Ambient Light and Proximity Sensor SFH 7770
Application Note

1 Abstract

This application note describes technical details and provides some application guidelines for the combined ambient light and proximity sensor sensor SFH 7770.

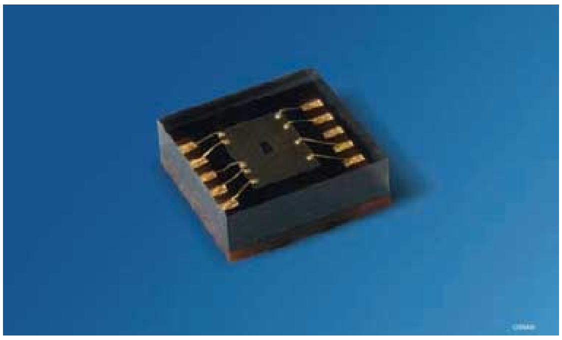


Figure 1: Ambient Light and Proximity Sensor SFH 7770

The document starts with a general introduction to the device, followed by a brief overview on the features of the sensor (Chapter 2). The integration and operation of the sensor in an I²C bus environment is described in Chapter 3.
Chapter 4 provides a functional description of the sensor. Optical design guidelines and application relevant information are given in chapter 5 followed by the guidelines for electrical design in chapter 6).

More general information about ambient light sensing, technical data and I²C bus are available in the following documents:

- OSRAM OS general application note on ambient light sensors [1]
- SFH 7770 datasheet [2]
- I²C bus specification [3]

2 Introduction

The SFH 7770 is a compact device which is designed for simultaneous detection of ambient light and proximity of reflecting objects. Applications are mobile phones, PDAs, notebooks, cameras and other consumer products.

The device includes the following features:

- *Proximity Sensor (PS)*
  - Detection-range up to 100mm
  - Gesture recognition possible
  - Outputs to drive up to three IR emitters
  - Optimized for 850nm emitters
  - Negligible influence from ambient light

- *Ambient Light Sensor (ALS)*
  - 3lx - 55000lx- High linearity
  - Spectral sensitivity well matched to the human eye

- *I²C interface*
  - 100kHz / 400kHz and 3.4MHz mode
  - 3 programmable measurement modes (STAND-BY, TRIGGERED, FREE-RUNNING)
- Current consumption < 5µA in STAND-BY mode
- Small package size, 2.8 x 2.8 x 0.9 mm³

2.1 Overview of the sensor features

The SFH 7770 comprises photodiodes for both ambient light detection and proximity sensing (See Fig. 2). The photodiodes are integrated into a single ASIC which also performs the A/D conversion of the detected signals and provides an interface for

communication with a host device via the I²C bus.
From functional points of view, the SFH7770 offers the following features and properties, which are briefly introduced in this section:

- Proximity sensor
- Ambient light sensor
- Operating modes : TRIGGERED, STANDBY, FREE-RUNNING
- LED drivers
- I²C communication
- Pinning

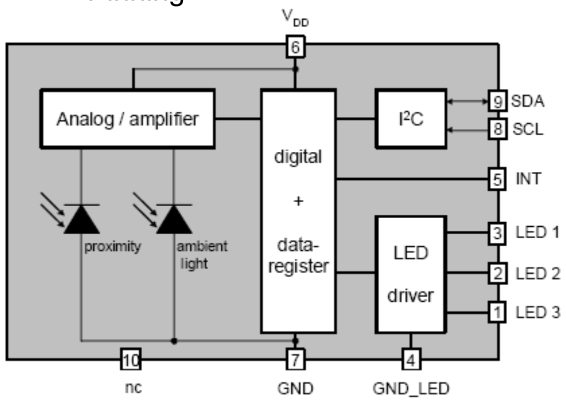


Figure 2: Circuitry of SFH 7770

For proximity sensing, up to 3 LEDs can be driven simultaneously (see Fig 2). This allows the operation of 3 independent proximity sensing channels. At maximum refresh rate, all 3 PS values are updated every 10ms, which makes the sensor ready for reliable gesture recognition. All proximity channels deliver continuous signals with 8bit resolution. Therefore the PS may not only be used for pure proximity detection, but also for distance measurements.
The ambient light sensor is working independently from the proximity sensor. The ambient light readings are updated with a rate up to 100ms.
Both , PS and ALS , allow to be operated in three modes: STANDBY, FREE-RUNNING and TRIGGERED mode. In FREE-RUNNING mode, measurements are repeated by the component itself, while at TRIGGERED mode each measurement has to be started by a separate I²C command. All combinations of ALS and PS operating modes are possible, see Fig. 3.

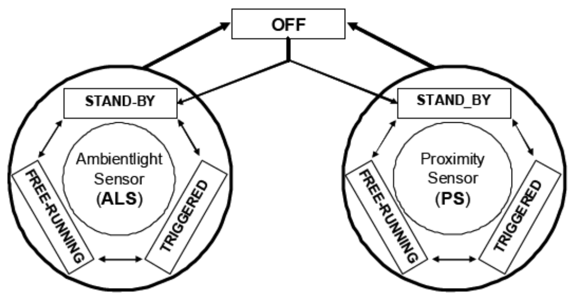


Figure 3: ALS and PS operating modes

Every of the 3 LED drivers is capable of sinking an LED current of 5 .. 200mA. The device is actively regulating the pulsed LED current. No additional resistors for current limitation are required.
All sensor settings are accessible via the I²C bus, as well as all sensor readings (ALS and PS values). The values are stored in data registers, which allow to be read out one-by-one or group-wise (‘block read mode’). In addition, a programmable interrupt function provides digital information on proximity- and ambient light events via the INT pin.
The SFH7770 is a 10 pin SMT device. The pinning is described in table 2-1

Pin no.	Pin label	Description
1	LED 3	Cathode of LED 3
2	LED 2	Cathode of LED 2
3	LED 1	Cathode of LED 1
4	GND_LED	Separate LED ground
5	INT	Interrupt pin
6	V_{DD}	Supply voltage
7	GND	V_{DD} Ground
8	SCL	I²C bus clock line
9	SDA	I²C bus data line
10	N.C.	Not connected

Table 2-1: SFH 7770 pinning

3 I²C bus communication

3.1 I²C bus environment

The SFH 7770 is a digital ambient light and proximity sensor. The communication is performed via a 2-wire I²C bus interface, so the device can be integrated into a typical multi master / multi slave I²C bus environment. A typical I²C bus network consists of a master and different I²C bus slave devices, see figure 4.

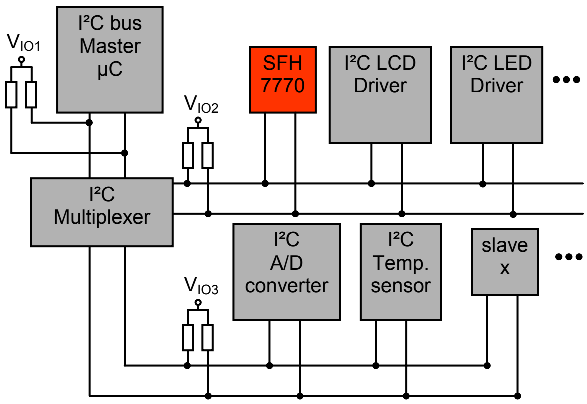


Figure 4: I²C bus network

Each bus device (running on the same I²C bus line) has a unique address to ensure the communication between slave and master. An I²C bus network can be expanded via multiplexers and repeaters [3] to embed multiple sensors (e.g. ambient light, temperature, voltage) and actuator slaves (e.g. LCD Display and LED drivers) in the application. Main advantages of the I²C bus compared to an analogue solution are the reduced PCB space, based on 2 wire communication and a simple expansion of the sensor / actuator network.

SFH 7770 I²C circuit and wiring

The minimum requirements to drive the SFH 7770 are shown in the simplified network (figure 5). In this case a microcontroller unit acts as the I²C bus master. The I²C bus lines SDA (Serial Data Line) and SCL (Serial Clock Line) need to be referenced via pull–up resistors to the digital voltage level V_{IO}. Typical pull-up resistors are 560 Ω to 1kΩ.

For more details on general circuitry and wiring of the device please see chapter 6.

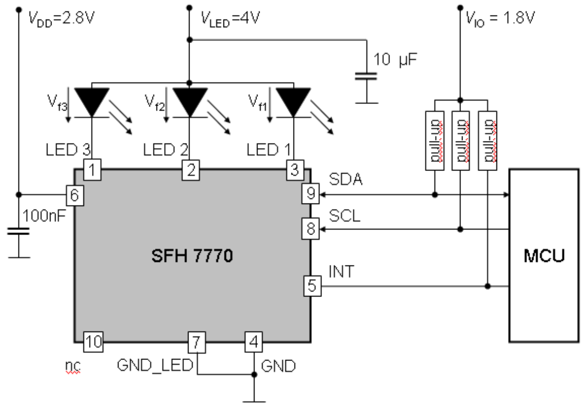


Figure 5: Application diagram for basic operation of SFH 7770

3.3 SFH 7770 I²C bus communication

By embedding the SFH 7770 in an I²C bus network (Chapter 0) and after applying V_{DD} = 2.5 V, the communication can start as follows:

1. Activation of the sensor:
The default mode of the sensor is STAND-BY and the SFH 7770 needs to be activated by the master.
Each I²C bus communication begins with a start command "S" of the Master (SDA line is changing from HIGH to LOW during SCL line stays HIGH) followed by the address of the slave (SFH 7770 address is 38 hex). The slave address is 7bit long followed by the Read (1) and Write (0) R/W bit of the master. R/W bit controls the communication direction between the master and the addressed slave. The slave is responding to the proper communication with an acknowledge command. Acknowledge "A" (or not acknowledge "NA") is performed from the receiver by pulling the SDA line down (or leave in HIGH state)

1. Activation of the ambient light sensor:

S	SFH 7770 Address (0x38)	W	A	SFH 7770 control register (0x80)	A	Activate to free-running mode (0x03)	A	P

2. Wait for 125 ms before starting the readout

3. Read first byte of 16 bit ALS output (LSB):

S	SFH 7770 Address	W	A	SFH 7770 LSB register	A	P

S	SFH 7770 Address	R	A	LSB data	NA	P

4. Read second byte of 16 bit output (MSB):

S	SFH 7770 Address	W	A	SFH 7770 LSB register	A	P

S	SFH 7770 Address	R	A	MSB data	NA	P

Communication from master to SFH 7770 (grey)
Communication from SFH 7770 to master (white)

W= Master writes
R = Master reads
A = acknowledge
NA = not acknowledge
S = START condition
P = STOP condition

Figure 6: I²C bus communication (for address and register values see section 3.4)

For the activation of the sensor the master needs to Write an activation command (0x03hex) into the corresponding control register (ALS: 0x80h, PS: 0x81h). Each command needs to be acknowledged by the slave. After activation the master ends the communication with a STOP command (SDA line is changing from LOW to HIGH while SCL line stays HIGH).

