LED Fundamentals

Basics of Heat Transfer

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Welcome to this presentation on “Basics of Heat Transfer” by OSRAM Opto Semiconductors.

In this presentation we will look at:

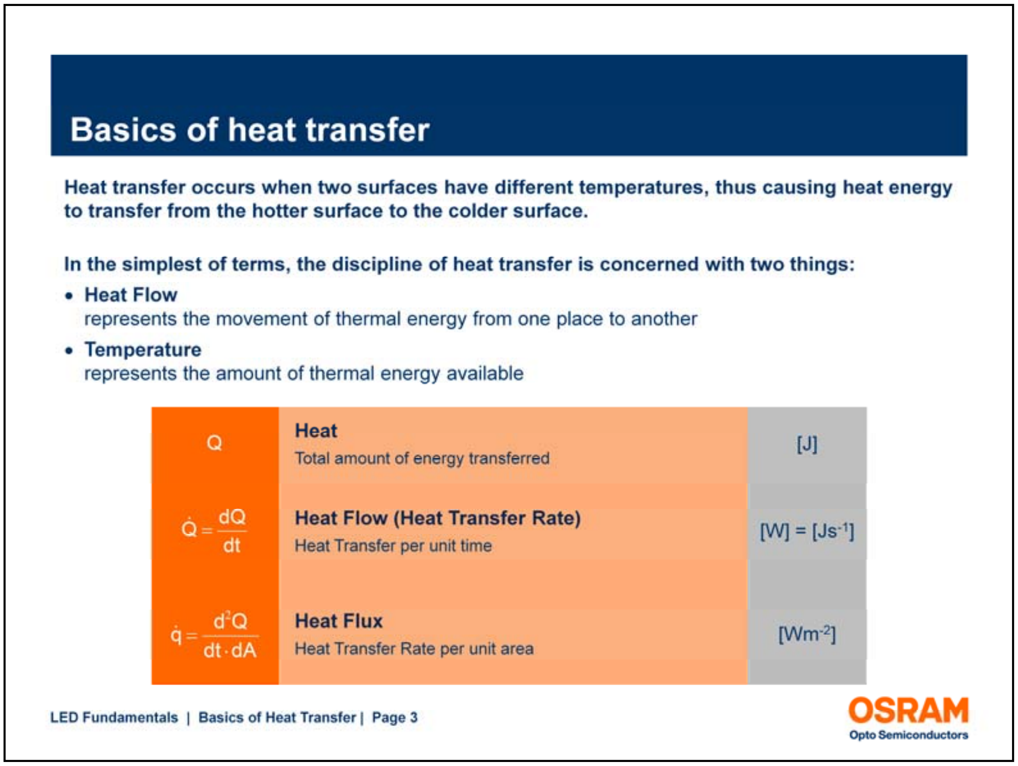
- the different modes of heat transfer in an LED system.
- thermal conductivity of typical materials used in LED system design.

and

- the various thermal resistances involved in an LED system.

This slide captures the path of heat flow in an LED system.

The heat tracks through the LED component, which is usually mounted on a printed circuit board, through a heat sink and housing, finally making its way to the ambient.



