

Reflective Optical Sensor SFH 7740

Application note

1. Introduction

The SFH 7740 is a very small reflective optical sensor for short distances with digital output. With dimensions of only 3.7x3.7x1 mm, and surface-mount solder contacts, the device may be integrated in applications where reflective sensors have previously not been considered. A photograph of the part is shown in figure 1.



Figure 1: Photo of the SFH 7740. Contact pads are on the bottom side of the package

This device was conceived to detect the position of mechanical parts. Two example applications are: a short-distance (mm regime) proximity sensor¹ (e.g. to detect whether a cover is open or closed), or a sensor that detects the relative position of a structured surface (e.g. slider-position in cellular phones), as shown in figure 2. With a bright, highly reflective object in front of the sensor the output switches to high (“H”), and with a dark object (or no object at all) in front of the sensor the output is low (“L”).

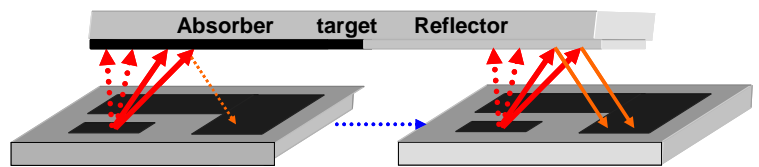


Figure 2: Schematic diagram of an example SFH 7740 application featuring a structured target. Target position is detected by measuring the amount of light reflected from different areas (with different optical properties).

This application note is structured as follows:

- General description of the part's design and operating principle
- Application circuit recommendations
- Customization/calibration to account for optical properties of the application
- Comments on the sensor's spatial resolution
- General application comments

2. Design and Operating Principle

The part consists out of an invisible infrared light emitting diode (LED) with a wavelength of 850nm, a phototransistor, and an ASIC. A block schematic diagram is shown in figure 3. For low current consumption (50µA average) the ASIC performs a measurement every 90ms and the result is latched at the output. The precise timing interval is not important for the application, as the output is never in an undefined state. When a measurement is performed, the emitter is driven with a current $I_f=10\text{mA}$ for 44µs. The

¹ For applications requiring longer distance proximity sensing (cm regime), a related product SFH 7741 is recommended.

phototransistor current is measured twice: immediately before and near the end of the emitter pulse respectively. The difference between the two measurements is compared with an internal threshold setting, and the output is set to the appropriate digital level (indicating presence, H, or absence, L, of reflected light). Since the difference in photocurrent is measured, the device is insensitive to ambient light conditions in most cases. If the device is used indoors (e.g. fluorescent lamps, light bulbs up to 1000 lx), the device functions as expected. For light sources with very high infrared content (e.g. light bulb >1000lx, direct sunlight > 10000lx), the amplifier in the ASIC may be pushed beyond its design dynamic range and the output will switch to H.

The device is designed to provide an operating range of approximately 0.6 to 1.4mm, assuming the preset emitter current (10 mA) and a target that reflects diffusely with a reflection coefficient of 90% (discussed further in section 4). In order to operate with targets of lower reflectivity, or with an operating range up to 4mm, the emitter drive current I_f can be increased up to 60mA by using an additional external resistor (see section 3).

3. Application Circuit

The electrical set-up and the proposed external components can be seen in Figure 3.

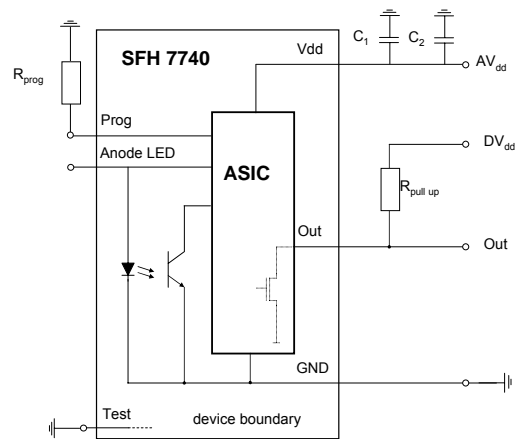


Figure 3: SFH 7740 application schematic diagram, also showing a block diagram of the internals of the part.