2. Wait time:
After activation the sensor will change from STAND-BY to e.g. FREE-RUNNING mode. After <10ms the first measurement starts. With a delay of <125ms the first full averaged ALS measurement value can be read via the I²C bus.

3. & 4. reading LSB and MSB:
The sensor's 16bit ALS measurement value is composed of 2 bytes (LSB & MSB). The bytes are accessible via 2 output registers, which can be addressed comparable to the control register. After addressing either the LSB (least significant byte) or the MSB (most significant byte) output register, the communication direction has got to be changed from the slave to the master by repeating the address & R/W byte with a changed R/W bit. After reading the LSB and the MSB, the communication is ended by the master with a not acknowledge "NA" followed by the stop condition "P". The output reading "OUT" of the SFH 7770 can easily be calculated:

Example:
DATALOW (LSB) = F0 (1111 0000)
DATAHIGH (MSB) = 83 (1000 0011)
Final result (hexadecimal): 83F0 counts
Final result (decimal): 33776 counts(=lux)

After finishing the measurement, the SFH 7770 mode may be changed to STAND-BY via the control register.

3.3.1 Combined mode

To ensure an interference-free communication, the I²C bus combined mode should be used. Instead of performing two independent read or write commands (COM 1 & COM 2) the commands can be combined by a repeated start condition “Sr”, see figure 7.

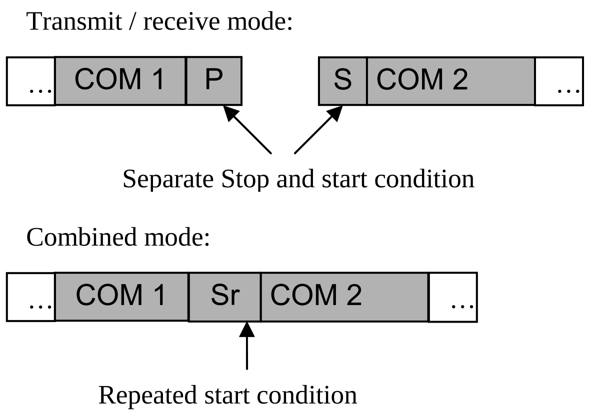


Figure 7: Combined mode

The start and repeated start commands (“Sr”) are the same: the SDA line is changing from HIGH to LOW while the SCL line stays HIGH. The “Sr” condition is placed behind “A” or “NA”. The combined mode is not limited to two read/write commands, so the addressing of the sensor and reading/writing of multiple register values can be performed in one block.

3.3.2 Block read mode

The Block read mode of the SFH 7770 can be used to read all output registers in a cyclic manner.
After addressing and reading an output register (e.g. LSB) in normal mode, the master is not placing the stop condition, but continues to read the output registers. The SFH 7770 will automatically increase the register address and the content of the next sensor output register can be read following the register addresses:

80→81→…→98→99→80→81→...

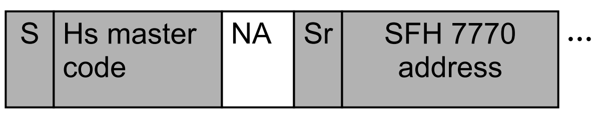
For register addresses and content see section 3.4. The block read mode can be ended by placing the stop condition by the master.

3.3.3 I²C bus modes / speeds

The I²C bus mode is primarily defined by the used master:

Mode	Bit rate
Standard mode (Sm)	≤100 kbit/s
Fast mode (Fm)	≤400kbit/s
Fast mode plus (Fm+)	≤1Mbit/s
High speed mode (Hs)	≤3.4Mbit/s

Although designed for I²C bus high speed mode, the SFH 7770 can also handle the standard mode Sm and the fast mode Fm. The device is *not* compatible to the Fm+ mode.
The serial data format in Hs mode differs from other modes. The SFH 7770 with Hs mode and other lower speed components might be combined in an I²C bus network. To avoid failure communication based on the changing bus speeds, the lower speed I²C bus components need to be shut down when communication is running at a bit rate of 3.4Mbit/s. This is performed with a master code (00001XXX) followed by “NA” of the slaves. By the repeated start condition “Sr” the Hs mode begins and the slave can be addressed:



Triggered from the master the Hs bit rate will return to lower I²C bus speeds after the next STOP condition [3].

3.4 SFH7770 registers and operation modes

In this section the data registers are listed and commented., as well as the available operating modes of the device (OFF, STANDBY, FREE-RUNNING, TRIGGERED).

3.4.1 SFH7770 registers

The choice of the measurement mode and the read-out of the data are done by communication via the I²C bus. The sensor settings are written into the sensor's internal registers and the data are read from them. The SFH 7770 has 23 different registers, see table 3-1. In the following, the SFH7770 read and write registers are described in more detail.

I²C Addr.	Type	Name	Description
0x80	RW	ALS CONTROL	SW reset , ALS operation mode control
0x81	RW	PS CONTROL	PS operation mode control
0x82	RW	I_LED1&2	Setting LED 1 and 2 pulse current
0x83	RW	I_LED3	Setting LED 3 pulse current
0x84	RW	ALS & PS TRIG	Triggered mode ALS and PS measurement triggering
0x85	RW	PS INTERVAL	PS measurement rate in FREE-RUNNING mode
0x86	RW	ALS INTERVAL	ALS measurement rate in FREE-RUNNING mode
0x8A	R	PART_ID	Part number and revision IDs
0x8B	R	MAN_ID	Manufacturer ID
0x8C	R	ALS_DATA_LSB	ALS measurement data, least significant bits
0x8D	R	ALS_DATA_MSB	ALS measurement data, most significant bits
0x8E	R	ALS_PS STATUS	Status of meas. data (ALS and PS)
0x8F	R	PS_DATA	PS measurement data from LED 1
0x90	R	PS_DATA	PS measurement data from LED 2
0x91	R	PS_DATA	PS measurement data from LED 3
0x92	RW	INT_SET	Interrupt settings
0x93	RW	PS_THR LED1	PS interrupt threshold level for LED 1
0x94	RW	PS_THR LED2	PS interrupt threshold level for LED 2
0x95	RW	PS_THR LED3	PS interrupt threshold level for LED 3
0x96	RW	ALS UP_THR LSB	ALS interrupt upper threshold level, least significant bits
0x97	RW	ALS UP_THR MSB	ALS interrupt upper threshold level, most significant bits
0x98	RW	ALS LO_THR LSB	ALS interrupt lower threshold level, least significant bits
0x99	RW	ALS LO_THR MSB	ALS interrupt lower threshold level, most significant bits

Table 3-1: SFH7770 control and data registers

ALS CONTROL: Software reset and control of ambient light sensor

By the ALS_CONTROL register, the operation mode of the ambient light sensor is set. The following modes are available: STANDBY, FREE-RUNNING and TRIGGERED. In all modes, the I²C circuitry is active. The SW reset (bit #2 „1“) sets all registers to default (same as POWER-UP). Afterwards it is automatically set back to „0“ by the SFH7770.

R/W-Register 0x80							
Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1** / **0**
	not used					**complete SW reset**	**mode of ambient light sensor**
default	**00000**					**0**	**00 STAND-BY**
						1 SW reset	00 STAND-BY
							01 STAND-BY
							10 TRIGGERED (by I²C master device)
							11 FREE-RUNNING (internally triggered)

PS CONTROL: Control of proximity sensor

By the PS_CONTROL register, the operation mode of the proximity sensor is set. The following modes are available: STAND-BY, FREE-RUNNING and TRIGGERED. In all modes, the I²C circuitry is active. Besides measurement triggering the register defines the active LEDs in measurement.

R/W-Register 0x81								
Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	not used						**mode of Proximity Sensor**	
default	**XXXXXX**						**00 STAND-BY**	
							00 STAND-BY	
							01 STAND-BY	
							10 TRIGGERED by MCU	
							11 FREE-RUNNING (internally triggered)	

I_LED 1&2: Emitter (LED) current setting

The register allows the activation of the LEDs. The following combinations of active LEDs are available: LED1, LED1+2, LED1+3 and LED1+2+3. In addition, the pulse current values of LEDs 1 and 2 are set.

R/W-Register 0x82								
Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	activation of LEDs		**setting LED2 pulse current**			**setting LED1 pulse current**		
Default	**00**		**011 50 mA**			**011 50 mA**		
	00 LED1 active		000 5 mA			000 5 mA		
	01 LED1 and 2 active		001 10 mA			001 10 mA		
	10 LED1 and 3 active		010 20 mA			010 20 mA		
	11 all LEDs active		011 50 mA			011 50 mA		
			100 100 mA			100 100 mA		
			101 150 mA			101 150 mA		
			110 200 mA			110 200 mA		

I_LED 3: Emitter (LED) current setting

By register 0x83, the pulse current value of LED 3 is set.

