Application Note

AN001054

AS7341 Details for Optomechanical Design

Calibration

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Content Guide

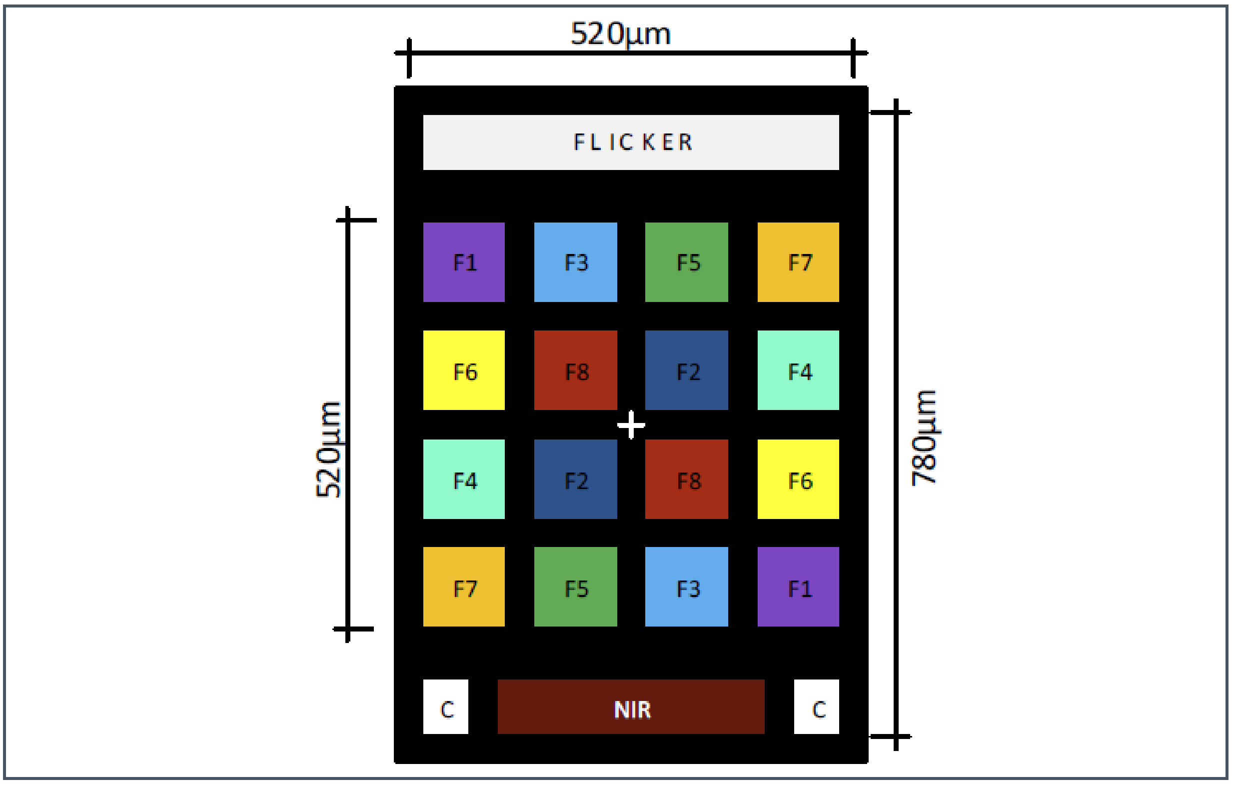
1 Introduction

This application note describes the most important optical and mechanical parameters that are needed to be considered when designing the AS7341 into an application-specific sensor system.

2 AS7341 Sensor Chip

The AS7341 is an optical multi-channel sensor with eight spectral channels in the visible light range (VIS), a NIR channel, and an open channel for flicker detection. The VIS channels are arranged in a 4 x 4 matrix with two photodiodes per channel. The NIR and flicker channels have one big photodiode, each placed next to the matrix.

