*Application Note*

# ***Light Source Detection Using the OPT4003-Q1 Ambient Light Sensor***


**ABSTRACT**

Light sensors are becoming more common in many different applications that need to extract lighting information from the surrounding environment. In addition to intensity and color information, the need to detect the type of light source is becoming more important in many systems. The OPT4003-Q1 is a dual-channel ambient light sensor (ALS) that measures the intensity of both visible and near infrared (NIR) light. This application report describes how to use the information provided by the NIR channel to detect different types of light sources.


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## 1 Introduction

Detecting the type of light that is being produced by a source can be an important feature for different applications. For example, in headlight systems light source detection can be used to distinguish between sunlight and artificial light to more accurately control illumination. Automatic display brightness controls need to adjust differently depending on the type of light in the environment, and it is necessary to distinguish between sunlight and other light sources.

The ratio of visible to NIR light is unique for different light sources, forming the basis of light source detection which is discussed in this report. Figure 1-1 illustrates the various visible to NIR light ratios of common sources. The specific test setup used to collect this data is described in more detail in Section 3.

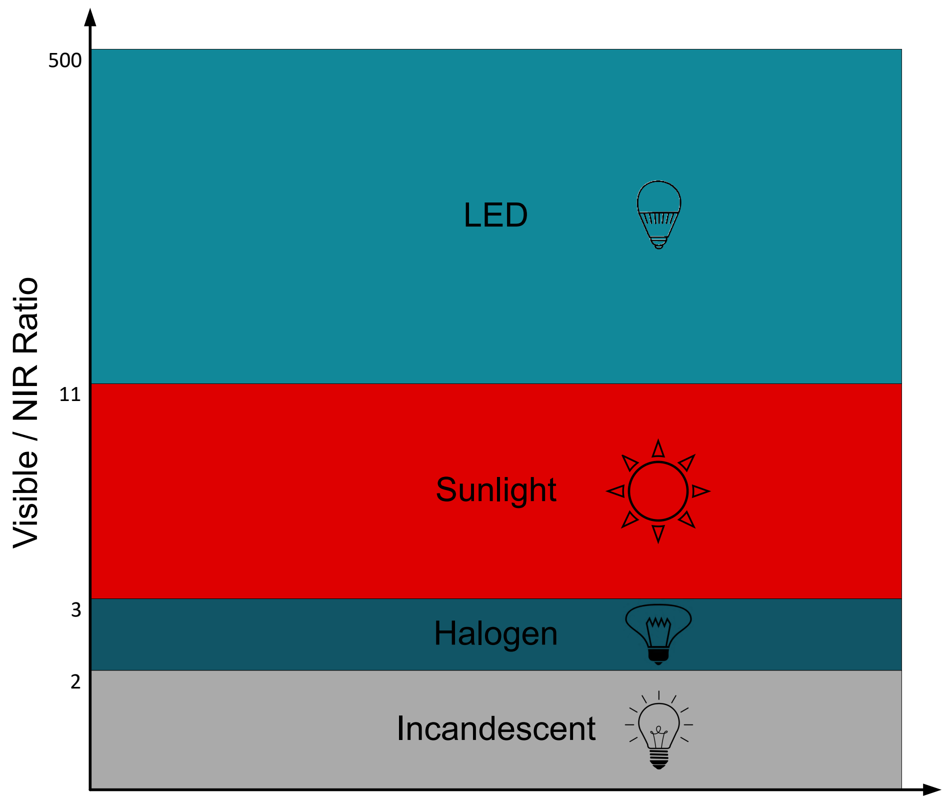


**Figure 1-1. OPT4003-Q1 Visible and NIR Channel Ratios**

## 2 Light Source Detection

Every light source has a unique emission spectrum, and the characteristics of these spectra can depend on the source that is producing the light. For example, an incandescent light bulb produces a spectrum with higher content in the NIR region than an LED light bulb. Focusing on the intensity of ambient and NIR light allows distinctions to be made between various sources. The OPT4003-Q1 NIR channel is crucial in making this determination, since it is only sensitive to wavelengths between 800 nm and 1000 nm. Additionally, the visible channel of the OPT4003-Q1 has excellent NIR rejection and ensures that the spectral response closely matches the human eye. The excellent IR light rejection of the visible channel and visible light rejection of the NIR channel prevents interference between channel measurements. Coupled with the superior sensitivity of these channels, the unique architecture of the OPT4003-Q1 enables reliable light source detection.