R/W-Register 0x83								
Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	not used					**setting LED3 pulse current**		
Default	**XXXXX**					**011 50 mA**		
						000 5 mA		
						001 10 mA		
						010 20 mA		
						011 50 mA		
						100 100 mA		
						101 150 mA		
						110 200 mA		

ALS & PS TRIG: I²C master device-triggered measurement (for ambient light sensor and proximity sensor)

If bit #0 or #1 is set to "1", a new measurement will start after the I²C stop command from the I²C master unit. As soon as the measurement is finished, the corresponding bit of the register will automatically be set to „0" by the SFH7770.

R/W-Register 0x84								
Bit	7	6	5	4	3	2	1	0
	not used						trigger ambient light	trigger proximity
default	XXXXXX						1	1

PS INTERVAL: Proximity measurement: time interval setting (repetition time) for FREE-RUNNING mode

The PS_INTERVAL register defines the time interval between subsequent proximity sensor measurements in FREE-RUNNING mode. Available time intervals range from 10ms to 2000ms.

R/W-Register 0x85								
Bit	7	6	5	4	3	2	1	0
	not used				time interval			
default	XXXX				**0101 100 ms**			
					0000 10 ms			
					0001 20 ms			
					0010 30 ms			
					0011 50 ms			
					0100 70 ms			
					0101 100 ms			
					0110 200 ms			
					0111 500 ms			
					1000 1000 ms			
					1001 2000 ms			

ALS INTERVAL: Ambient light measurement: time interval setting (repetition time) for FREE-RUNNING mode

The ALS_INTERVAL register defines the time interval between subsequent ambient light measurements in FREE-RUNNING mode. Available time intervals range from 10ms to 2000ms.

R/W-Register 0x86								
Bit	7	6	5	4	3	2	1	0
	not used					time-interval		
default	XXXXX					**010 500 ms**		
						000 100 ms		
						001 200 ms		
						010 500 ms		
						011 1000 ms		
						100 2000 ms		

PART_ID: Part number and revision Identification

R-Register 0x8A								
Bit	7	6	5	4	3	2	1	0
	Part number ID				Revision ID			
	1001				0100			

MAN_ID: Manufacturer Identification

R-Register 0x8B								
Bit	7	6	5	4	3	2	1	0
	Manufacturer Identification							
	0000				0011			

ALS_DATA_LSB: Ambient light measurement data (0x8C: LSB)

The result of the ambient light sensor is a 16bit word with MSB and LSB. It is stored in two registers. The binary data can be converted directly to decimal „lx“ values (max. 65535lx), see sections 3.3 and 4.1.3.

R-Register 0x8C								
Bit	7	6	5	4	3	2	1	0
	LSB data							
default	00000000							

ALS_DATA_MSB: Ambient light measurement data (0x8D: MSB)

R-Register 0x8D								
Bit	7	6	5	4	3	2	1	0
	MSB data							
default	00000000							

ALS_PS STATUS: Status of measurement data for the ambient light sensor (ALS) and proximity sensor (PS)

After the measurement data are available in the register (0x8E), the corresponding status bit (bit #6 for ALS; bit #0, 2 and 4 for PS LED 1, 2 and 3, respectively) is set to “1“. After the data have been read by the I²C master device , the statusbit is automatically reset to “0” by the SFH 7770. Bit #7 is set „1“, if the measured ALS value is outside the threshold level settings (registers 0x96... 0x99). Bit #1 , 3 and 5 are set to “1” if the measured PS value from LED 1, 2 and 3 , respectively are above the threshold level (registers 0x93, 0x94 and 0x95). The status of register 0x8E will always be updated if new measurement data are available.

R-Register 0x8E								
Bit	7	6	5	4	3	2	1	0
	ALS Threshold	ALS data	PS LED3 threshold	PS LED3 data	PS LED2 threshold	PS LED2 data	PS LED1 threshold	PS LED1 data
default	00000000							

PS_DATA: Proximity measurement data (LED 1 , 8bit, logarithmic scale)

R-Register 0x8F								
Bit	7	6	5	4	3	2	1	0
	data							
default	00000000							

PS_DATA: Proximity measurement data (LED 2 , 8bit, logarithmic scale)

R-Register 0x90								
Bit	7	6	5	4	3	2	1	0
	data							
default	00000000							

PS_DATA: Proximity measurement data (LED 3 , 8bit, logarithmic scale)

R-Register 0x91								
Bit	7	6	5	4	3	2	1	0
	data							
default	00000000							

INT_SET: Interrupt register / INT output.

In bit #6 and #5 the trigger source for the last interrupt event is stated. Data from the status register (0x8E) are used. In latched mode (set by bit #3) this remains unchanged until the interrupt register has been read by the I²C master device. Afterwards the bits are reset automatically to "0" by the SFH 7770. In unlatched mode it is updated after every measurement. The output polarity of the interrupt function can be changed by bit #2. The interrupt can be triggered by an ambient light sensor event and / or by a proximity sensor event (bit #1 and bit #0). "Z-state" means that the INT output pin is in a high-impedance state.

R/W-Register 0x92								
Bit	7	6	5	4	3	2	1	0
	not used	Interrupt trigger source		not used	Output mode	Output polarity	Interrupt mode (triggered by..)	
R/W	not used	R only		not used	R/W	R/W	R/W	
default	X	00		X	1	0	00	
		00 ALS			0 latched	0 active L	00 Z state	
		01 PS (LED 1)			1 not latched	1 active H	01 only PS	
		01 PS (LED 2)					10 only ALS	
		01 PS (LED 3)					11 PS and ALS	

PS_THR LED1: Threshold level for the proximity sensor (LED1)

RW-Register 0x93								
Bit	7	6	5	4	3	2	1	0
	data							
Default	11111111							

PS_THR LED1: Threshold level for the proximity sensor (LED2)

RW-Register 0x94								
Bit	7	6	5	4	3	2	1	0
	data							
Default	11111111							

PS_THR LED1: Threshold level for the proximity sensor (LED3)

RW-Register 0x95								
Bit	7	6	5	4	3	2	1	0
	data							
Default	11111111							

ALS UP_THR LSB: Upper threshold level for the ambient light sensor (LSB)

RW-Register 0x96								
Bit	7	6	5	4	3	2	1	0
	LSB data (upper threshold)							
Default	11111111							

ALS UP_THR MSB: Upper threshold level for the ambient light sensor (MSB)

RW-Register 0x97								
Bit	7	6	5	4	3	2	1	0
	MSB data (upper threshold)							
default	11111111							

ALS_LO_THR LSB: Lower threshold level for ambient light sensor (LSB)

RW-Register 0x98								
Bit	7	6	5	4	3	2	1	0
	LSB data (upper threshold)							
default	11111111							

ALS_LO_THR MSB: Lower threshold level for ambient light sensor (MSB)

RW-Register 0x99								
Bit	7	6	5	4	3	2	1	0
	LSB data (upper threshold)							
default	11111111							

3.4.2 SFH7770 operation modes

The SFH 7770 allows to be operated in three different modes, in which the proximity resp. the ambient light function can be used independently from each other. The three basic modes are:

FREE-RUNNING: The sensor measures continuously and writes the results in the relevant registers, ready to be read via the I²C-bus interface. Optionally the interrupt alert function with the user-defined threshold levels (PS and/or ALS) will be executed if such an event takes place.

TRIGGERED: The measurements are initiated via I²C-bus instruction. The data are available after processing is finished.

STAND-BY: This is the initial state after power-up. The SFH 7770 is in low power mode, no operations are carried out, but the device is ready to respond to I²C-bus commands.

Additionally, there is the off-state:

OFF: The SFH 7770 is inactive. The SDA, SCL and INT pins are in Z-state (high impedance). All register entries are reset to the default values.

3.4.3 Interrupt functionality

The SFH7770 offers several interrupt functionalities, which are accessible via software and hardware. The interrupt function compares the ALS and/or PS measurement results to preset threshold levels. If the results exceed the levels, interrupt bits are set and the (hardware) logic signal at the INT pin is changed.

The INT pin is set up as an open drain logic output, which has to be connected to an external logic voltage via a pull-up resistor:

4 Functional description of SFH 7770

The SFH7770 comprises an ambient light sensor (ALS) and a proximity sensor (PS) on one single chip. In this section, the operation and properties of ALS and PS parts are described.

4.1 Ambient light sensor

The SFH7770 has an on-chip photodiode which detects the level of the ambient light. The analog photodiode signal is processed by the IC. Finally, the (digital) value is stored in a register and allows to be read via the I²C bus. The value is already available in 'lux', hence no post-processing of the reading is necessary.

4.1.1 Spectral sensitivity

Ambient light sensors are used wherever the light level of a system[1] needs to be adjusted as perceived by humans [1]. They are designed to detect brightness with a similar spectral sensitivity as human eyes do. Figure 8 compares the spectral sensitivity of the SFH 7770, a standard silicon (Si) photo sensor and the human eye (V-lambda, photopic).

A standard Si-detector has its maximum sensitivity in the IR range, where the human eye is not sensitive. Some lamps however do emit light in this "invisible range", which then leads a standard Si detector to "see" higher brightness levels than detected by human eyes. A light bulb, for instance emits a high portion of IR radiation, which is detected by the standard Si-detector, but not seen by the human eye. Fluorescent lamps, on the other hand, do not emit much IR light. Hence the signals detected by the standard Si-detectors are much higher for light bulbs than they are for fluorescent lamps, even though both lamps appear equally bright to the human eye.