Figure 1:
AS7341 Sensor Array



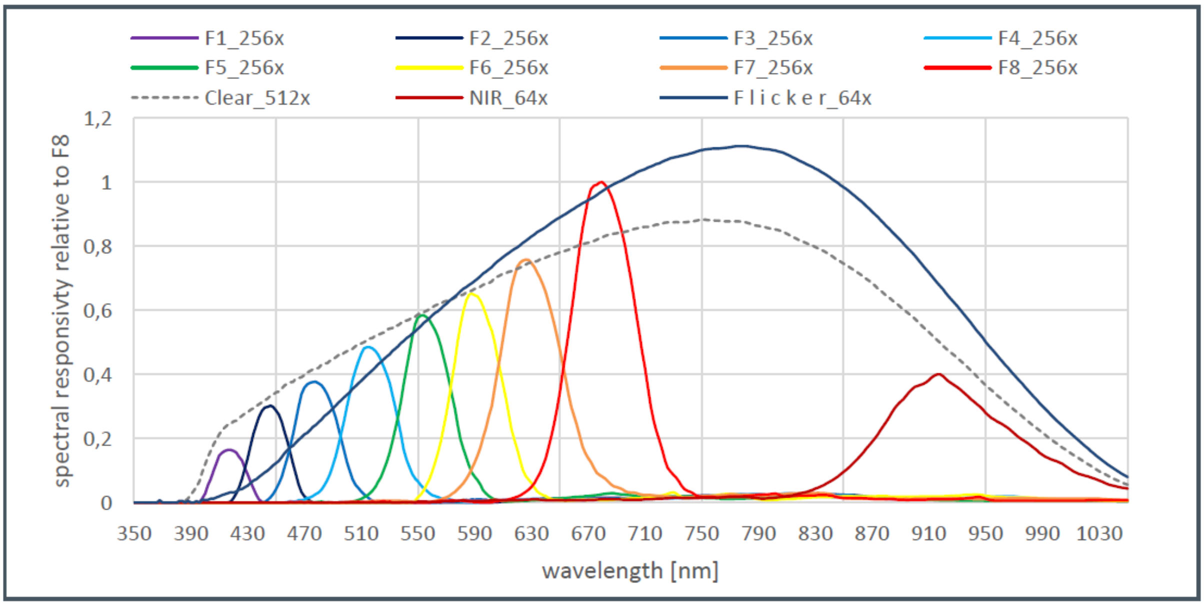
The AS7341 integrates interference filters into standard CMOS via nano-optic deposited interference filter technology. These filters are stable over a lifetime without any drifts. They are designed as spectral filters with an even arrangement over VIS and one filter in NIR.

The optical filter characteristics, such as irradiance responsivity, center wavelength, and FHWM are listed in the AS7341 datasheet [1]. Please take a note of the minimum and maximum values that are specified, based on the series deviations.

The data for responsivities of the spectral channels were defined under specific conditions Therefore, the measured values may deviate from these values under changed conditions.

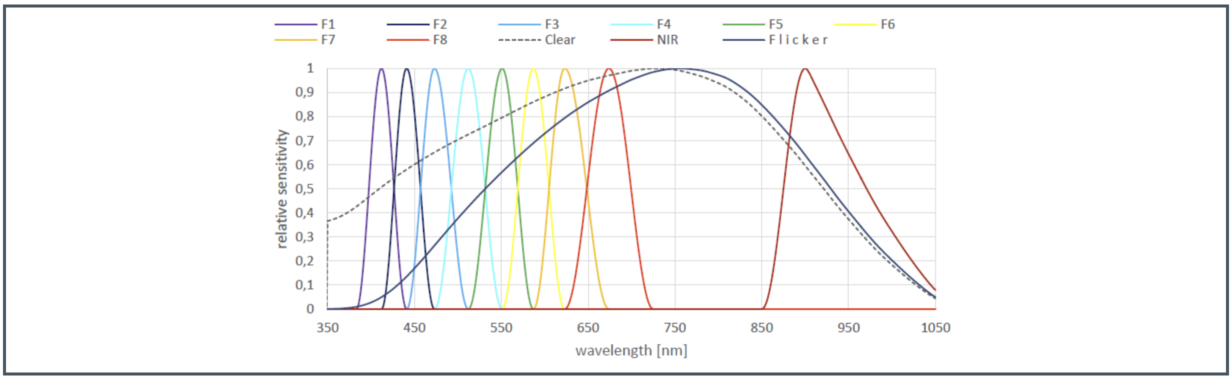
The same applies to the electronic amplifier/converter results (exclude the AutoZero function on the chip) and temperature dependencies. We recommend that such variations should be investigated and corrected in the overall system. For more details, please check the datasheet [1].

Figure 2:
Measured Spectral Responsivity Relative to F8(1)