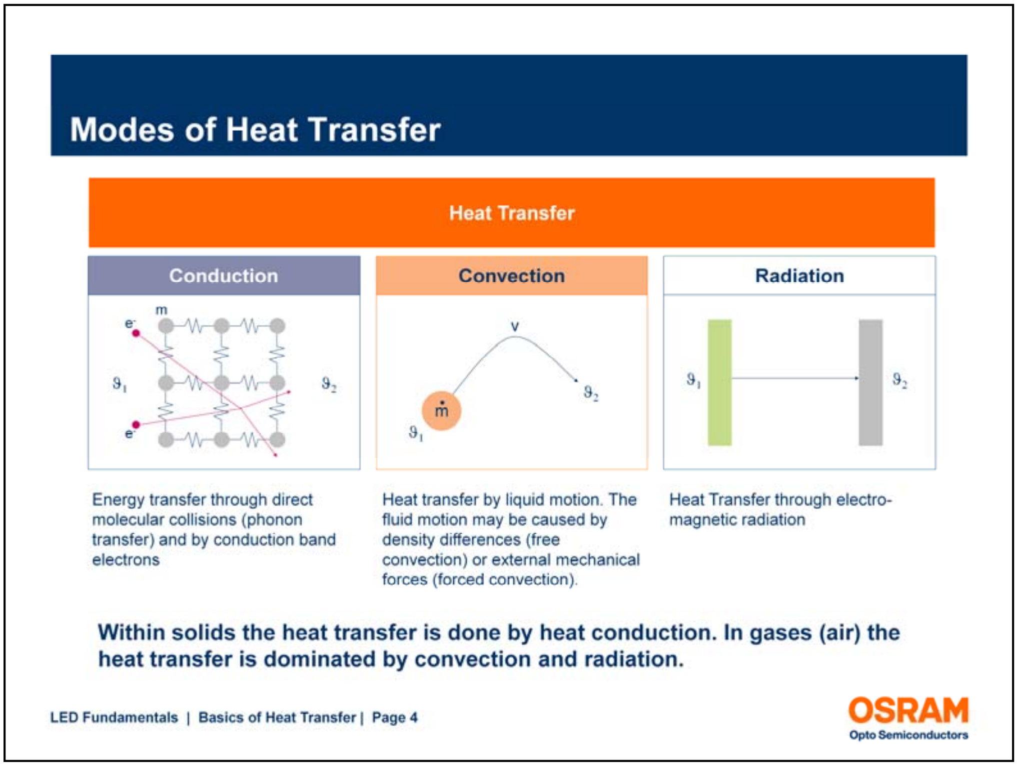
Here are a few basic definitions of heat transfer.

Heat represents the total amount of energy that is transferred between two surfaces by a difference in temperature. The SI unit for heat is joule (J).

Temperature, on the other hand, represents the amount of energy available.

Heat flow or rate of transfer of heat, represents the movement of thermal energy from the areas of high temperature to areas of lower temperature. The SI unit for heat flow is Joule per second or Watts.

Heat flux is defined as rate of heat transfer per unit cross-sectional area, resulting in units of watts per square meter.



The Three modes of heat transfer are conduction, convection and radiation.

Conduction:

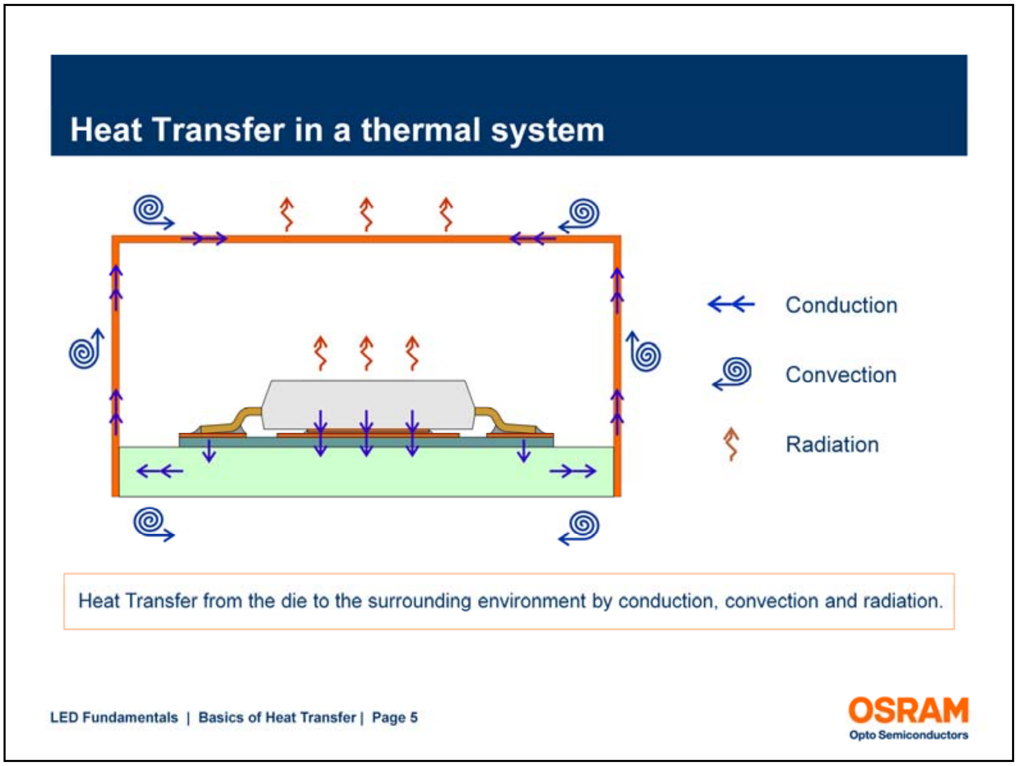
On a microscopic scale, heat conduction occurs as hot, rapidly moving or vibrating atoms and molecules interact with neighboring atoms and molecules, transferring some of their energy (heat) to these neighboring atoms. In other words, heat is transferred by conduction when adjacent atoms vibrate against one another, or as electrons move from one atom to another. Conduction is the most significant means of heat transfer within a solid or between solid objects in thermal contact.