[1] Such as the level of backlighting of mobile devices

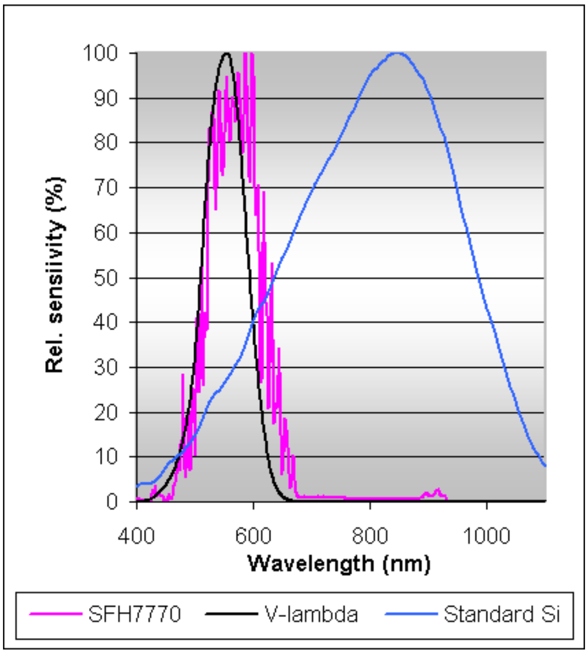


Figure 8: Spectral sensitivity of the SFH 7770, compared to the sensitivity of the human eye and of a standard Silicon detector.

4.1.2 Flicker rejection and timing

Flicker rejection describes the attenuation of light source fluctuations to the sensor output. Light source fluctuations are mainly caused by AC line voltage . The line frequency (50/60 Hz or higher) is transferred to a 100 Hz / 120 Hz optical signal. Flicker rejection means the attenuation of the optical input noise level compared to the sensor output noise level. The SFH 7770 is able to suppress the optical input noise by averaging the input signal over 100ms. This time interval also represents the maximum measurement repeat rate; at the minimum rate in stand-alone mode, a measurement takes place every 2s.
The flicker rejection is typically 13dB for the SFH 7770, i.e. only 5% of the optical input noise will be transferred to the sensor output.

4.1.3 Output and linearity

The sensor output is a 16 bit serial I²C bus output. The maximum output signal is 65535 counts (=65535lx). The final 16 bit data is spread over two 8-bit registers: the ALS data register 0x8C includes the 8 least significant bits, while register 0x8D includes the 8 most significant bits.

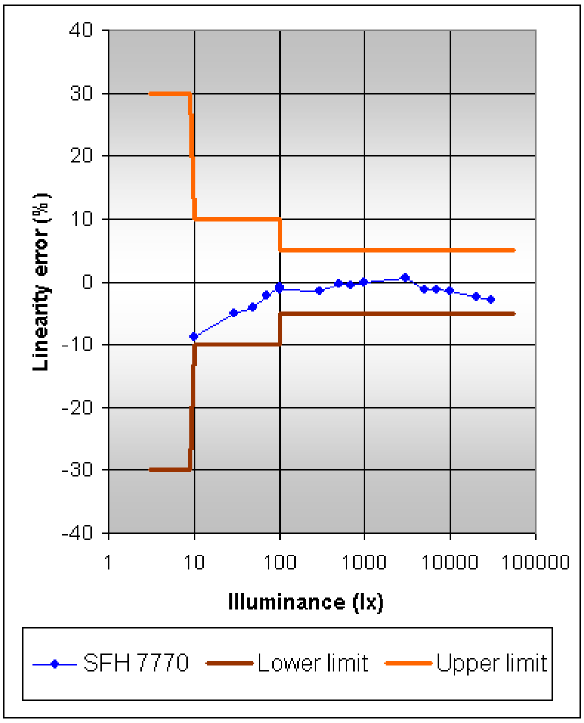


Figure 9: SFH 7770 deviation of the linear output characteristic referenced to 1000lx versus illuminance Ev [lx].

In the following, an example for converting the ALS reading into a lux values is given:

Register 0x8C value = 1001 0001 (binary) and 0x91 (hex), respectively.

Register 0x8D value = 1000 0010 (binary) and 0x82 (hex), respectively.

The actual illuminance value is calculated by combining the registers as below:

1000 0010 1001 0001 lx (binary)

= 0x8291 lx (hex)

= 33425 lx (decimal)

The sensor reading is proportional to the illumination level E_V over a wide illumination range. The specified limits for the linearity error are shown in Figure 9, together with a sample curve.

4.1.4 I²C sample programs for ALS readout

The SFH7770 is operated completely via the I²C bus. All read and write commands must be given by an I²C *master* device (e.g. microcontroller unit). The SFH7770 always acts as an I²C *slave* device with I²C address 0x38.

Step No	Register	R/W	Value	Comment
1	0x80	W	0x04	Reset device
2	0x80	W	0x03	Set ALS to FREE-RUNNING mode
3	0x86	W	0x02	Set repetition time to 500ms
4	---	---	---	Wait >500ms
5	0x8C	R		Read LSB of ALS
6	0x8D	R		Read MSB of ALS
7	---	---	---	Wait >500ms
8	0x8C	R		Read LSB of ALS
9	0x8D	R		Read MSB of ALS

Table 4-1: Simple program for ALS operation

Table 4-1 shows a simple program for reading out the ALS values when SFH7770 is operated in stand-alone mode. The setting of the SFH7770 is performed by the yellow marked steps. It is sufficient to execute those only one single time after power-up of the SFH7770. The other steps may be executed repeatedly.

Table 4-2 contains a more complex program for ALS operation. The ALS is operated in TRIGGERED mode, i.e. each measurement has to be initiated by an I²C master device. The upper/lower threshold levels are set to 1024lx and 128lx, respectively. The operation mode of the interrupt pin is also set (step 7):

a) The interrupt acts in NON-LATCHED mode
b) The interrupt bit and the logic level at the interrupt pin is “0” when the ALS signal is within the threshold range (128lux-1024lux)
c) Only the ALS can trigger interrupt (not PS)

Step No	Register	R/W	Value	Comment
1	0x80	W	0x04	Reset device
2	0x80	W	0x02	Set ALS to TRIGGERED mode
3	0x96	W	0x00	Set upper threshold level to 1024 lx (LSB)
4	0x97	W	0x04	Set upper threshold level to 1024 lx (MSB)
5	0x98	W	0x80	Set upper threshold level to 128 lx (LSB)
6	0x99	W	0x00	Set upper threshold level to 128 lx (MSB)
7	0x92	W	0x0A	Set INTERRUPT output pin
8	0x84	W	0x02	Trigger ALS measurement
9	---	---	---	Wait 20ms
10	0x8E	R		Read status of ALS data: if bit6 is “0” goto step 9.
11	0x8C	R		Read LSB of ALS
12	0x8D	R		Read MSB of ALS
13	0x92	R		Check interrupt bit (bit 7)

Table 4-2: Complex program for ALS operation

Once a measurement is triggered by the I²C master device, the status of the measurement can be read from register 0x8E (step 10). If new ALS data are available, the bit #6 of the register contains "1". Once the data have been read out (steps 11,12), the bit is set back to "0" automatically. If the ALS value is out of the bounds as defined in registers 0x8C and 0x8D, one bit in register 0x92 is set to "1" (step 13). This allows to detect whether the ALS interrupt conditions are fulfilled by just reading a single bit, rather than reading out the complete lux value.

4.2 Proximity sensor

The SFH7770 is capable of detecting the proximity of objects via reflection of pulsed IR light (850nm). Up to three LEDs may be operated, where LEDs are pulsed subsequently (multiplexing, see figure 10). This allows the receiver unit of the proximity sensor to separate signals coming from the different LEDs. For each of the 3 signals, threshold levels for an interrupt alert can be set via the I²C bus.

4.2.1 Functionality and LED drivers

The chip contains drivers for up to 3 external LEDs. Each of the 3 LED drivers is capable of sinking an LED current of 5 .. 200mA. The device is actively regulating the pulsed LED current. No additional resistors for current limitation are required.
The reflected light is detected by an on-chip photodiode. The photodiode signal is processed by analog amplifiers and digital logic. Finally, the signal level is stored in an 8-bit register and allows to be read out via the I²C bus. The output represents the presence of an object which reflects the IR light and can assume values between 0 and 254 (logarithmic scale). Hence, no post-processing of the reading is necessary. In order to reduce the noise of the proximity signal, several data points may be averaged by the master device, which is operating the SFH7770..

To achieve a high ambient light suppression, the SFH 7770 uses a 667 kHz LED burst for only 300 µs per LED for a single measurement. Figure 10 illustrates the burst signal during a complete measurement cycle (all three LEDs are operated). After the initial e.g. I²C-bus triggered request, the proximity data are available after 10ms, the physical measurement is even completed within 1ms. Measurement repetition time in the free running mode can be selected between 10ms and 2000ms. The emitter for proximity measurement shall operate at 850 nm, as an optical filter on top of the photodiode is designed for this wavelength.

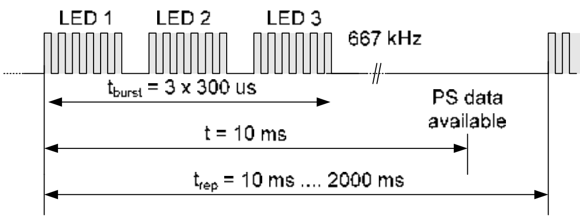


Figure 10: LED current and timing during one proximity measurement cycle.

4.2.2 Proximity signal and detection range

The strength of the reflected proximity signal and hence the output reading of the PS depends on the current setting of the LEDs. Large detection ranges are obtained for LED currents 100 mA, 150 mA or 200 mA.
Fig. 11 presents the proximity values vs. distance for a 50 x 50 mm^2 Kodak White (90% reflectivity) target. The emitter (SFH4650) was placed 5mm away from the SFH7770.
As indicated by Fig. 11, the above setup allows a maximum detection range of about 8 cm (by using 200 mA LED current and setting a threshold level of >70 counts)[2].