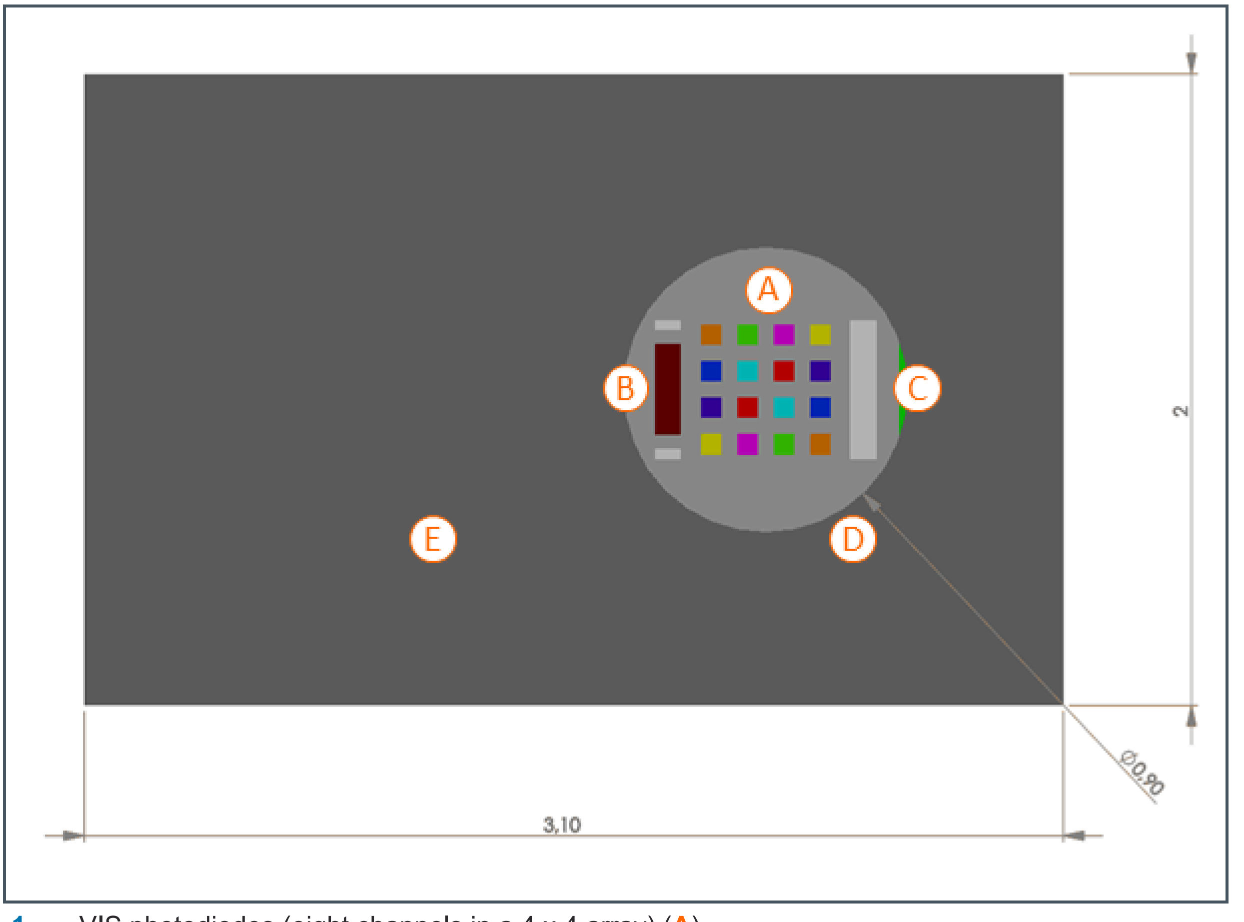
(1) Fx_256x…AGAIN = 256x, diffuser mounted on top of the surface of the package.