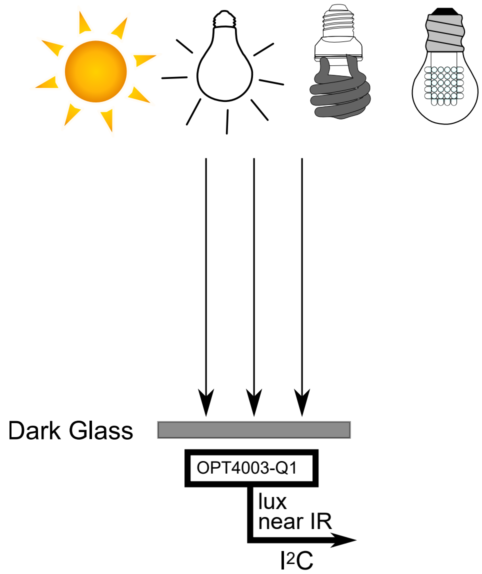


**Figure 2-1. OPT4003-Q1 Typical Application Diagram**

Channel 0 (visible light) and channel 1 (NIR) of the OPT4003-Q1 report ADC codes proportional to the measured light levels. Calculating a ratio of the channel 0 to channel 1 measurements can create a value that is unique to a given light source type. This calculation is shown in Equation 1.

$$\text{light source ratio} = \frac{\text{visible}}{\text{NIR}} = \frac{\text{CH0 codes}}{\text{CH1 codes}} \quad (1)$$

It is expected that LED sources can have similar ratios to each other, and that these ratios can be different from other source types. A measured LED ratio should be much higher than an incandescent ratio, since LED light sources do not produce content in the NIR region. As a result, the visible light measurement can be much larger than the NIR measurement. Refer to Section 5 for more detailed information about the spectra of common light sources.

For more detailed information on device measurements and register structure, please refer to the OPT4003-Q1 data sheet.

## 3 Light Source Ratios

Figure 3-1 shows measured data from the OPT4003-Q1. The ratio of channel 0 codes to channel 1 codes is shown on the x-axis, with the light source categories listed on the y-axis. Each broader category includes different sources, which can be seen in Figure 3-2.