[2] Due to limited resolution, the first PS readings at low irradiance are restricted to the discrete 0→47→59→66→72→80→83. Above 83, the value increases count by count until it reaches the saturation

If used as a proximity switch, it is recommended to set the threshold level not below 80 to avoid interference with noise.

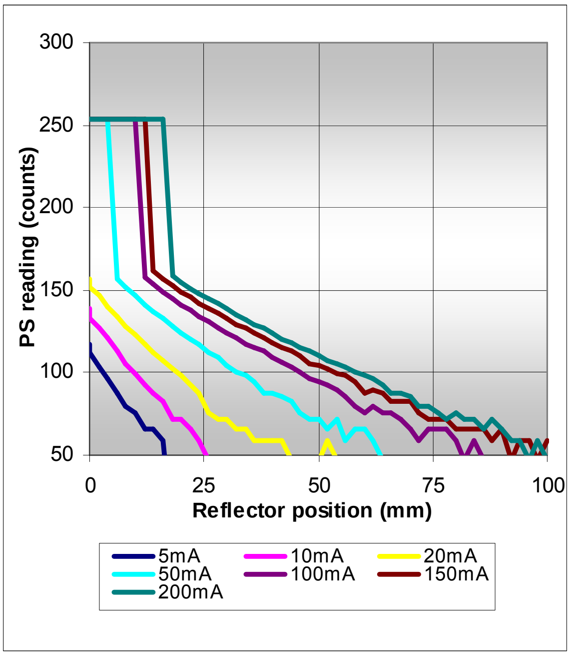


Figure 11: SFH 7770 proximity signal vs reflector distance (with emitter SFH4650)

The proximity count signal is correlated to the detected irradiance E_e. There is an approximate logarithmic relationship between PS signal counts and the irradiance:

$$E_e = \left(10^{0.02 \cdot counts}\right) \frac{\mu W}{cm^2} \qquad \text{Eq. (1)}$$

Please note that this approximation is only valid for PS output readings of ~60 to163.

4.2.3 I²C sample programs for PS readout

The SFH7770 is operated completely via the I²C bus. All read and write commands must be given by an I²C MASTER device (e.g. microcontroller unit). The SFH7770 always acts as an I²C SLAVE device with I²C address 0x38.

Table 4-1 shows a simple program for one single PS channel (and thus one external LED). The SFH7770 is operated in stand-alone mode. The setting of the device is performed by the yellow marked steps. It is sufficient to execute these steps only one single time after the power-up of the SFH7770. The other steps may be executed repeatedly.

Step No	Register	R/W	Value	Comment
1	0x80	W	0x04	Reset device
2	0x81	W	0x03	Set PS to FREE-RUNNING mode
3	0x85	W	0x05	Set repetition time to 100ms
4	0x82	W	0x06	Operate LED1, I_LED=200mA
5	---	---	---	Wait >100ms
6	0x8F	R		Read PS data (LED1)
7	---	---	---	Wait >100ms
8	0x8F	R		Read PS data (LED1)
9	…			

Table 4-1: Simple program for PS operation with single LED (LED1)

Table 4-2 contains a more complex program for PS operation with three LEDs. The PS is operated in TRIGGERED mode, i.e. each measurement has to be initiated by an I²C master device. The threshold levels for all 3 channels are set to 90 counts. The operation mode of the interrupt pin is also set (step 8):

a) Interrupt pin is triggered by LED1
b) Interrupt acts in NON-LATCHED mode
c) The interrupt bit and the logic level at the interrupt pin is "0" when the PS signal is below the threshold
d) Only PS can trigger interrupt (not ALS)

level of 163. At higher irradiance, the reading jumps to 254. The typical noise level (no target present) is in the range 0/47/59 for the 200 mA range and 0/47 (1 bit noise) at the 100 mA range.

Step No	Register	R/W	Value	Comment
1	0x80	W	0x04	Reset device
2	0x81	W	0x02	Set PS to TRIGGERED mode
3	0x82	W	0xF6	All LEDs active, I_LED1&2=200mA
4	0x83	W	0x06	I_LED3=200mA
5	0x93	W	0x5A	Set LED1 threshold level to 90 counts
6	0x94	W	0x5A	Set LED2 threshold level to 90 counts
7	0x95	W	0x5A	Set LED3 threshold level to 90 counts
8	0x92	W	0x2D	Set INTERRUPT output pin (trigger source LED1)
9	0x84	W	0x01	Trigger PS measurement
10	---	---	---	Wait 2ms
11	0x8E	R		Read status of PS data: if bits 0,2,4 are "0" goto step 9.
12	0x8F	R		Read PS value (LED1)
13	0x90	R		Read PS value (LED2)
14	0x91	R		Read PS value (LED3)
15	0x92	R		Check PS interrupt bits (bits)

Table 4-2: Complex program for PS operation

Once a measurement is triggered, the status of the measurement can be read from register 0x8E (step 11). If new PS data are available, the bits 0,2,4 for channels 1,2,3, respectively of the register are set to "1".
Once the data have been read out (steps 12,13,14), the bits are set back to "0" automatically.
If the PS value of a channel is above its limit (defined in registers 0x93, 0x94 and 0x95), the corresponding bit (bit 1,3 and 5 in register 0x92) is set to "1" (step 15). This allows the user to detect PS events for each channel by reading single bits, rather than reading out the complete set of PS values.

5 Optical design guidelines

In many applications, the SFH7770 will be operated together with one or more LEDs. This section contains recommendations for the optical design of the whole ensemble, e.g. relative positions of SFH7770 and the LED(s), optical separators and optical crosstalk features.
Optimal setups for gesture recognition (like hand movements) are discussed.

5.1 Component arrangement

The arrangement of the SFH7770 and the LEDs depends on the desired application. If only the presence and/or the distance of an object (e.g. hand, ear, hair) has to be detected, one LED is sufficient. If the movement of an object in 2 or 3 dimensions has to be detected, all 3 channels of the proximity sensor will be used.
In the following sections some example configurations for the placement of the LEDs and the SFH7770 will be given. In any case it is recommended to check the functionality under the customer's application conditions (eg. cover model, placement distance, and height above the sensor,…)

5.1.1 Setup for simple proximity detection

The emitter should be placed close to the SFH7770 (distance <1 cm), see figure 12. This ensures a high level of the reflected signal, when the object is close to the detector. Alternatively, the LED current can be kept low, which leads to less power consumption. On the detection *distance* , the component spacing only has minor influence. The effect of different emitter-detector spacings is also shown in figure 12.

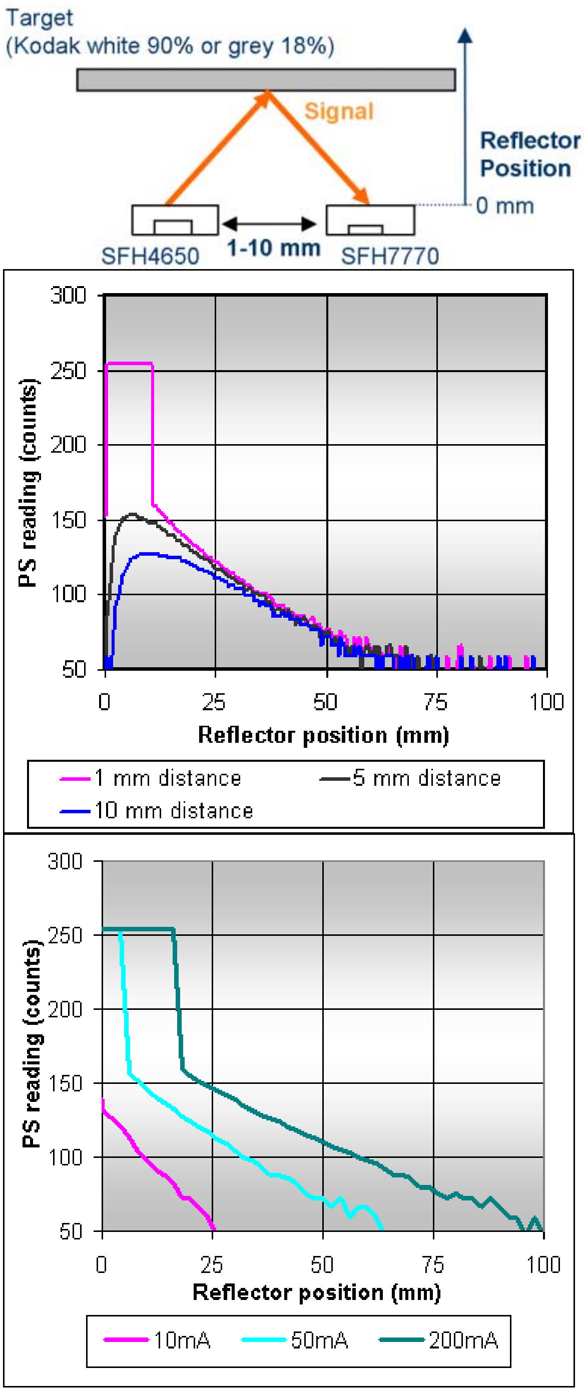


Figure 12
Top: Setup for SFH7770 and LED SFH4650 for single signal detection.
Middle: SFH 7770 proximity signal vs reflector distance (with LED 5mm apart) for different LED currents.
Bottom: SFH 7770 proximity signal vs reflector distance for different LED distances (LED current 100 mA, reflector Kodak grey 19%).

As an example, figure 12 also shows the reading of the proximity sensor for different LED current settings, when the emitter (SFH4650) is placed 5mm away from the SFH7770. Detection ranges up to 100 mm are possible.
When the signal is within the operating range of the SFH7770, the reading of the proximity sensor decreases in an almost linear way with the distance of the object. In this case the PS reading can be used to estimate the distance quantitatively. Please note that the intensity of the reflected signal depends strongly on the reflectivity of the object (e.g. color of the hair). This has to be taken into account during the evaluation of the signal.