Figure 3:
Normalized Spectral Responsivity



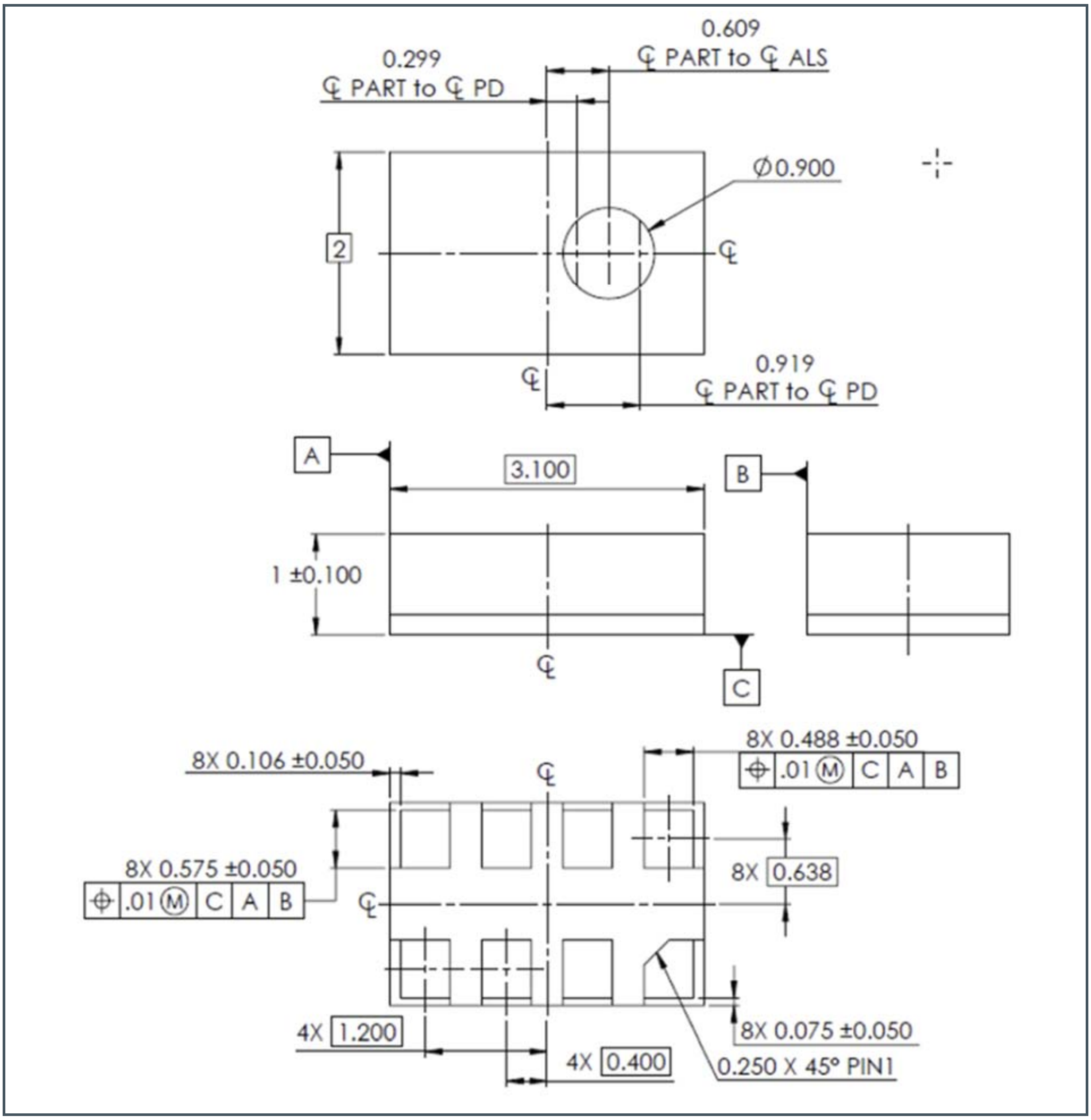
The device is available in an ultra-low profile package with the dimensions 3.1 mm x 2.0 mm x 1.0 mm. For more details on the dimensions and position of the photodiodes, please see Figure 4 and Figure 5.

Figure 4:
Top View of the AS7341 Sensor (all dimensions in millimeters)



1 VIS photodiodes (eight channels in a 4 x 4 array) (**A**)
2 NIR photodiode (**B**)
3 Flicker detector photodiode (without a filter) (**C**)
4 Sensor aperture/pinhole (**D**)
5 Sensor package (**E**)

Figure 5:
Top View of the AS7341 Sensor (all dimensions in millimeters)



3 Optical Diffuser Requirements

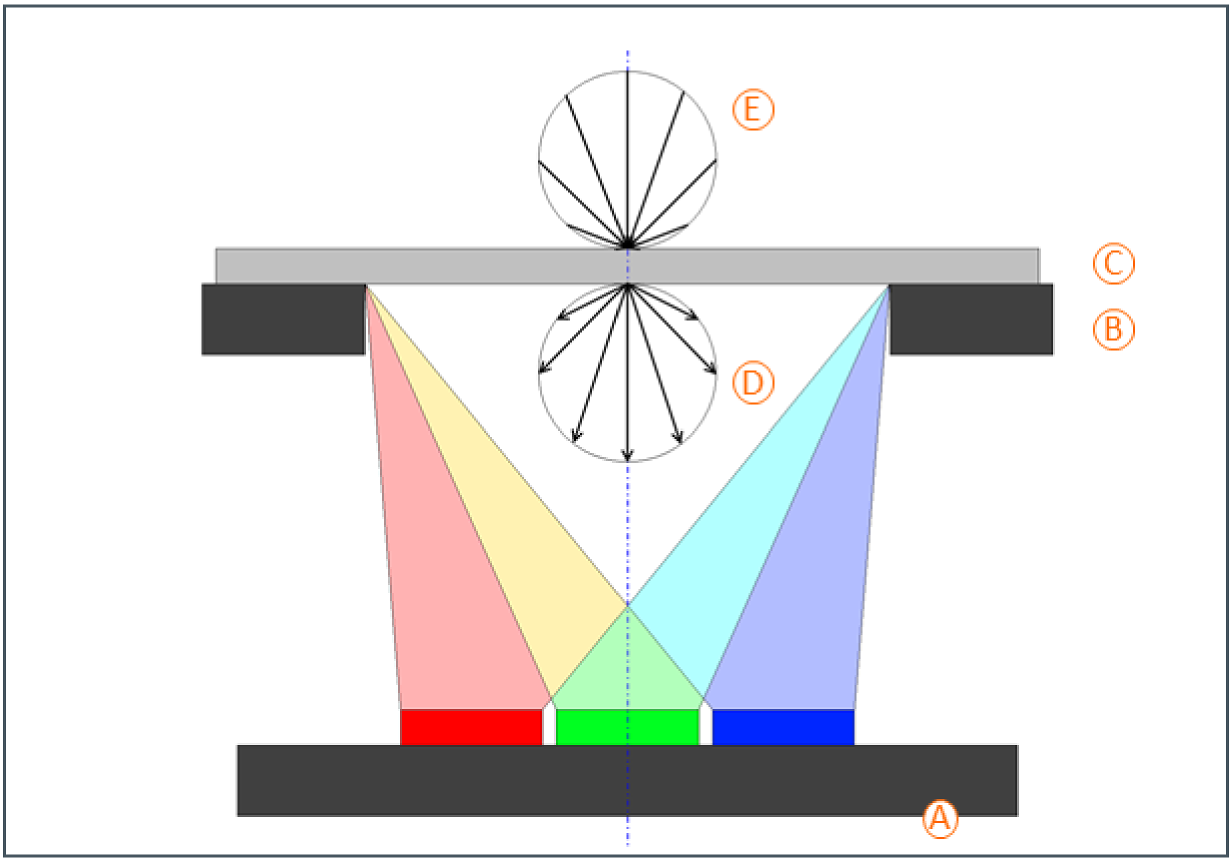
The photodiodes within the AS7341 have a near-cosine response to incoming light. Color filters used for the channel separation are specifically designed interference filter stacks on top of the photodiodes. Due to physical effects in the filter stacks, the interference filters are only designed for a limited range of the angle of incidence (AOI) and expect a Lambertian power distribution.