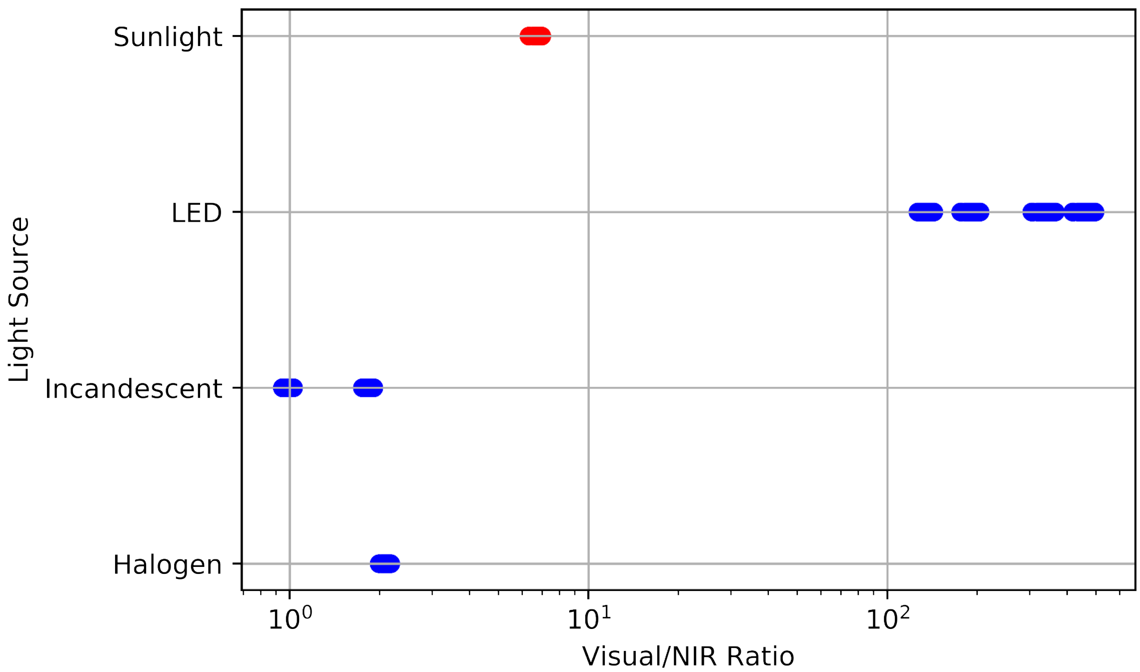


**Figure 3-1. Example of OPT4003-Q1 Light Source Ratios**

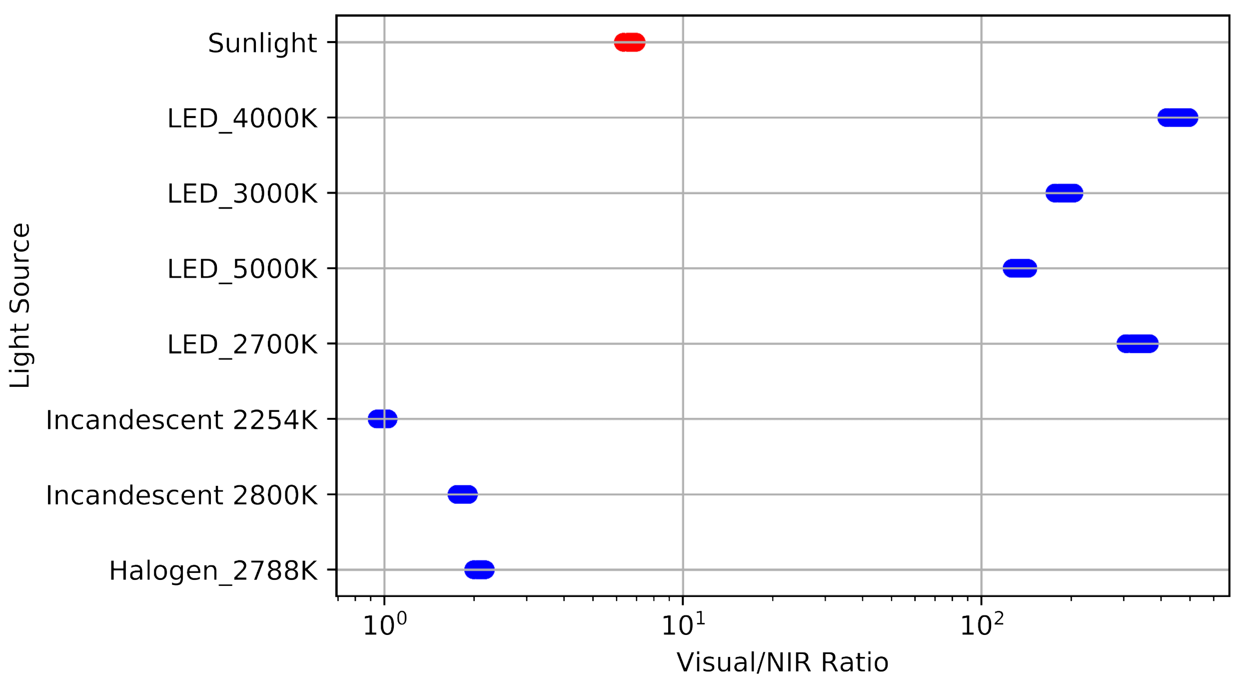


**Figure 3-2. Expanded Example of OPT4003-Q1 Light Source Ratios**

Measurements were taken with twenty-five OPT4003-Q1 devices to make sure of stability across units. The resulting light source ratios have clear and defined boundaries. For this data set, thresholds can be created to identify sunlight versus artificial sources.Table 3-1 lists the minimum and maximum ratios of all the indiviudual sources shown in Figure 3-2. The variation of ratios in each category is due to different color temperature sources being grouped together.

**Table 3-1. OPT4003-Q1 Test Data Ratios**

| Source | Minimum Measured Ratio | Maximum Measured Ratio |
|---|---|---|
| Sunlight | 6.31 | 6.97 |
| LED | 126.52 | 495.19 |
| Incandescent | 0.94 | 1.91 |
| Halogen | 1.99 | 2.18 |

Specific distinctions can be made by defining thresholds for each light source category, following the same pattern shown in the block of code below.

```
if (ratio > 2.2 and ratio < 11):
     source = sunlight
else:
     source = artificial
```

## 4 Design and Calibration Considerations

There are key concerns regarding the electromechanical design of any ambient light sensing system. Proper design can make sure that there is enough light transmission for proper operation, and system-specific calibration can help make sure of the performance.

### 4.1 Cover Materials

In many ambient light sensing applications, the sensor is placed behind a dark glass for aesthetic purposes. The material type and spectral transmission properties will determine the level of overall light transmission. In any application, the OPT4003-Q1 sensor area must be centered with respect to any window opening. These dimensions are described in Figure 4-1, with the channel 0 photodiode indicated with light gray and the channel 1 photodiode indicated with dark gray. Refer to Section 10 of the OPT4003-Q1 data sheet for complete package dimensions.