5.1.2 Setups for gesture recognition

Detecting an object's movement in 3 dimensions can be done with a rectangular arrangement of SFH7770 and 3 LEDs. Figure 13 shows two possible arrangements.

The setup shown in the upper part of figure 13 has LED1 placed close to the SFH7770, while LED2 and 3 are placed in some distance in a rectangular “L” type fashion. LED1 is intended to measure the distance of the moving object, as discussed in the previous section. Observing the signals of LED1 and 2 simultaneously gives information on left/right movements of the object, while LED 1 and 3 measure forward/backward movements. This setup is preferably used when the components have to be arranged around a rectangular shaped touchscreen or the display of a mobile phone.
If the SFH7770 and the LEDs can be arranged more freely, it is recommended to use the setup shown in the lower part of figure 13. The components are arranged in a “T” shaped form, with all LEDs placed in equal distance from the SFH7770. When an object finds itself right above the SFH7770, all 3 proximity channels will have

approximately the same signal height. The "L" shaped setup in figure 13a will always show a dominant signal from LED1, since it is placed close to the SFH7770. The "T" shaped setup allows easy interpretation of the relative signals of the 3 LEDs. As an example, the ratio of the proximity signals from LED 2 and 1 gives direct information on the left/right position of the object.
In order to draw such conclusions it is assumed that all LEDs have the same radiation characteristics and optical power which is not the case in reality. To cover the variations of the LEDs it may be necessary to perform a calibration of each ensemble individually.

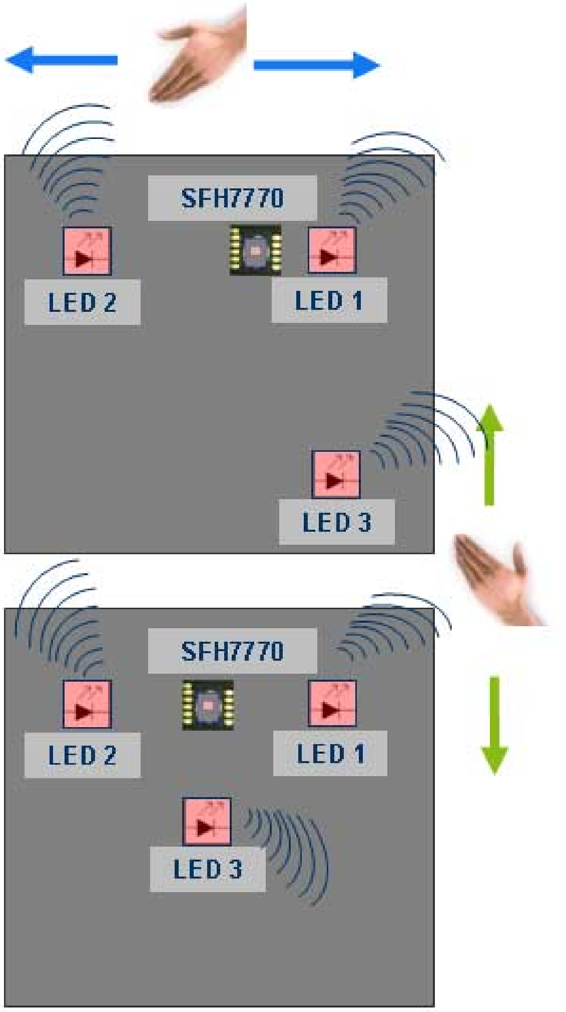


Figure 13: Setups for 3D gesture recognition with SFH7770, each containing 3 LEDs.
a) "L" shaped setup
b) "T" shaped setup

5.1.3 Example: gesture detection setup & flow

In this section, a sample setup for gesture recognition is presented, together with a flowchart for distinguishing different movements of a reflecting object.

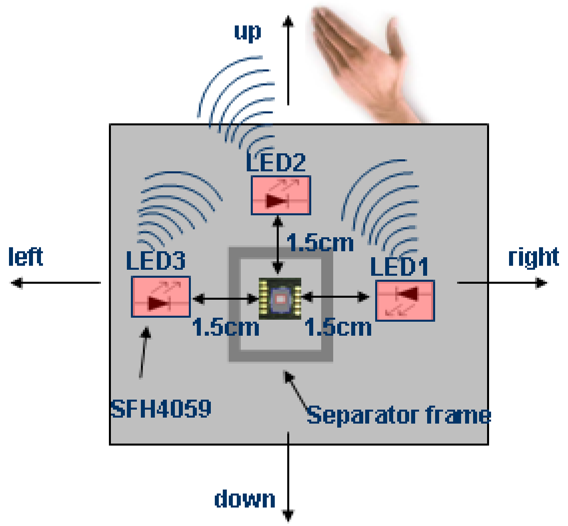


Figure 14: Sample setup for gesture recognition with SFH7770, each containing 3 LEDs

For the hardware setup one of the configurations from the previous section is used, see figure 14. The SFH7770 is surrounded by 3 LEDs of type SFH4059 at a distance of 1.5 cm. In order to eliminate optical crosstalk, a separator frame of height ~3mm is inserted between the LEDs and the SFH7770.

The setup is intended to detect horizontal hand movements. The open hand is expected to be moved left/right and back/forth across the arrangement in a distance of a few centimeters above the SFH7770. The movement direction is detected by evaluating the relative signal height of LEDs 1,2 and 3.

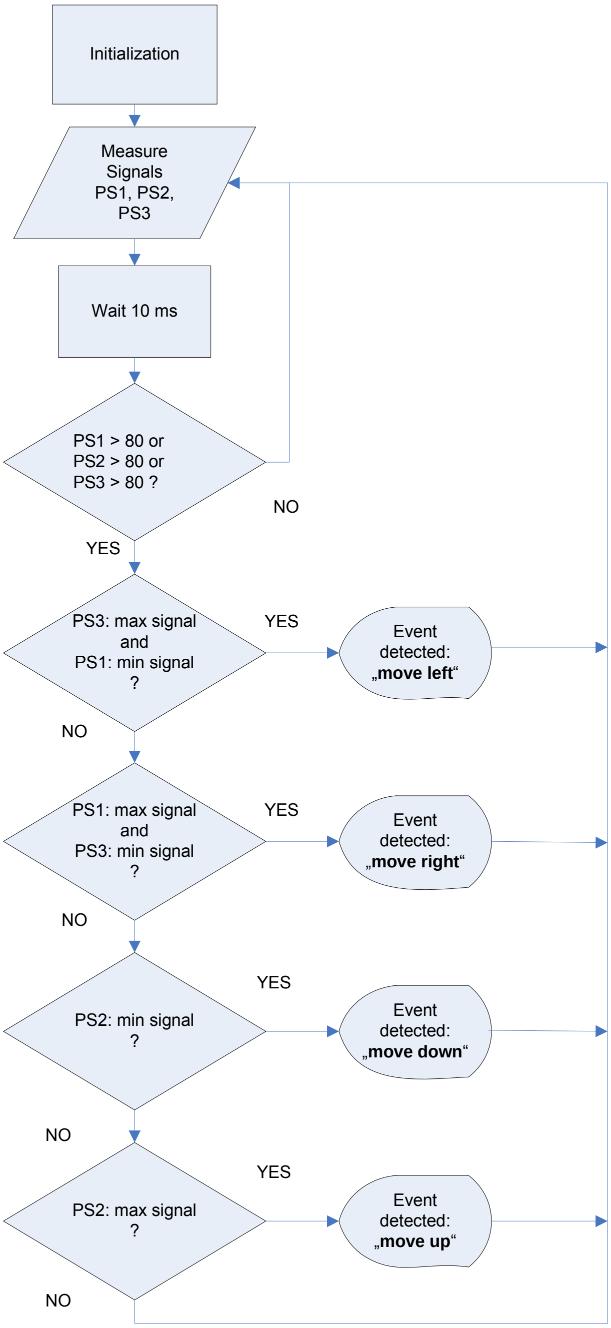


Figure 15: Gesture recognition sample flow for SFH7770 and 3 LEDs

A flowchart how to derive the direction of the hand movement is presented in figure 15. The operating principle of the flow is as follows:

1) *Readout of all PS channels every10ms.*
A repeat rate of 10ms is the fastest possible measurement rate for the proximity sensor. The actual measurement of all 3 proximity channels occurs within 1ms. The remaining time is used for processing the data and making them accessible via the I²C bus.

2) *Check if a least one PS signal (channel 1, 2 or 3) is above a given threshold.*
In order to eliminate unwanted response of the sensor to noise, the signal value must be above a fixed threshold level. A suitable level has to be determined for each application separately. Typical levels are ~80-100 output counts of the proximity sensor.

3) *Determine which channel has the maximum and minimum signal values*
The min&max evaluation is only done if at least one of the considered proximity signals is above the threshold level. Otherwise, a new proximity measurement is initiated.

4) *Decide from maximum and minimum reading which event has taken place*
For each of the four events, different (and exclusive) criteria have to be fulfilled. For example, if channel 1 and 3 deliver the maximum and minimum signal, respectively, the event is interpreted as a desired movement to the right (direction from SFH7770 to the LED1).

5.2 Choice of LED type

The proximity sensor of SFH7770 is designed for the use of 850nm infrared LEDs. The typical radiation characteristics depends on the type of the LED.
If collimation optics (like lens, reflector) are included, usually the emission half angle of the LED is small. An LED without collimation optics shows a nearly Lambertian (cosine shaped) angular characteristic, with an emission half angle of ~±60°.
The dependence of the PS reading on the emitter type is shown in figure 16. A stripe shaped reflector with 15mm width is swept over SFH7770 and one LED. The reflector

shape is supposed to imitate a finger which is swept across the devices.
The sweep was done at a (vertical) distance of 25mm to SFH7770 and LED. At reflector position “0” the reflector is centered above the SFH7770.