The maximum angle of incidence to the photodiodes is limited to the design requirements of the filter stack by the aperture/pinhole of the package. The rays with the most obtuse angle hit the edges of the photodiodes from the opposite edge of the aperture (Figure 6).

To meet the requirements of power distribution, it is necessary to use an achromatic diffuser that emits light with a Lambertian characteristic to the sensor independent of the angle of incidence. The minimum scatter characteristic is shown in Figure 7. If the diffuser is placed very close to or directly on the AS7341 package, its structure has to be very fine to get the same distribution to each photodiode of the detector array.

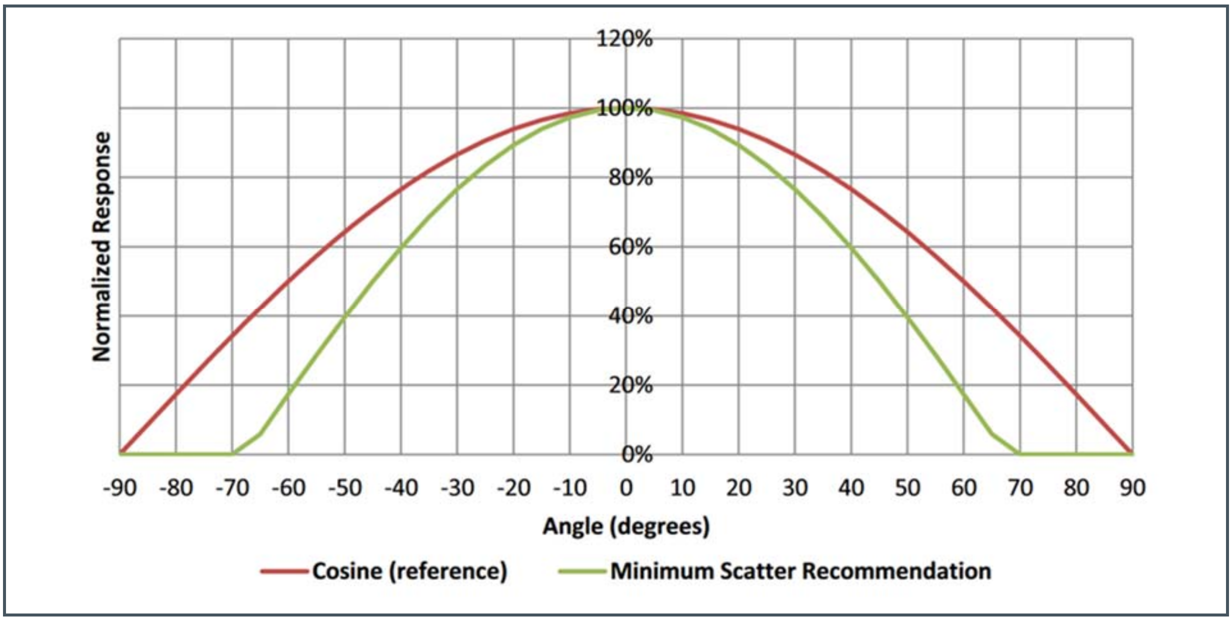
It is also important to note that the technical parameters listed in the datasheet [1] apply to a diffuser in front of the sensor. Different diffusers, and the use without a diffuser, lead to different sensor parameters.