An external **pull-up resistor** is required at the output. A value of 100kΩ is recommended, but up to 1MΩ can be used to keep the current consumption low. In this case the circuit will be more sensitive to noise.

The power supply **bypass capacitor C₁** is necessary to reduce high frequency noise – 10-100nF is recommended, but this is strongly dependent on the quality of the power supply.

A further (larger) **bypass capacitor C₂** may be necessary to stabilize V_{dd} during the “on-time” (44μs) of the IR-emitter. The voltage drop of the supply voltage during this time must be < 200mV, otherwise the sensor will not function reliably. This is particularly important when the conductive path to the V_{dd} pins has a high resistance or is switched by a series transistor in combination with higher emitter drive currents.

The LED current may be increased by adding a resistor R_{prog} . The choice of the resistor value is discussed in section 4.

The **Test** pin should be connected directly to GND in the application. Connecting this pin to V_{dd} activates the ASIC test mode, used in the final factory functionality test. The part in principle functions properly, but with significantly higher power consumption than in normal operating mode. The part is not qualified or warranted to run in Test mode for any significant period of time.

The **anode** of the emitter is provided for testing purposes at OSRAM. This contact must not be connected in the application

4. Optical design

The default setting of the emitter drive current I_f is 10mA. In this case the pin R_{prog} is left open. This results in an operating range of 0.6-1.4 mm for a target with 90% reflectivity. For applications with a larger operating distance or lower target reflectivity, it is necessary to increase the sensitivity of the sensor by increasing the drive current I_f .

The procedure is relatively simple and consists of three steps:

1. Measurement of target material reflectivity.
2. Extraction of required I_f for the desired operating range.
3. Calculation of the R_{prog} value.

4.1 Measurement of the target material reflectivity

The target reflectivity directly determines the required current I_f . If the reflectivity is not known, it should be measured as part of the design process. It is generally sufficient to use an IR emitter with an 850nm wavelength (e.g. SFH 4257) and a photodiode (e.g. BPW34FAS) in a set-up as shown in Figure 4. For the most accurate result (i.e. to account for reflection directionality), the ratio

of target height to emitter-detector separation in the measurement setup should be the same as the ratio of desired operating range to SFH 7740 emitter-detector spacing (2 mm).

The photocurrent due to reflection from the target of interest should be normalised to the photocurrent due to reflection from KODAK neutral white paper (90%). (This card is an international standard and can be ordered from KODAK (Cat. No. E 152 7799 Publication R-270). OSRAM uses this test-card in the final device functionality test. All SFH7740 are tested for sensitivity with this standard.

For example, in a particular test setup with KODAK neutral white paper (90%), the detector BPW 34 FAS yields a photocurrent I_p of $90\mu A$ for some defined drive current I_f . The target of interest yields $80\mu A$ under same conditions. Therefore, the absolute reflectivity of the target is calculated to be $90\% * (80\mu A / 90\mu A) = 80\%$.

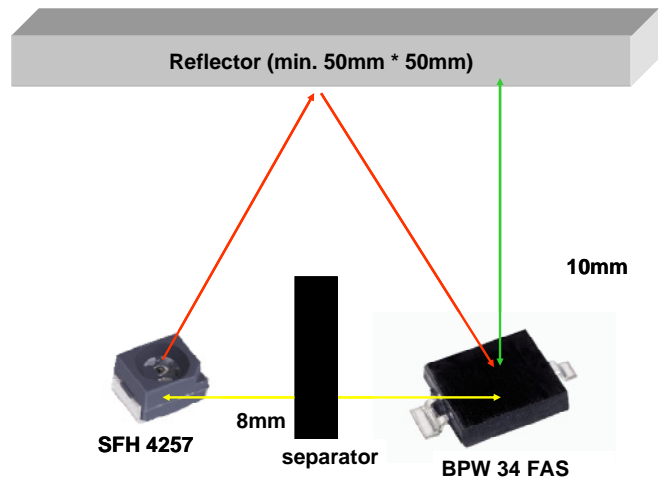


Figure 4: Target reflectivity measurement setup. The dimensions shown would correspond to an SFH 7740 operating range of approximately 5 mm.