Convection:

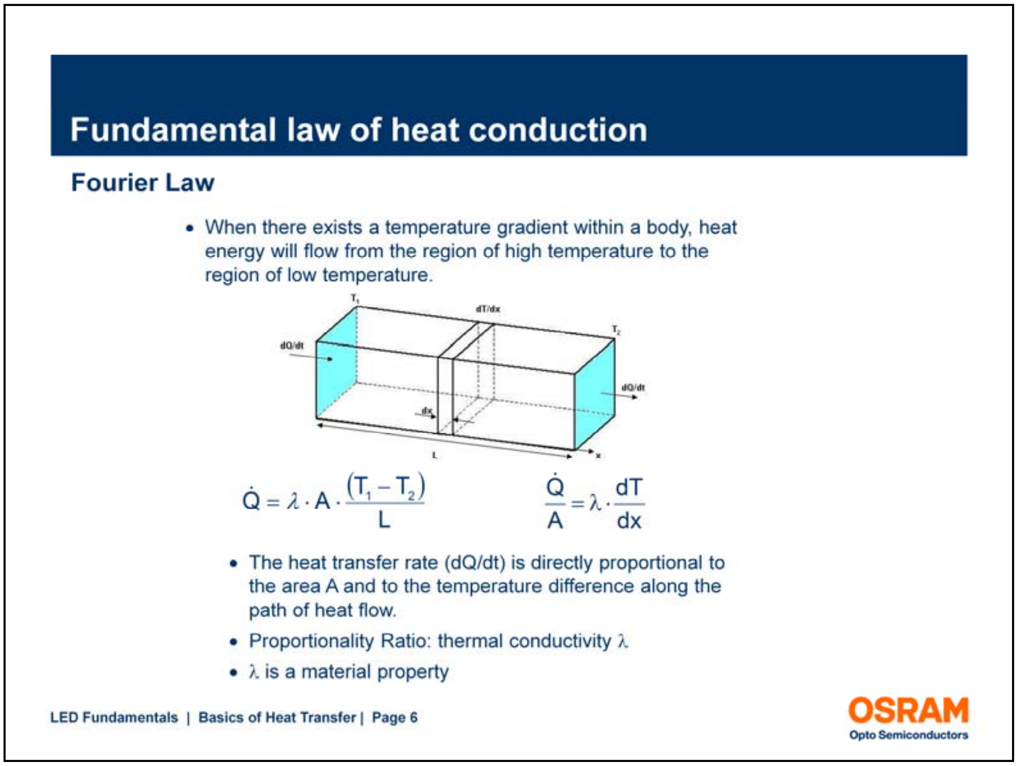
Convective heat transfer is the transfer of heat from one place to another by the movement of fluids. Convection is usually the dominant form of heat transfer in liquids and gases. Free or natural convection occurs when the fluid motion is caused by buoyancy forces that result from the density variations, due to variations of temperature in the fluid. Forced convection is when the fluid is forced to flow over the surface by external sources such as fans, stirrers and pumps, creating an artificially induced convection current.

Radiation:

Thermal radiation is the transfer of heat energy through empty space by electromagnetic waves. All objects with a temperature above absolute zero radiate energy. Thermal radiation is a direct result of the movements of atoms and molecules in a material. Since these atoms and molecules are composed of charged particles (protons and electrons), their movement results in the emission of electromagnetic radiation, which carries energy away from the surface. At the same time, the surface is constantly bombarded by radiation from the surroundings, resulting in the transfer of energy to the surface.



