictured in this slide is the external circuitry required to boost LED current using Infineon's BCR402R. If more than 65mA is required, the LED current can be taken up to 500mA by adding a transistor.



One of the key advantages of linear regulators is the stability of linear drivers over temperature. The stability of the BCR400 series over a wide range of operating temperature is illustrated here. As seen from the graph, the change in reference voltage between 20°C and 100°C is only one milli volt.



As with resistor based driving, linear regulators are also very inefficient. The difference in input and output voltages are simply wasted as heat within the regulator itself. Therefore, wasted power is directly proportional to how wide the difference is. The difference between input and output voltages should be taken into consideration when designing with linear drivers, to ensure the power rating on the driver is not exceeded.



Linear regulators are very simple to design and a cost effective solution for driving LEDs. Also, with linear drivers, the fundamental variations such as Vf mismatch, are addressed. As with any driving method, there are also disadvantages, which are listed here.

Summary

In summary, the table below compares resistor drive and linear drive in LED systems/ circuits.

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

LED Fundamentals | Driving LEDs - Resistors and Linear Drivers| Page 20

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In conclusion, resistor based and linear regulator based driving are the simplest and most cost efficient ways of driving LEDs, even though they come with some disadvantages. Linear drivers address some of the fundamental variations that LEDs have, but still isn't a very efficient way of driving LEDs. There are other available options when it comes to driving LEDs.

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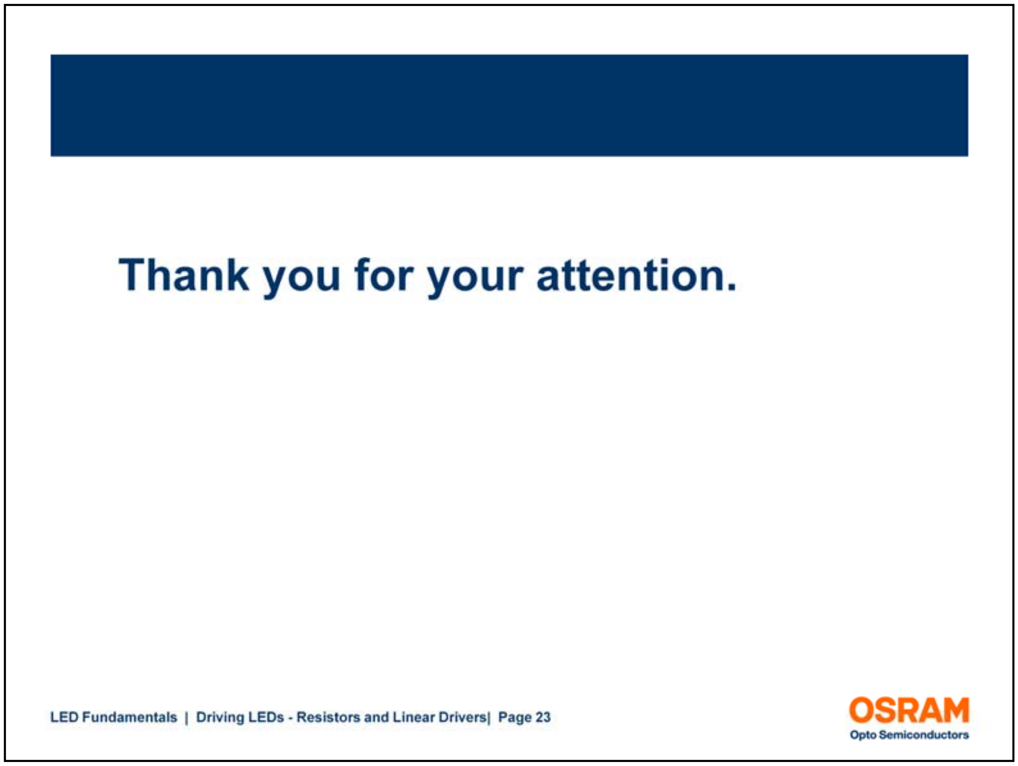

Please refer to the LED Fundamental **“Driving LEDs - Switching Drivers”** on this website for additional information.

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