Important issues for this measurement are:
 - **ambient light** (photocurrent when the LED is off) has to be avoided. In case this can not be avoided it has to be subtracted from measured data

- **crosstalk** (photocurrent measured under dark condition with the LED on but no reflector present) must be subtracted from the measured data. The crosstalk will be low when SFH4257 is used because of its black, light-absorbing package. For other set-ups the crosstalk can be minimized by using an additional separator between emitter and detector as shown in figure 4

- **Reflector size:** The minimum size of the reflector should be 50x50mm².
- **The devices** used should have a Lambertian (cosine, half angle +/-60°) emission and detection profile because the emitter and detector of the SFH7740 have a similar radiation-characteristic.

The ratio of the signal with object and the signal without object (or dark area, as in figure 2) should always be >10 (reflection ratio) for robust operation. Measurements show that metal surfaces (like aluminium, steel, metallised plastic) have usually a reflection of 60 – 70%, while black surfaces (like used for cameras) usually reflect <4%.

4.2 Extraction of the LED drive current (I_f)

The reflected optical signal depends strongly on the distance between sensor and the reflector. This behaviour is shown in figure 5.

Using the reflectivity data from the above measurement, an appropriate I_f can be read from the y-axis for a desired working distance. The sensor will function in a +/- 0.4 mm range around the nominal working distance.

The individual curves represent target reflectivities as measured above.

4.3 Calculation of R_{prog}

The required emitter drive current I_f for the application is derived from figure 5. Based on this information, R_{prog} can be calculated using the following formula:

$$R_{prog} = \frac{V_{dd} * 6}{I_f - 10mA}$$

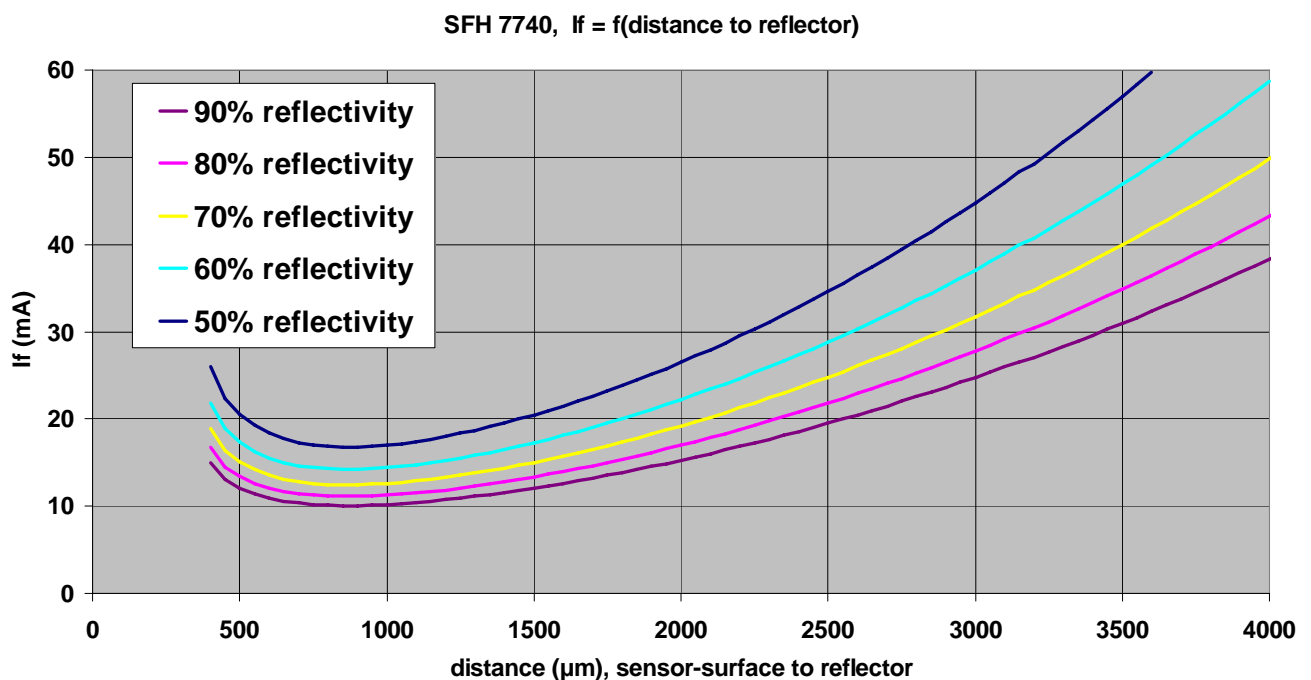


Figure 5: I_f as a function of working distance

Where

- 10 mA is the ASIC default I_f setting
- the factor of 6 is based on ASIC properties

The maximum allowed forward current I_f is 60mA. For higher I_f the above formula is no longer valid.

5. Optical resolution of the sensor

When using structured targets (as in figure 2), the optical resolution of the sensor as a function of sensor-target spacing should be considered.

5.1 Optical resolution with diffuse reflector

Figure 6 shows the analogue signal of the SFH 7740 phototransistor when a reflector is moved laterally above the sensor at different working distances (1 to 4mm). The diffuse reflector is divided into dark and bright halves.

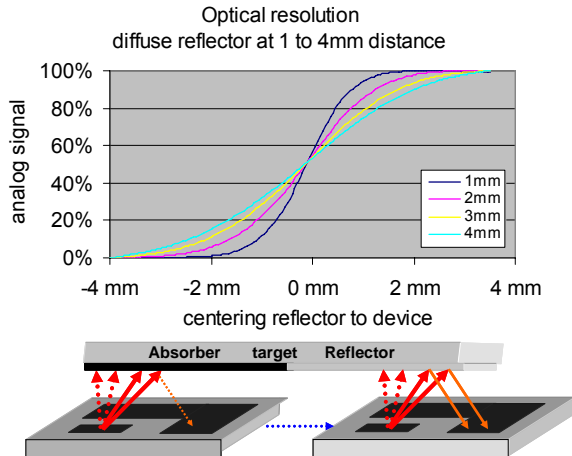


Figure 6: Optical resolution, diffuse reflector

(Please refer to the end of this application note for a higher-resolution version of the figure)

At 1mm working distance (blue curve) the change of the analogue signal from 5% to 95% of the end value occurs within a movement range of 4 mm. This means that the minimum detectable spot size is $4 \times 4 \text{mm}^2$, for a robust design the size should be increased by 50% (meaning $6 \times 6 \text{mm}^2$) If the working distance is 4mm, a movement of 8mm is needed to achieve the same change (5 to 95%) in the analogue signal; also in this case the size should be increased by 50% for improved robustness.

5.2. Optical resolution with glossy reflector

When using glossy reflectors the resolution is improved (see Figure 7). A glossy reflector results in primarily specular reflection, and the spot size is therefore defined to first order by the emitter and phototransistor chip dimensions (approximately $400 \mu\text{m}$).

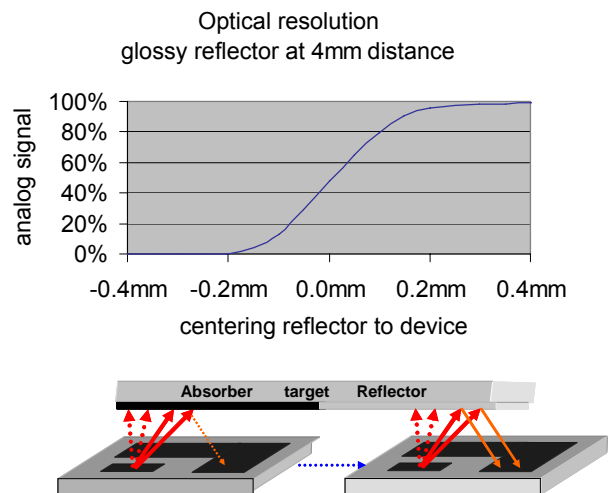


Figure 7: Optical resolution, glossy reflector

6. General comments

6.1 Tolerances

The tolerances listed below are already considered in the design of the sensor, and are accounted for by internal testing limits, thereby making the design-in easier:

- Temperature behaviour of emitter, detector and ASIC (working range from -20 to +85°C)
- degradation of the emitter over lifetime
- ASIC variability
- reflector distance tolerance (+/- 0.4mm) from the typical value

As stated previously, for robust operation a factor of >10 between reflector and absorber signal is strongly recommended. This factor is needed to cover the variability of the sensors' production range and the above tolerances.

ATTENTION:

The narrow sensitivity distribution of the SFH7740 can lead to a false sense of security when attempting to use a lower reflection ratio than 10. In this case, it is possible that the device will fail under certain circumstances (e.g. varying temperature, device aging) as all design variabilities would no longer implicitly be taken into account.

In addition a careful check of geometric tolerance limits as well as optical reflection/absorption properties, also over time, in the customer's application is necessary.

6.2 Use of regulated power supplies

When operating the SFH 7740 regulated voltage supplies should be avoided. Since the IR emitter pulse is much higher than the ASIC current draw (i.e. a high, low-duty cycle supply pulse), it can influence the stability of the supply voltage. This instability will influence the function of the SFH 7740. This effect does not occur during normal operation of the sensor with batteries,

storage batteries, or stabilized voltage supplies

6.3 Internal timing of the SFH7740

The timing diagram can be seen in Figure 8. During the test cycle t_{awake} the phototransistor is "on". At the end of the test cycle, the output will latch to "H" or "L". The current consumption during t_{sleep} is typically 20µA, while during the "LED on" time (44µs) the current consumption is dominated by I_f (therefore 10 to 50mA, depending on R_{prog})

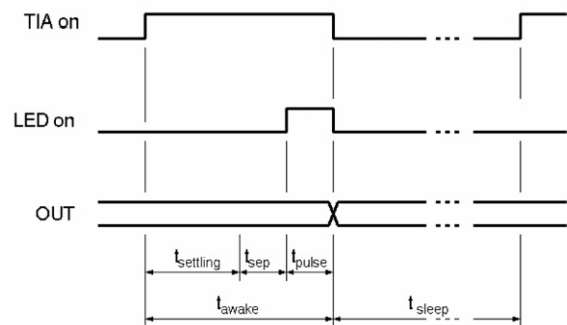


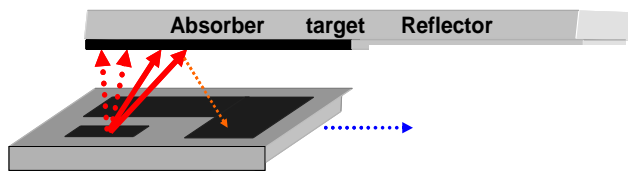
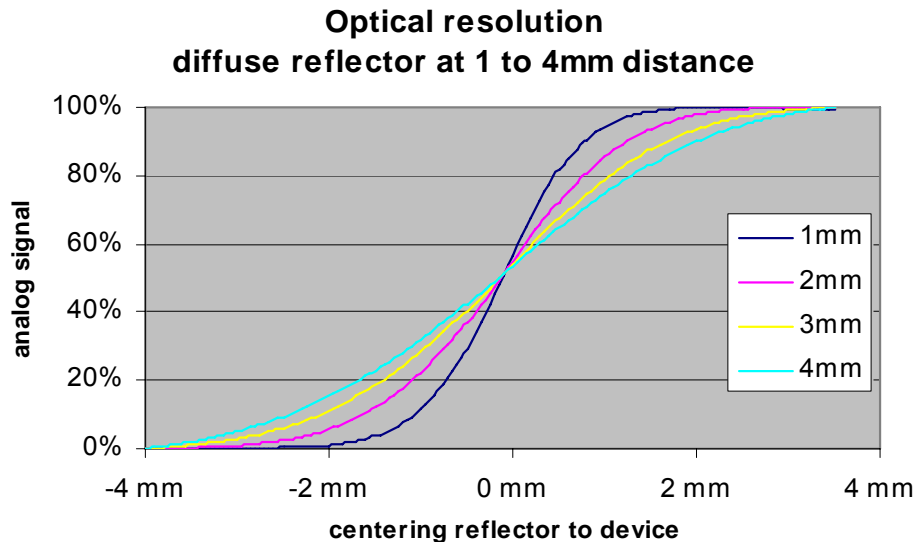
Figure 8: Timing diagram