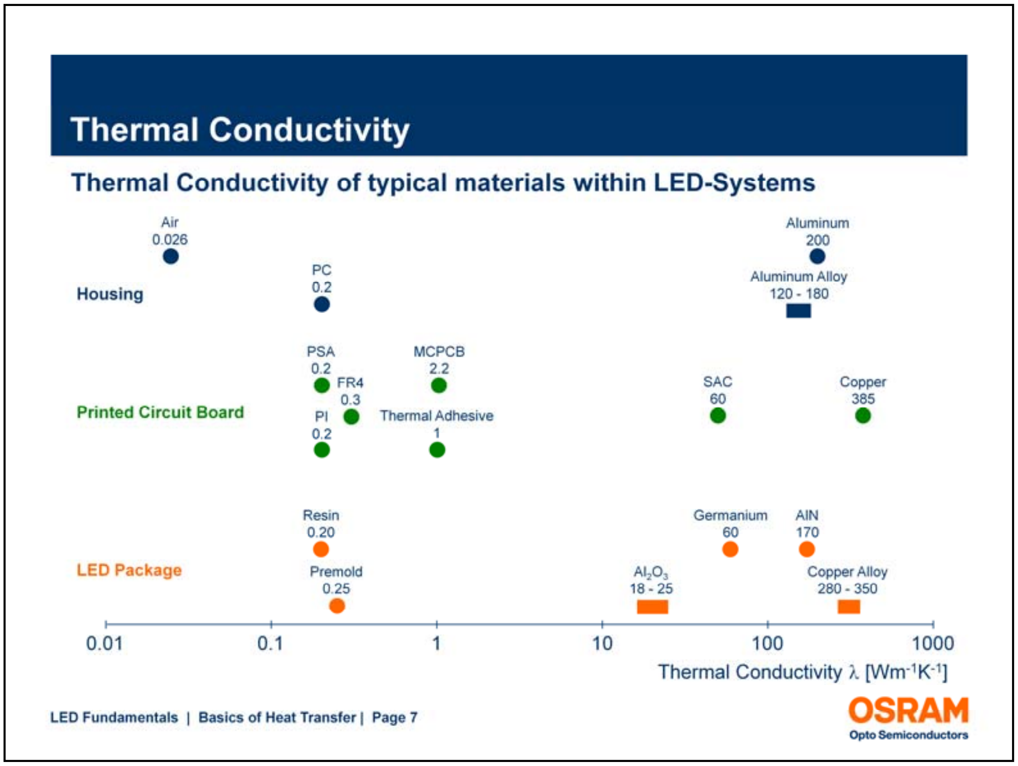
In an LED system all three forms of heat transfer (discussed in the previous slide) play a role in maintaining the temperature of the LED die. Generating a good thermal path from the LED to the environment is critical in maintaining the temperature of the LED.



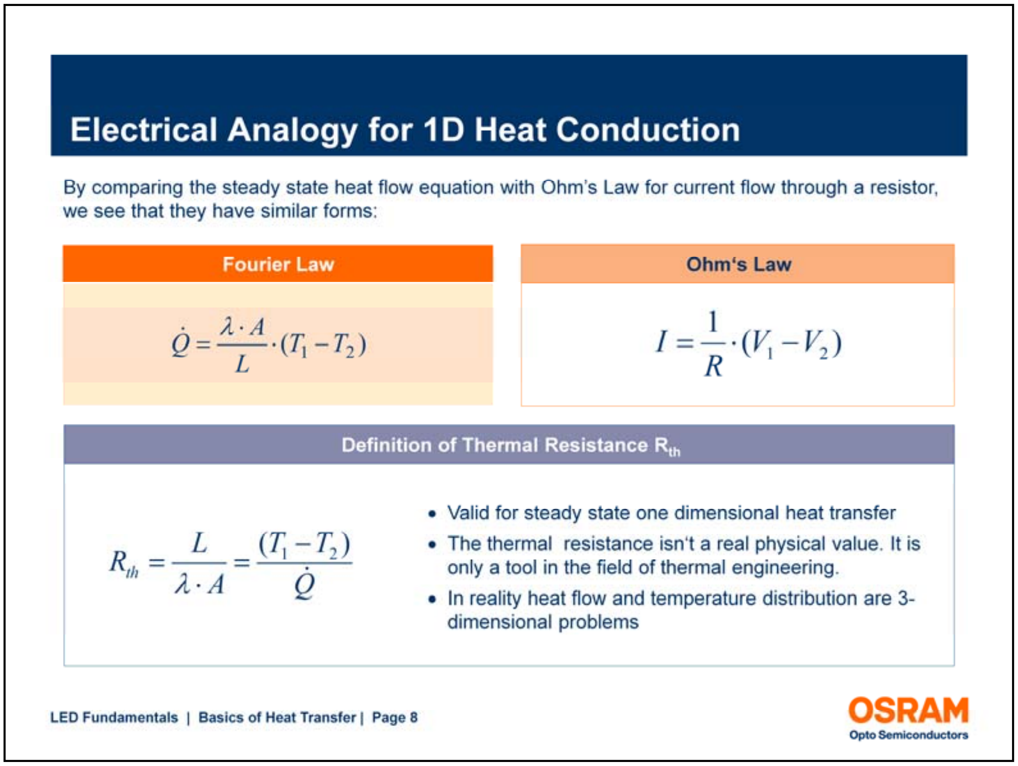
The law of Heat Conduction, also known as Fourier's law, states that the rate of heat transfer through a material is proportional to the negative gradient in the temperature and to the area, at right angles to that gradient, through which the heat is flowing.