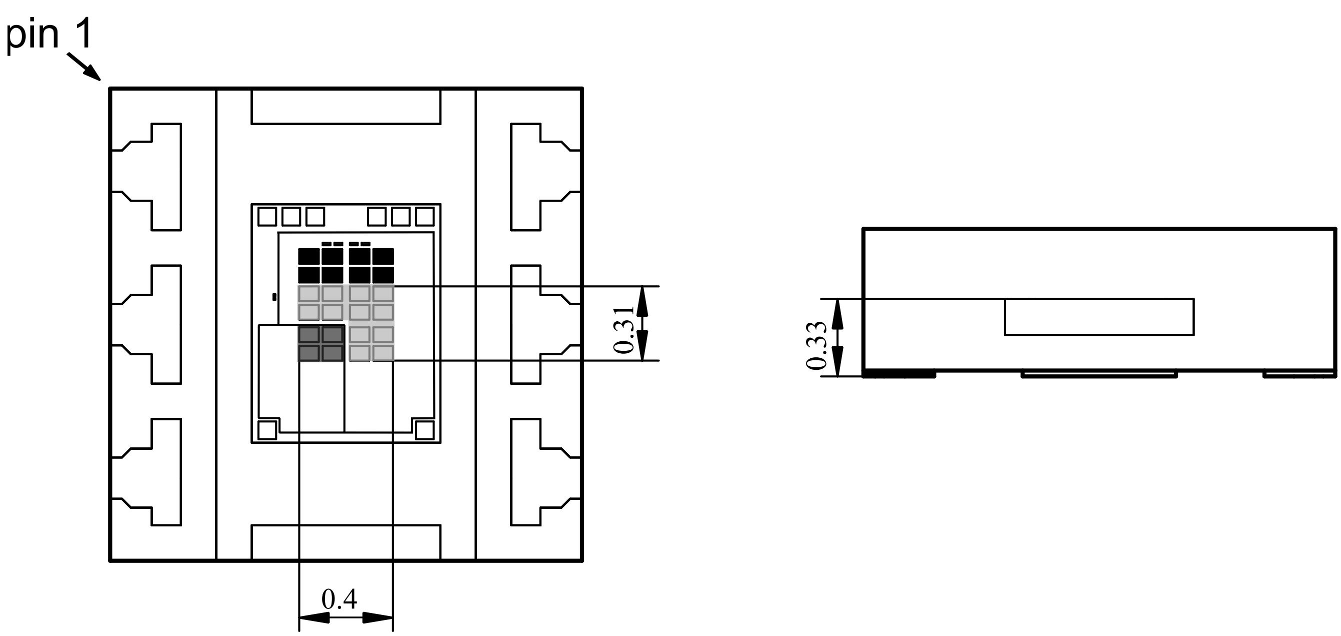


**Figure 4-1. OPT4003-Q1 Sensor Position**

Dark materials allow less light to illuminate the sensor, impeding accuracy. Choosing a material that is dark enough to optimize the balance between the aesthetics of the device and sensor performance is important.

In automotive applications that require light source detection the OPT4003-Q1, can be placed behind the windshield, in addition to dark cover glass.

Dark inks used on cover materials typically pass 2% to 20% of the light incident, reducing the amount of light hitting the sensor and reducing low light sensitivity of the sensor.

For example, if the ink transmits 2% of ambient light at 50 lux, the sensor can only see 1 lux. System resolution can be calculated using Equation 2, based on the transitivity of the cover material.

$$\text{Resolution}_{\text{System}} = \frac{\text{Resolution}_{\text{Sensor}} \times 100}{\%\ \text{Transmission}} \tag{2}$$

For more detailed information regarding proper window sizing and cover glass compensation, please refer to the *Ambient Light Sensor Application Guide*.

## 4.2 Cover Glass Application Example

To illustrate the effect of cover glass on the calculated visible/ NIR ratios, a 3000K LED bulb was used to illuminate the OPT4003-Q1. The initial measurements were taken without a window or cover glass to attenuate light transmission.

The sensor output was recorded, and then the testing was repeated with a 0.1% transmission cover glass placed on top of the sensor. The measurements for both cases were compared and used to calculate the CH0 / CH1 ratio across samples. Table 4-1 shows the observed change in ratio.

**Table 4-1. OPT4003-Q1 Visible / NIR Attenuation, 3000K LED Bulb**

| | Average ALS Response | Average NIR Response | ALS / NIR |
|---|---|---|---|
| No Cover Glass | 6577341 codes | 21715 codes | 303 |
| Cover Glass | 9361 codes | 113 codes | 83 |

The dark cover glass prevents a portion of visible light from reaching the sensor and results in signal attenuation. Depending on the characteristics of the chosen cover glass, the attenuation of visible and near infrared light can vary. Therefore, it is important to consider how the cover glass affects both the visible and near infrared channels before setting light source detection thresholds.

# 5 Near Infrared Components of Common Light Sources

Spectral plots show the amount of power that is radiated at each wavelength. Different light source types can have different spectral plots because of the way the light is produced. This section discusses the illumination mechanisms of common light sources, as well as the corresponding spectral plots. Each spectral plot shows wavelength in nanometers on the x-axis and relative intensity on the y-axis. The y-axis has been normalized to the peak intensity, allowing each plot to be directly compared.

For more information on types of light sources, please refer to the Fundamentals of Light Sensing chapter in the Ambient Light Sensors video series.

### 5.1 Incandescent

Incandescent bulbs produce illumination by running an electrical current through a tungsten filament. The filament is heated, typically between 2,000 and 3,000 Kelvin, and the inert gas inside the bulb reacts with the tungsten to produce a spectrum that radiates in the visible light region. This visible spectrum is what causes the filament to illuminate, although the peak of the intensity is in the infrared region. The spectral plot of a 2254K incandescent bulb can be seen in Figure 5-1.