In addition to the LED and ASIC current consumption, extra current is consumed by the output pull-up. In order to minimize the current consumption in the case of a structured target (figure 2), it is recommended to design the slider or other mechanical interface such that the normal output state is "H". This is done by choosing the appropriate reflector/absorber placement sequence.

6.4 Contamination

Due to the fact that the SFH 7740 is an optical device it is sensitive to contamination. Dust may directly influence the optical parameters and the sensitivity, and may lead to decreased operating range or failure.

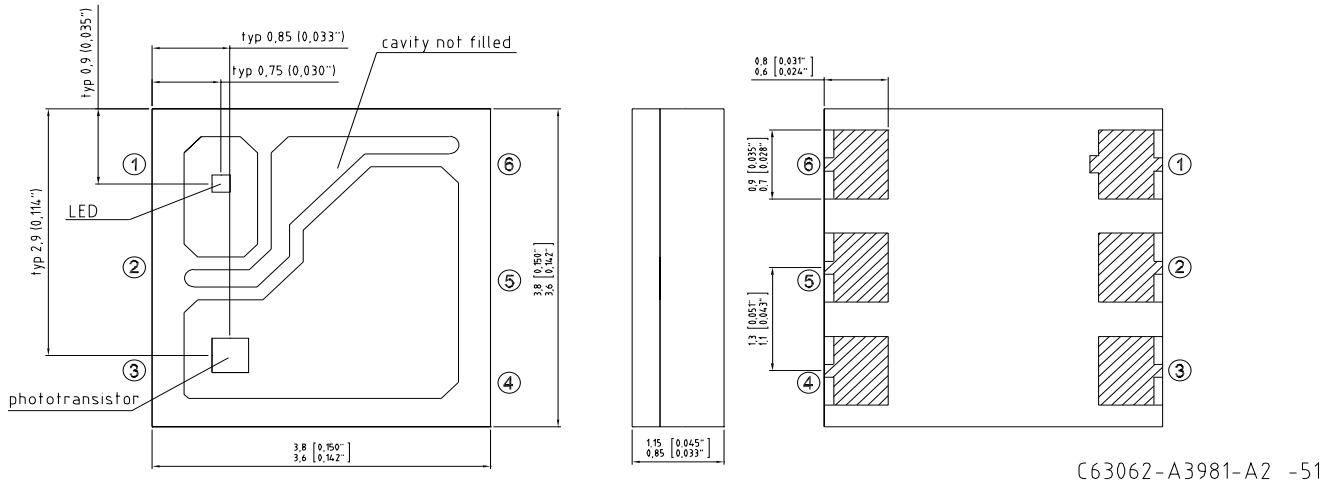
Nevertheless a glass or plastic cover may not be placed between the SFH 7740 and the target of interest. In that case, light reflected from the cover will lead the ASIC to provide a “false positive” result.



6.5 Eye safety

The SFH 7740 sensor is eye safe by design under normal operating conditions defined in the product datasheet and according to IEC 62471 (exempt group).

Package drawing and pin configuration of the SFH 7740



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Figure 10: Package drawing of the SFH 7740.

Pin	Description
1	Anode LED (must not be connected)
2	GND
3	Out
4	Test (must not be connected)
5	V _{dd}
6	Prog

Table 2: Pin configuration of the SFH 7740

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