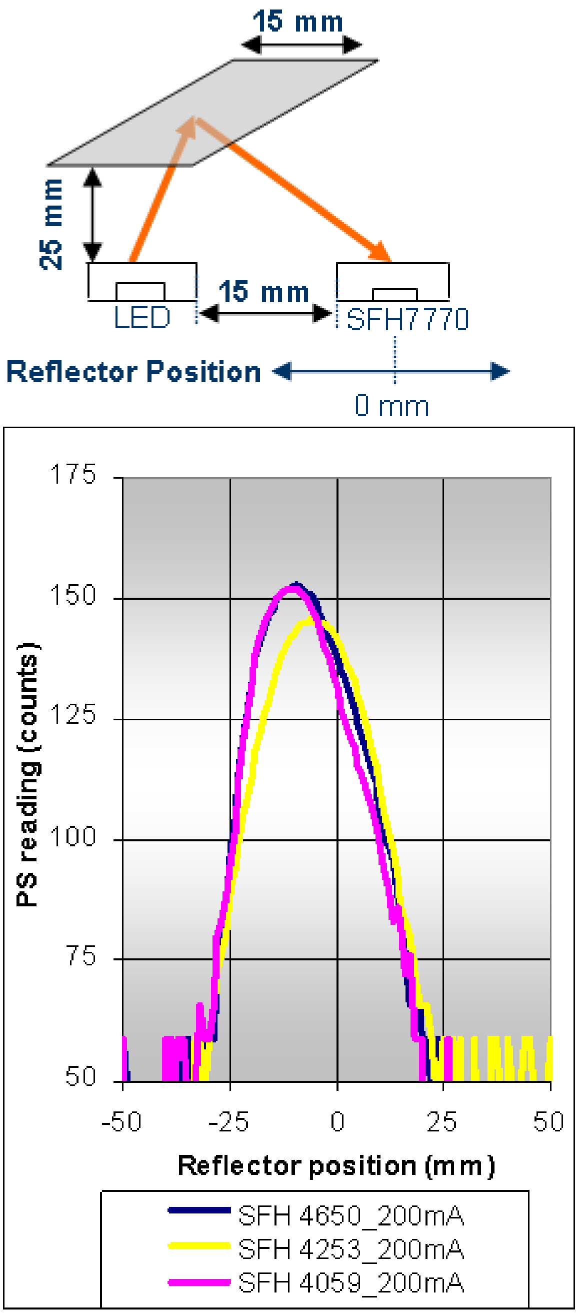


Figure 16
Top:A stripe-shaped reflector is swept across the SFH7770 and the LED
Bottom: SFH7770 proximity sensor reading during the reflector sweep for 3 LED types.

The sweep has been performed for 3 different emitters: SFH4650, SFH4059 and SFH4253. The emitters and the corresponding emission angles are shown in table 5-1. For more information on IR emitters please visit the OSRAM OS website at

http://www.osram-os.com/osram_os/EN/

Figure 16 shows that emitters with a narrow emission angle are showing a slightly higher reflected peak signal. The reflector position where the reflected signal has a maximum is shifted also.

Emitter type	**Image**	**Half angle**	**Dimensions (LxWxH)**
SFH4059		+/-10°	3.20 mm x 1.60 mm x 1.85 mm
SFH4650		+/-15°	3.10 mm x 2.25 mm x 1.60 mm
SFH4253		+/- 60°	3.20 mm x 2.80 mm x 1.90 mm

Table 5-1
Selection of 850nm IR emitters

The choice of the emitter type depends on the requirements of the application. If a high signal at a comparably small spatial region is desired, an emitter with narrow emission angle will be the best choice. If detection contrast is not an issue and a wide spatial region has to be covered, a wide angle emitter will fit best.

5.3 Separators and LED spacing

A stronger spatial confinement of the radiation characteristic and hence the detection region can be achieved by the use of apertures positioned above the sensor. Any restriction of the LED beam leads to a better contrast at gesture recognition applications. On the other hand, any aperture reduces the intensity of the reflected signal.

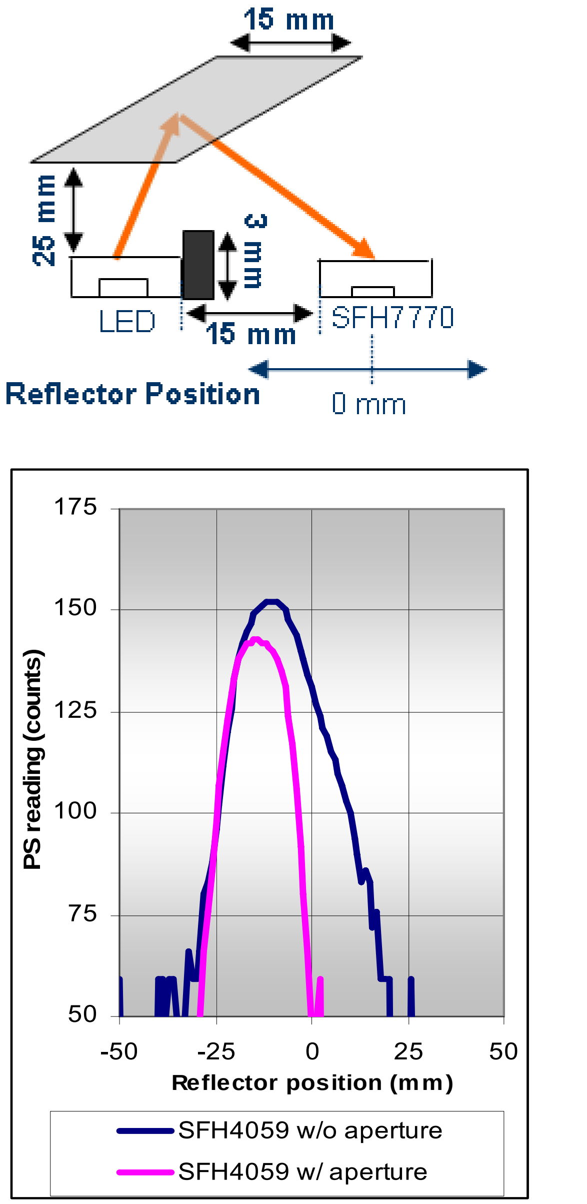


Figure 17
a) A stripe-shaped reflector is swept across the SFH7770 and an LED
b) SFH7770 proximity sensor reading at sweeping a stripe reflector for SFH4059.

The effect is demonstrated in figure 17. The same reflector sweep has been performed as in figure 16. The aperture is created by placing an optical absorber with 3mm height next to the LED.

The distance between SFH7770 and the LED also influences the relative signals for multi-LED operation and hence the contrast at gesture recognition applications.

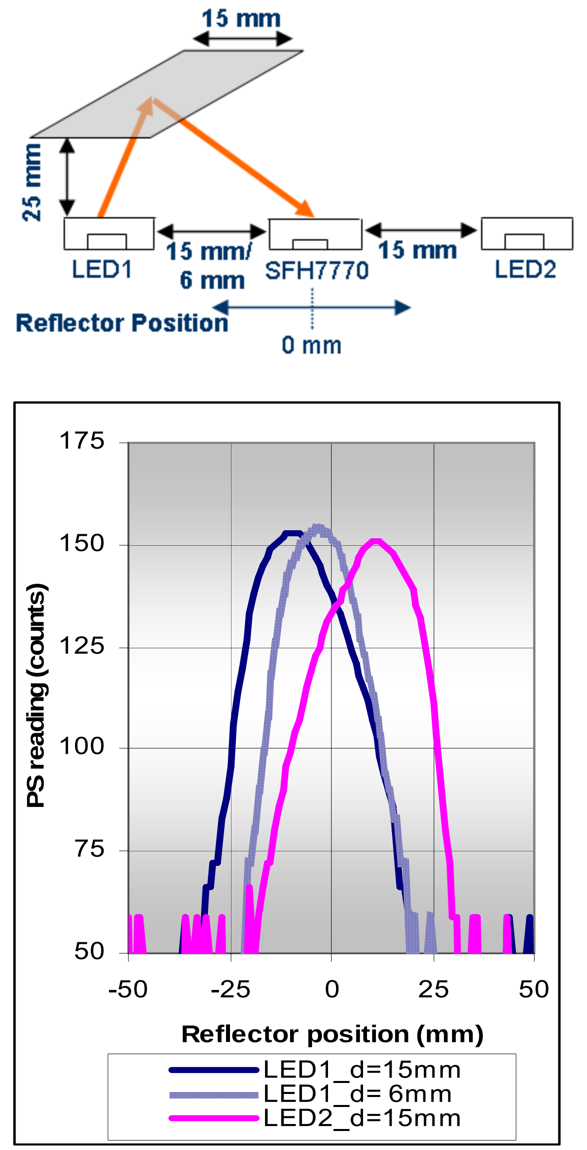


Figure 18
a) Setup for sweep of stripe-shaped reflector
b) SFH7770 proximity sensor reading at sweeping a stripe reflector. Emitter: SFH4650 at distance 6mm/15mm.

In figure 18 two LEDs (SFH4650) are operated with SFH7770. The LEDs are placed on opposite sides of the SFH7770 and a stripe reflector is moved horizontally. The difference between the signals from LED1 and 2 allows to make a good estimate for the position of the reflector. When the LEDs are spaced at 15mm from the SFH7770, the detection contrast is sufficient for many applications. When the LEDs are moved closer to the SFH7770 (to 6 mm in figure 18), the LED beams are overlapping more and the contrast between the two signals gets lower. At the same time, the signal height increases. Thus, a tradeoff between signal height and contrast has to be performed.