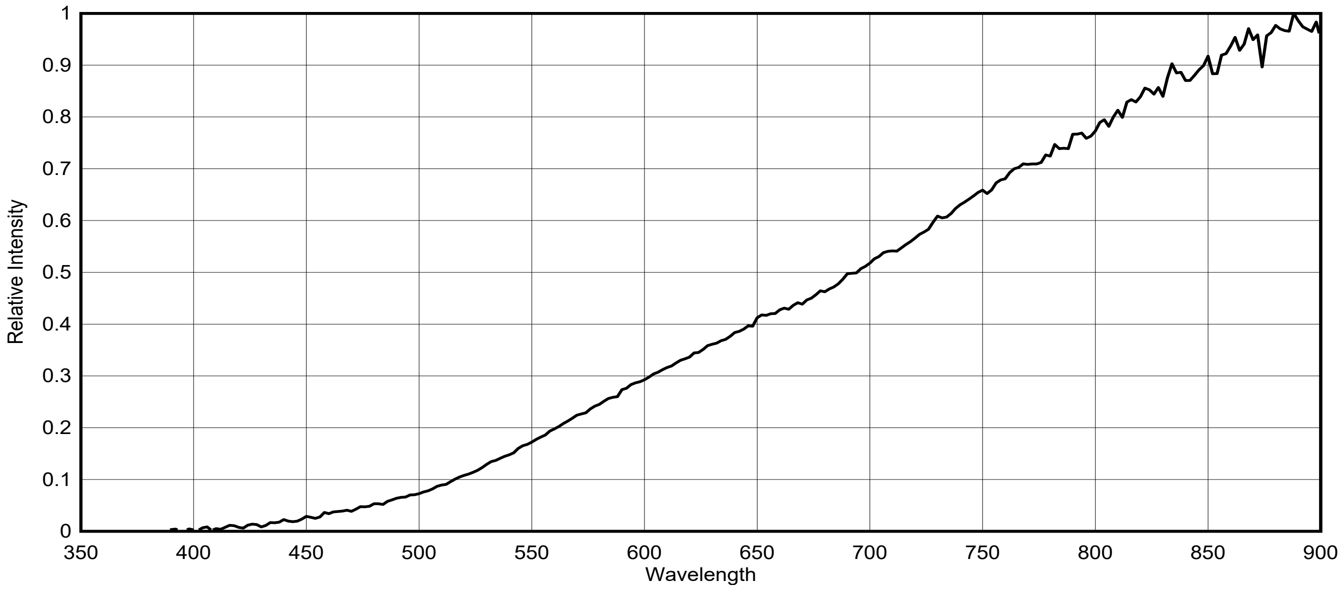


**Figure 5-1. 2254K Incandescent Bulb**

### 5.2 Halogen

Halogen light sources are similar to incandescent sources in that halogen lights contain tungsten filament, except a halogen bulb contains halogen gas instead of the inert gas used in incandescent bulbs. The filament in halogen light bulbs typically operates at temperatures over 2,700 Kelvin, producing a spectrum that is shifted left toward the lower wavelengths of the visible region. An example spectral plot can be seen in Figure 5-2, showing that the spectrum of a halogen light bulb peaks in the NIR region.

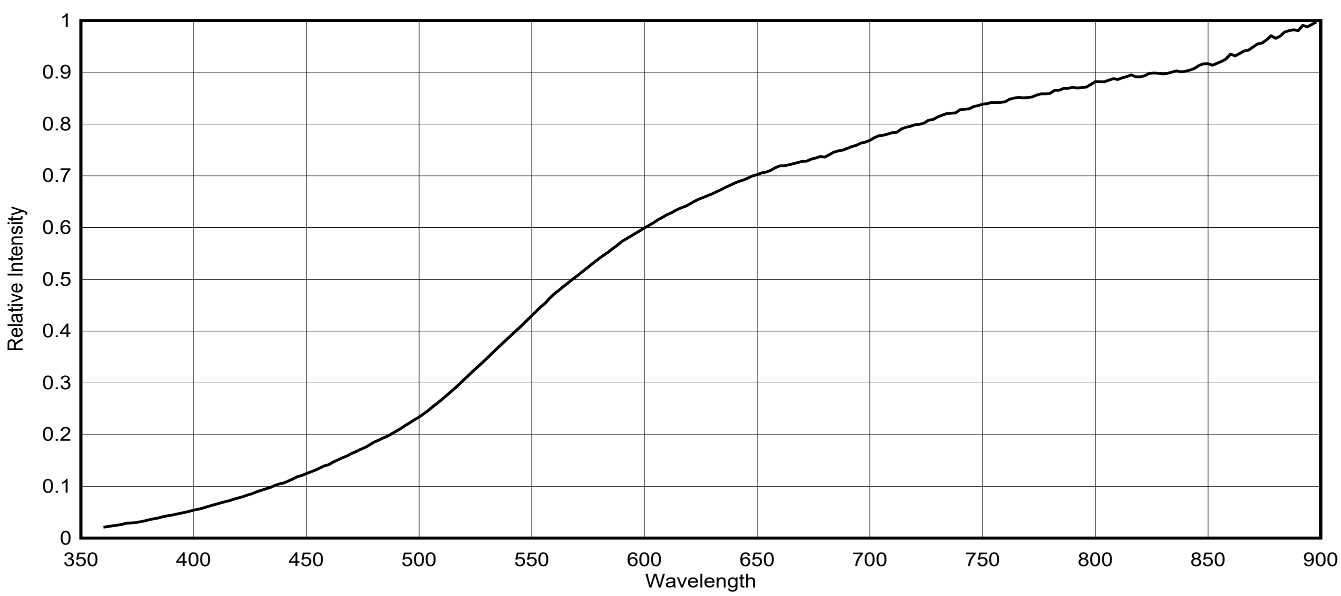


**Figure 5-2. 2788K Halogen Bulb**

## 5.3 Light Emitting Diode

Light emitting diode, or LED, light sources are able to produce light from the electrons passing through the PN junction of the diode. There are many different types of LEDs that produce different wavelengths of light. White LEDs are a combination of different LEDs with unique spectra, combining to produce a white light color.