The proportionality ratio is called the thermal conductivity and is a property of a particular material.

Thermal conductivity is measured in watts per Kelvin per meter.

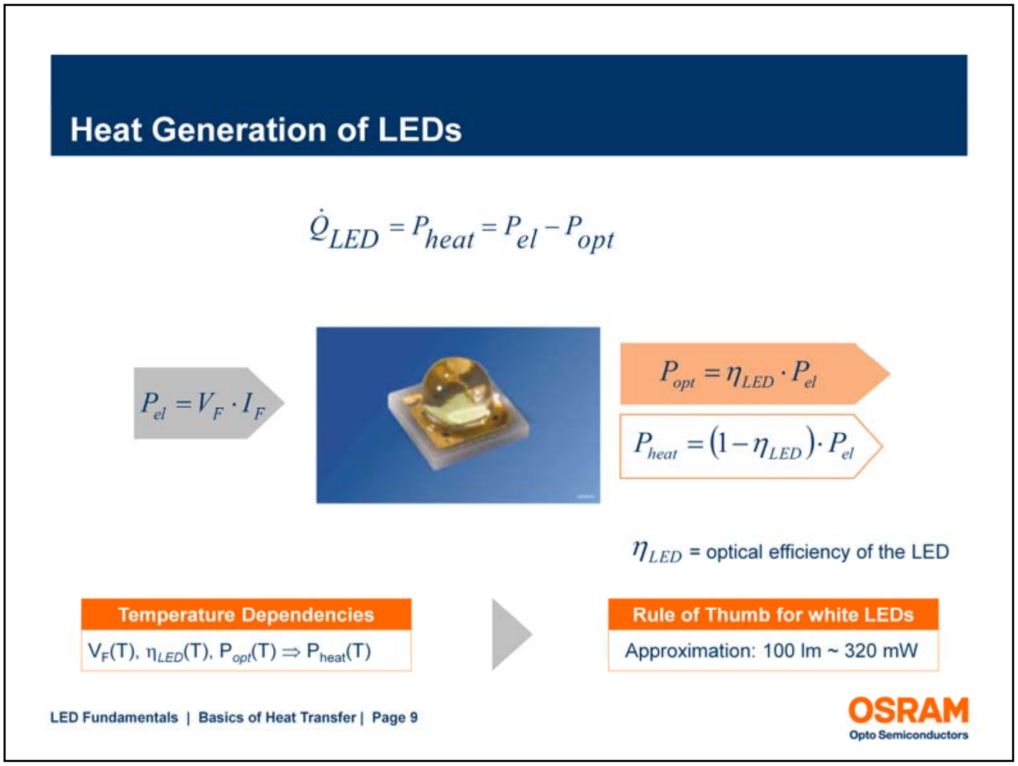


This slide shows the thermal conductivity of typical materials used in an LED system.



An analogy can be drawn between Fourier's Law of heat conduction and Ohm's Law for current flow.