Figure 6:
Vertical Cross-Section of the Structured Color Sensor with a Perfect Diffuser



1. Photodiode array (structured detector) (**A**)
2. Aperture/pinhole in the package (**B**)
3. Diffuser with a perfect cosine power distribution (**C**)
4. Cosine power distribution on the sensor side – the usable range of angles depends on the maximum angle of incidence of the filters and defines the efficiency of the sensor system. (**D**)
5. Angular response of the sensor system, including the diffuser, is independent from the sensor AOI; vector length is equivalent to the response; the highest response for the normal input and the decreasing response for increasing angles. (**E**)

Figure 7:
Diffuser Characteristics: Cosine and Minimum Scatter Recommendation



A recommended diffuser is pre-mounted on the AS7341 evaluation kit, directly above the sensor using two simple plastic shells as a diffuser holder and adapter, which are fixed on the evaluation kits by two bolts and nuts. During the new installation of the diffuser holder, ensure that the diffuser is correctly placed between the upper and lower plastic holder. Fix the bolts and nuts by hand and check that all are fixed. Ensure not to touch the optical diffuser with your fingers.

Figure 8:
Installation of the Diffuser Holder on the AS7341 EVK

- Please note that the diffuser specification depends on the customer application and planned position in front of the sensor. Therefore, check the technical parameters of the standard diffuser (see Figure 9 for the technical details) before starting any tests. Select a diffuser with sufficient diffusing power such that the sensor has a smooth angular response (no spikes in the angular response curves) exceeding ±45° (FHWM). Limited tests of the diffuser can be made using the AS7341 EVKs.
- The diffuser in the EVK can be changed quickly and easily. Ensure not to touch the diffusers with your fingers during any mounting activities. The surface of the diffusers is very sensitive, and any touch, mechanical stress, or dirt can dramatically change the optical behavior. Changing and reassembling the diffuser typically changes the calibration parameters and requires recalibration for optimal results.

Figure 9 lists the recommended diffuser parameters and/or the parameters of the Kimoto diffuser used in the AS7341 EVK.

Figure 9:
Diffuser Parameters

Parameter	Value
Diffuser material	Kimoto 100 PBU
Diffuser thickness	125 microns
Transmission	66%
Haze	89.5%
Half-angle	35.5°

4 Diffuser Types and Recommendations for Selection

For application in front of the AS7341, a translucent diffuser is required, which uses scattering centers to spread incoming directed light in pseudorandom directions. These scattering centers can be tiny surface structures on the top (e.g. grounded glass) or small white particles inside (e.g. opal glass) the diffuser. This property can be used to divide diffusers into two main groups: surface diffusers and volume diffusers.

4.1 Surface Diffusers

Surface diffusers usually consist of a clear base material, which is structured on one or both plane surfaces. The structures are microscopically small and random to refract incoming light depending on the orientation of every single ray towards the surface segment where it hits the diffuser. According to Snell's law, the level of refraction also depends on the wavelength, which could cause chromatic aberrations in the border regions. Scattering is often enhanced by structuring the input and output surface of the diffuser, which leads to multiple refractions and partly to internal reflections. Due to refraction as the main effect, the transmission efficiency can be very high for diffusers with a narrow radiation pattern and is superior to volume diffusers with a wider radiation pattern. Regarding the angular limits of surface structures and the lower count of interactions, surface diffusers do not reach perfect cosine characteristics.

The parameters of the diffusers are typically determined with far-field measurements. For surface diffusers, these parameters are usually scaled with the resolution/size of the structures. This makes it necessary to prove the chosen diffuser individually for the use case.

A double-sided surface diffuser with a wide radiation pattern used by ams OSRAM is "Kimoto 100 PBU", with a thickness of 125 micrometers.

4.2 Volume Diffusers

In volume diffusers, incoming light is scattered when it hits a scattering center within it. The scattering centers are typically microscopic small white particles. Depending on the design, each particle can generate a Lambertian reflection on its surface, which leads to multiple internal reflections and creates random light paths through a labyrinth of particles. The result is a nearly perfect cosine and wavelength-independent/achromatic characteristic even in near field. However, due to multiple Lambertian reflections, a high percentage of the light is also reflected to the input side of the diffusers. Due to this reflection, the transmission efficiency of cosine volume diffusers is smaller than 50%.

A volume diffuser with nearly Lambertian characteristics used by ams OSRAM is "Lexan 8B28 – opaque white", with a thickness of 250 micrometers.

The selection of a diffuser always depends on the use case, the irradiance on diffuser or sensor, and the needed flexibility of the setup.

For low light applications, a surface diffuser with high transmission and the widest radiation pattern as possible should be used. Narrowing the radiation pattern for higher transmission efficiency is only possible for detecting large and homogenous light sources (see chapter 5) or if the conditions for calibration are stable and equal to the measurement geometry. Under stable conditions, chromatic effects, etc. could be compensated by calibration.