An LED bulb with more blue tones can have a higher correlated color temperature (CCT). Figure 5-3 shows the spectral plot of a 5000K LED bulb, and Figure 5-4 shows the spectral plot of a 2700K LED bulb. From these images, it can be observed that the spectrum of the 2700K bulb is shifted to the right, toward the longer wavelengths. Neither spectral plot has significant content in the NIR region, which is characteristic of all LED light sources.

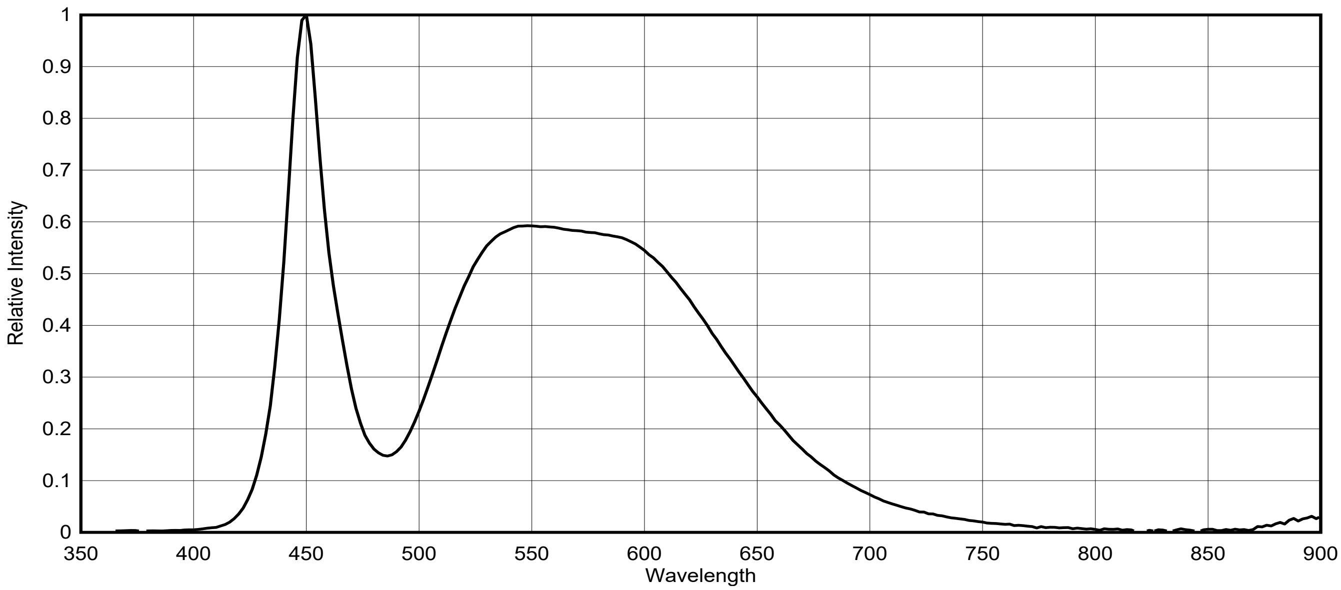


**Figure 5-3. 5000K LED Bulb**

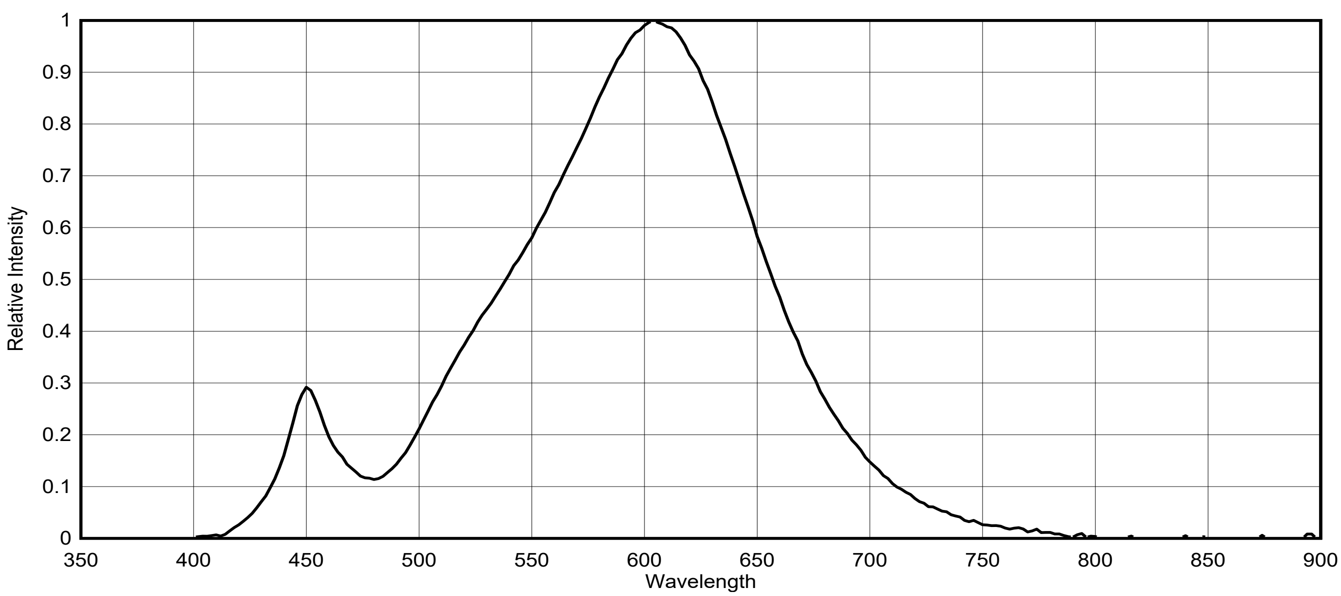


**Figure 5-4. 2700K LED Bulb**

## 5.4 Fluorescent

Fluorescent light bulbs contain mercury gas inside of a tube that is coated with a fluorescent material. Fluorescence is the process by which electrons in an atom absorb a shorter wavelength of light and emit a photon of a longer wavelength of light.