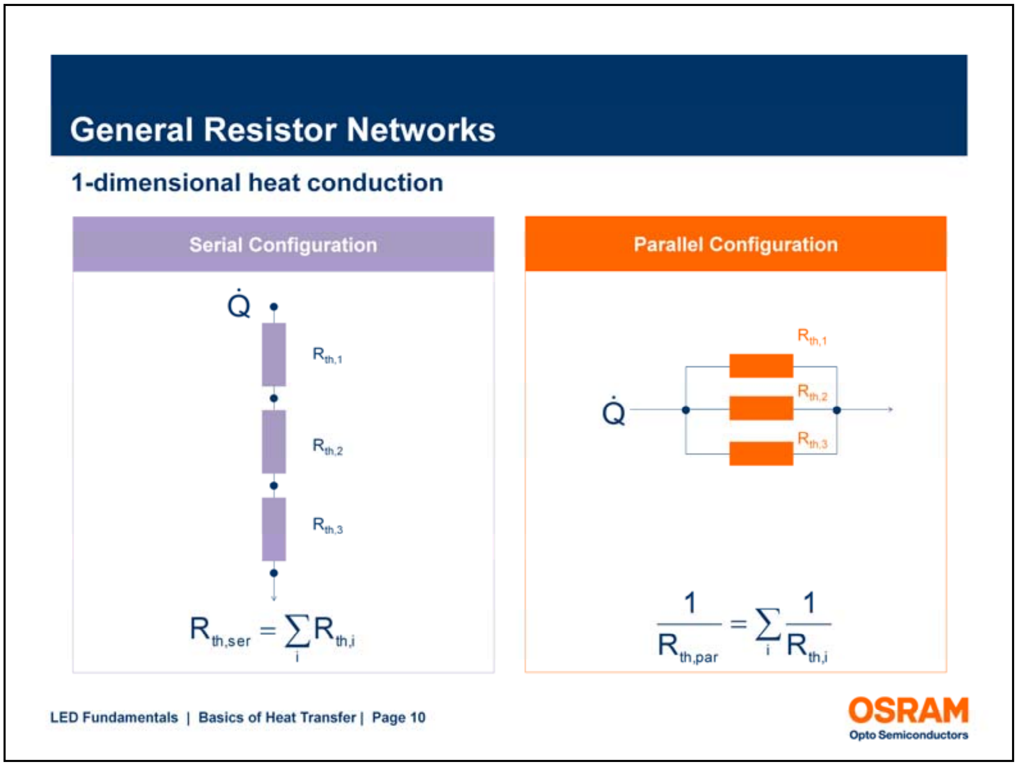
This analogy helps us better understand the definition of thermal resistance.



The heat generation of LEDs is not equal to the supplied electrical energy.

A part of the electrical energy is converted into radiant energy (in the form of light).

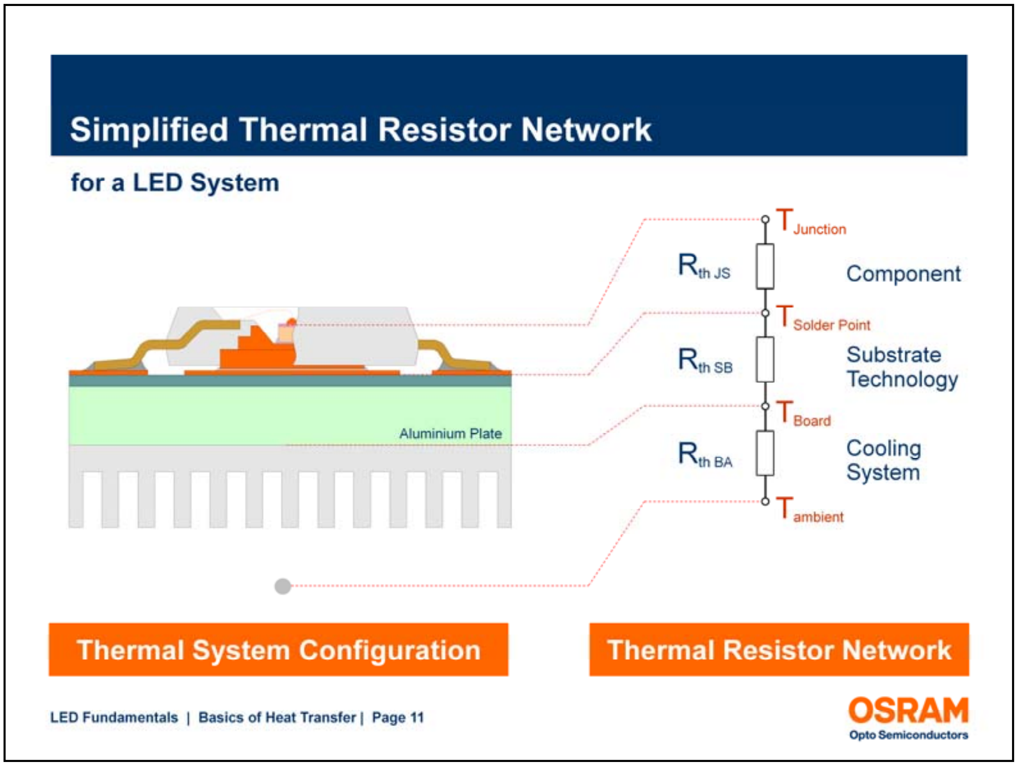
The temperature increase in LEDs is caused by that portion of the power dissipation that is not transformed into light.