In applications under changing conditions regarding size, direction, and/or orientation of the light source, a volume diffuser with nearly Lambertian and achromatic characteristics is the best choice to create a sensor system that is not affected by the direction of incoming light.

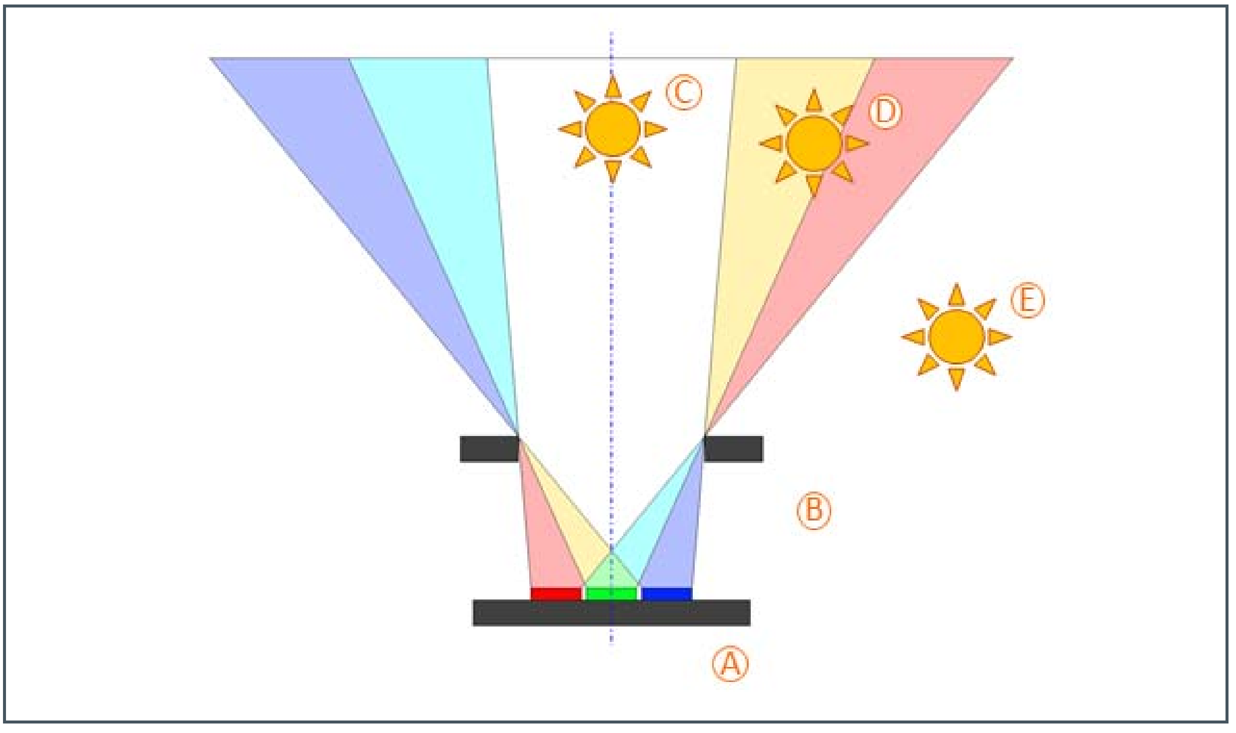
5 Average Angular Response and Light Homogeneity

The average angular response of the AS7341 is related to the angle of incidence and it is limited to ±40° over all the channels. Due to the structured detector (4 x 4 array), the field of view is individual for each photodiode; almost symmetrical for the centered photodiodes and more asymmetrical for those in distance to the center. To avoid a blurred imaging of a light source or its position onto the sensors array the diffuser is also used (see Figure 10).

Regarding its characteristics, the diffuser also modifies the average angular response of the sensor system (AS7341 + diffuser). When using diffuser, which is not a perfect Lambertian and meets just the minimum scatter recommendation (see Figure 7), the angular response of the system will only have the same characteristics in the case of normal incidence. In the case of a tilted light incidence, the response may shift to an asymmetrical shape. This causes different color measurements in relation to the positioning light source and sensor and decreases the accuracy.

To avoid such inaccuracies during calibration, it is necessary to illuminate the diffuser with homogeneous light over the hemisphere.