The mercury gas inside the bulb produces ultraviolet (UV) light when exposed to an electric current, and this UV light reacts with the fluorescent coating to produce visible light.

The distinct peaks in the spectra of fluorescent bulbs are a result of the specific emission wavelengths of the electrons. These peaks can be seen in the spectral plots shown in Figure 5-5 and Figure 5-6. This unique spectrum can make it more difficult to identify light generated from fluorescent tubes or compact fluorescent light (CFL) bulbs.

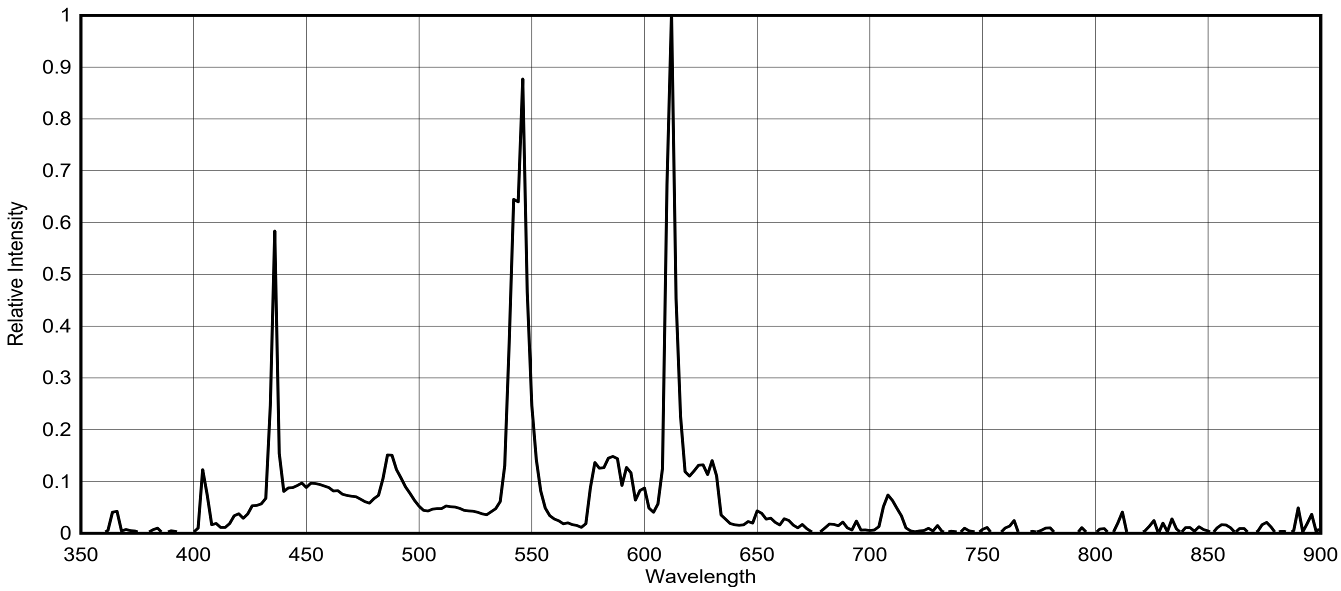


**Figure 5-5. 5000K CFL Bulb**

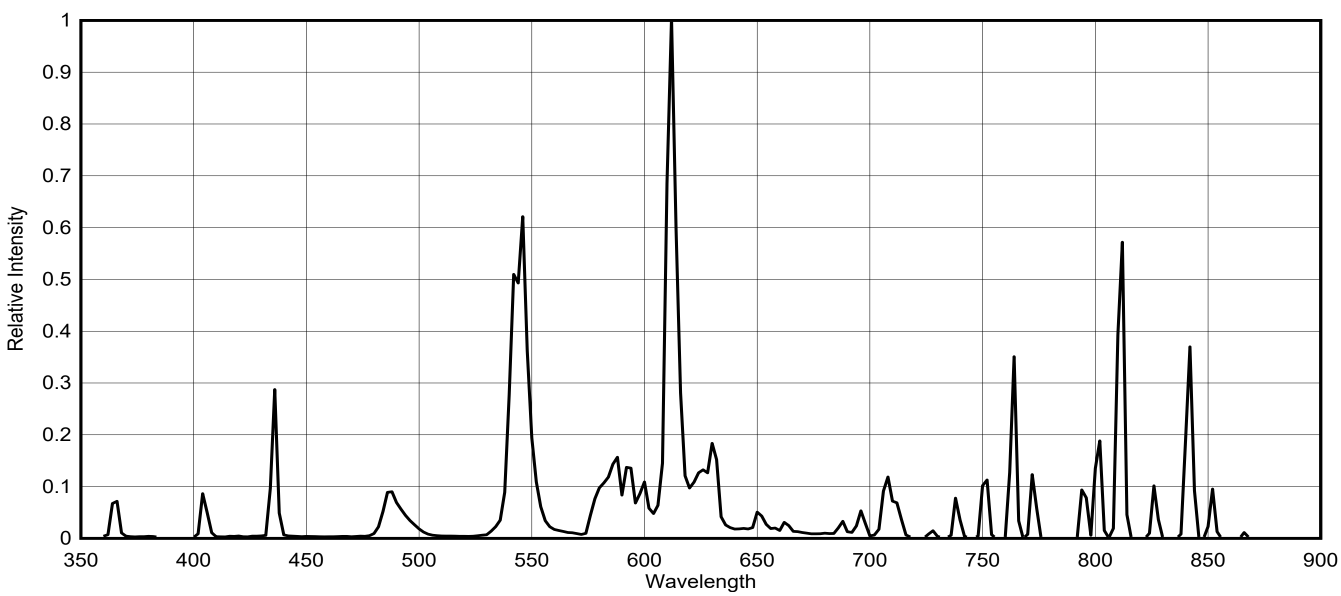


**Figure 5-6. 2700K CFL Bulb**

### 5.5 Sunlight

The sun emits a wide range of wavelengths across the electromagnetic spectrum, but the focus of this report can be on the visible and near infrared components of sunlight. Figure 5-7 shows a spectrum that was measured outside during lightly cloudy conditions.

Many of the wavelengths emitted by the sun are in the visible light spectrum, but there is a large near infrared component that can be seen in sunlight spectral plots.