The thermal resistances in a system can be represented by Ohmic resistors.

The resistance network is essentially a serial or parallel connection to the ambient temperature.

The effective thermal resistance in a system can be calculated for a serial or parallel configuration.



This illustration shows a simplified network of thermal resistances in an LED system.

The total thermal resistance of the system can be divided into internal and external thermal resistances.

The internal thermal resistance is from the junction to the package of the LED.

The external thermal resistance includes the selection of the cooling mode, heat sink design, selection of substrate material, and attachment process.

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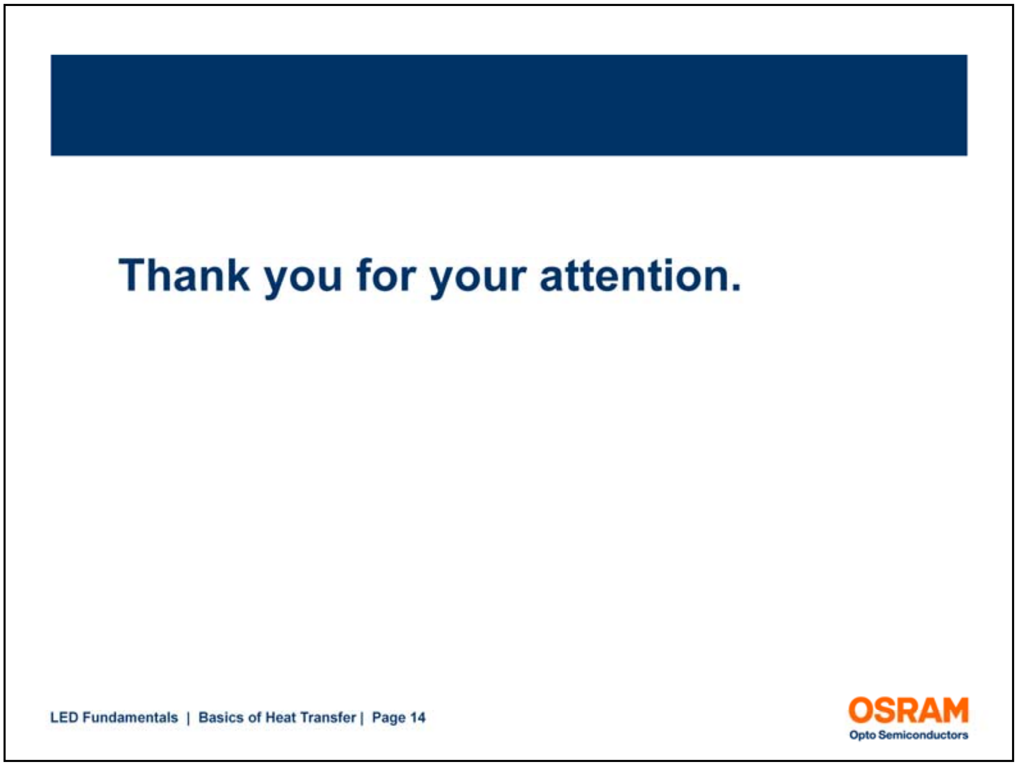

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