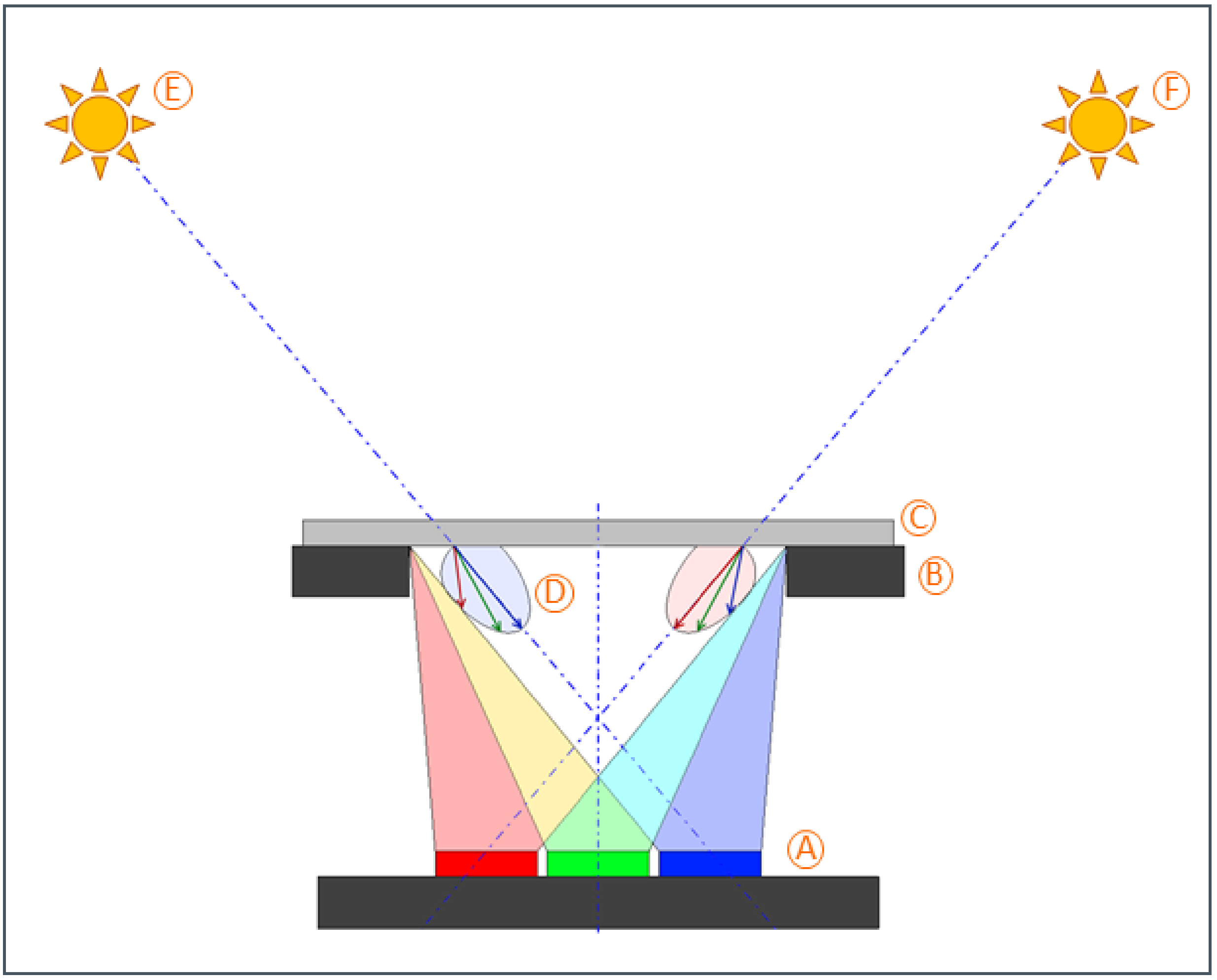
Figure 10:
Vertical Cross-Section and Field of View (FOV) of the Structured Color Sensor Without a Diffuser (simplified diagram with exaggerated dimensions for illustration)



1 Photodiode array (structured detector) (A)
2 Aperture/pinhole in the package (B)

3 Light source 1 → correctly detected by all channels (**C**)
4 Light source 2 → partly shadowed blue channel; detected as yellowish light (**D**)
5 Light source 3 → out of FOV; not directly detected (**E**)

Figure 11:
Vertical Cross-Section of the Structured Color Sensor with a Non-Cosine Diffuser (simplified and not drawn to scale)



1 Photodiode array (structured detector) (**A**)
2 Aperture/pinhole in the package (**B**)
3 Diffuser with non-cosine power distribution (**C**)
4 Angular dependent power distribution: vector size is equivalent to the power hiding in each channel (**D**)
5 Light source at position 1 → detects mostly blueish (**E**)
6 Light source at position 2 → detects mostly reddish (**F**)

6 Additional Documents

The following list includes a selection of additional documents with more technical details for the AS7341 Sensor and its test kits. This list is not fixed and it is constantly changing. Ask us for new details.

For further information, please refer to the following documents:

1. ams-OSRAM AG, *AS7341 11-Channel Multi-Spectral Digital Sensor* (DS000504), Datasheet.

7 Revision Information

Changes from previous version to current revision v1-00	Page
Initial version	

- Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
- Correction of typographical errors is not explicitly mentioned.

8 Legal Information

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