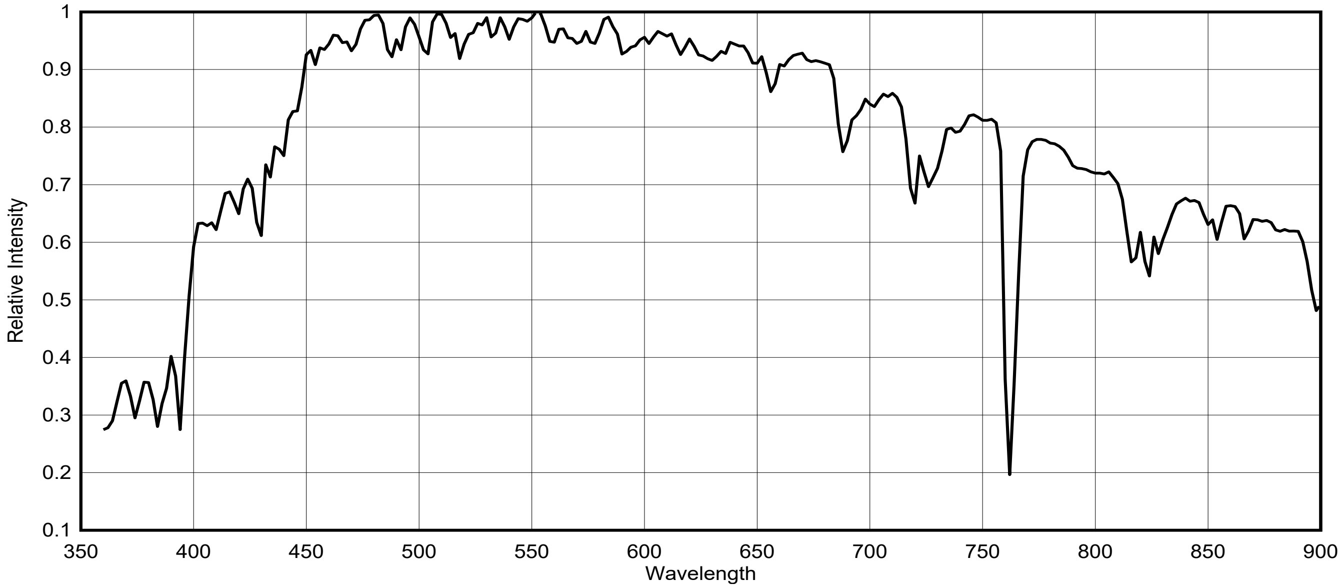


**Figure 5-7. Sunlight**

## 6 Summary

Light source detection can be an important part of systems that require additional environmental information to make lighting decisions. The harsh glare that sunlight creates on a display can create worse user conditions than an equally bright LED source. Identifying sunlight can ensure that the display is readable. Automotive headlight systems can make intelligent choices by differentiating between daylight and LED-illuminated tunnels, making sure that the headlights stay on in bright tunnels. The sensitivity and superior rejection of the OPT4003-Q1 visible and near infrared channels enable systems to use light source detection algorithms, allowing for these more advanced lighting decisions.

## 7 References


- Texas Instruments, *OPT 4003-Q1 Automotive High-Speed, High-Precision, Digital Ambient Light Sensor* data sheet.
- Texas Instruments, *Ambient Light Sensor Application Guide* application note.
- Texas Instruments, *Ambient Light Sensors* video series.