5.4 Optical crosstalk

When proximity sensing is performed with up to 3 LEDs, it is desirable that only light from a reflecting object reaches the SFH7770. Depending on the optical setup, additional and unintended light paths from the LED to the detector may exist, which is referred to as '(optical) crosstalk'. In this section, several sources of crosstalk are discussed, together with measures for suppression of the effect.

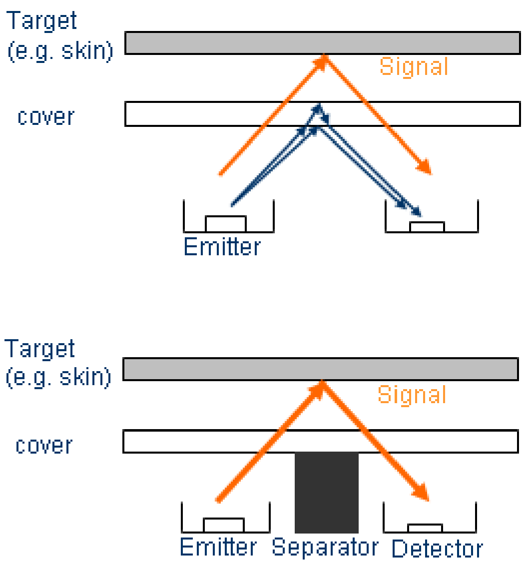


Figure 19
a) Optical crosstalk via cover glass
b)Crosstalk elimination by introducing a separator

Usually, the LED and the SFH7770 are operated behind a cover glass, which has a reflectivity of typically 4% for each surface. If there is an air gap between LED/SFH7770 and the glass, a considerable portion of light gets reflected directly to the detector by the glass surfaces, see figure 19. In extreme cases, the signal reflected via the cover glass exceeds the signal of interest. The result is a decreased operating range for the detection distance: the signal of interest clearly has to exceed the noise floor generated by the crosstalk, in addition to the SFH7770 inherent noise.

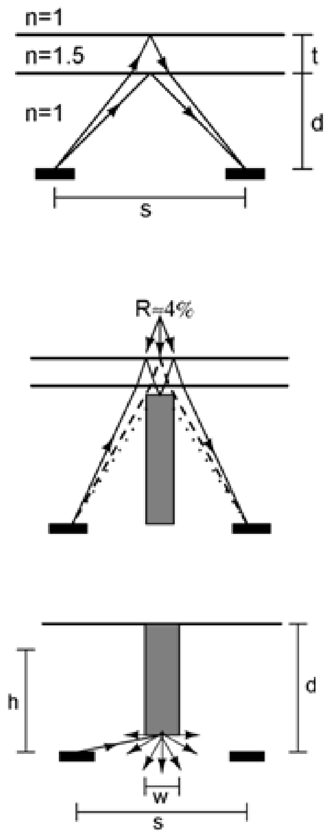


Figure 20
Top: Optical crosstalk via cover glass
Middle: Crosstalk via cover glass & separator surface
Bottom: Crosstalk via bottom side of separator

The crosstalk can be reduced by introducing a separator between IRED and the detector, see also figure 19. A careful design of separator (width, height) can minimize range reduction by eliminating the crosstalk. The remaining crosstalk may be suppressed by offset subtraction.

Figure 20 shows additional sources of crosstalk:

a) Since the reflection of the IR light occurs not only at the bottom surface of the cover, but also on the top side, a separator design is recommended, which is blocking both reflections. The separator material should be absorbing and preferably diffusely reflecting. This also leads to the attenuation of multiple reflections within the cover.

b) If an air gap between separator and cover glass exists, additional light paths between emitter and detector may be created. Especially, when the surface of the separator is reflective, light from the emitter may reach the detector via multiple reflections (see also figure 20). In order to avoid this, the surface of the separator should be diffusely reflective. Additionally, it should be placed as close to the cover glass as possible.

c) If there is a gap between the separator and the PCB upon which the LED and the SFH7770 are mounted, some reflection may occur also at the bottom of the separator. The height of this air gap should be minimized as well.

For further technical support please contact OSRAM OS sales at

http://www.osram-os.com

5.5 Zero distance detection

In some cases the detection of objects is required, which are in direct touch with the cover glass ('zero distance detection', see figure 21). For example, this 'object' can be a finger, hair or the human ear. In principle, the SFH7770 is capable of detecting the presence of objects in direct contact with the cover. It is important to design the separator between LED and SFH7770 carefully. If it is too wide, it will block the signal reflected by the object. If it is too narrow, the crosstalk signal will increase and thus mask the signal of interest.

The light path for reflection from the zero-distance object is very similar to the reflection at the top side of the cover glass. Nevertheless, zero distance detection is made possible by the following effects:

a) The reflecting object (e.g. hand) is not placed exactly above the separator.

b) Although a finger is placed on the cover, the light scattering takes place within the skin, and not on its surface.

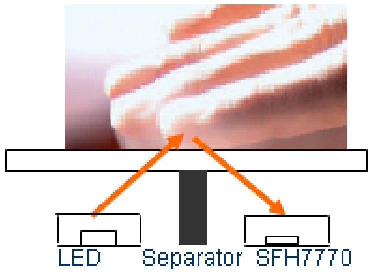


Figure 21: Zero-distance detection

5.6 Placement of the SFH 7770

The photosensitive area of both ALS and PS detectors is located within a square of 0.5mm x 0.5mm in center of the package. Figure 22 shows the position of the sensitive area.

At designing apertures and the field of view of the sensor, only this sensitive area has to be taken into account. The same holds for placing the part behind a light guide.

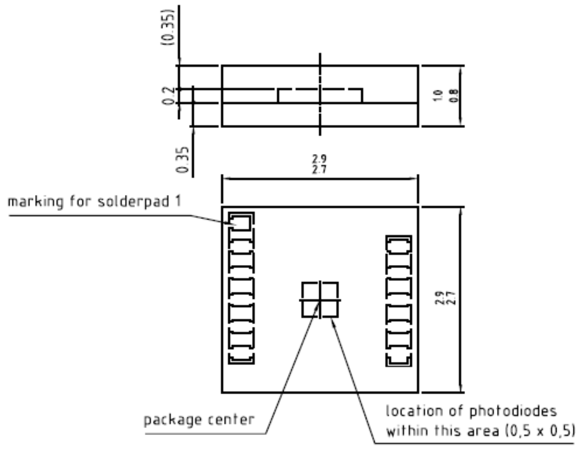


Figure 22: Position and size of the sensitive area within the SFH 7770

When placing the sensor behind a cover window opening, the recommended cover opening aperture α is > +/- 60° (see figure 22).

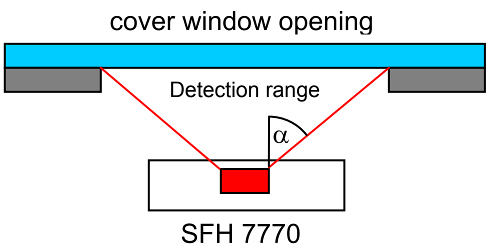


Figure 22: Cover window opening

Optical properties of a light guide or the limited aperture based on a cover window opening will shadow the sensor within certain angular ranges. The overall directional characteristic is getting changed and the horizontal detection range will be reduced.

6 Electrical design guidelines

This section contains guidelines for electrical circuitry and operation of SFH7770.

6.1 General circuitry and pinout

The SFH7770 is a 10-pin SMT device. The pin assignment is shown in figure 23, together with some external components which are required/recommended for operation. The 10 pins may be classified as follows:

a) *Supply voltage* (VDD, GND, pins 6 and 4): For safe operation of the device, the supply voltage must be in the range 2.3V …3.1V. A bypass capacitor of >100nF close to the device is required.

b) *LED connectors* (LED1,2 & 3, LED_GND , Pins 1-3, 7): Each LED pin is set up as open drain output, where the cathode of an external 850nm IRED can be connected to. The anodes of all LEDs are connected to an external voltage V_{LED}, which in turn is buffered via a 10µF blocking capacitor. The LED_GND connector is separated from the GND pin. Please note that the voltage difference between GND and LED_GND must not exceed 500mV for proper operation of the device.

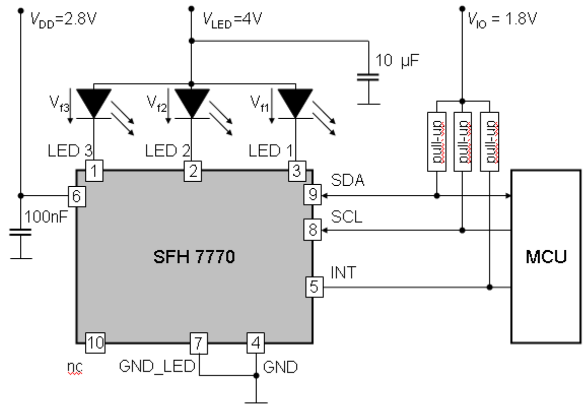


Figure 23: Application diagram for basic operation of SFH 7770

c) *I²C bus pins* (SCL, SDA, pins 8&9): The I²C bus communication with a microcontroller unit is performed via these pins. Pull-up resistors to a voltage level of 1.6V … 2.0V are required. For details please be referred to chapter 3.

d) *Interrupt pin* (INT, pin 5): The INT pin is set up as an open drain logic output, which should be connected to an external logic voltage via a pull-up resistor. The resulting logic signal can be evaluated by external circuitry, like a microcontroller unit.

e) *Pin 10:* not connected. It is recommended to connect pin 10 to GND.

The pin assignment of SFH7770 is shown in figure 24 for top/bottom view. At top view, pin 1 is clearly marked with an extra metal spot. The size of the soldering pads of the device can also be seen from figure 24.

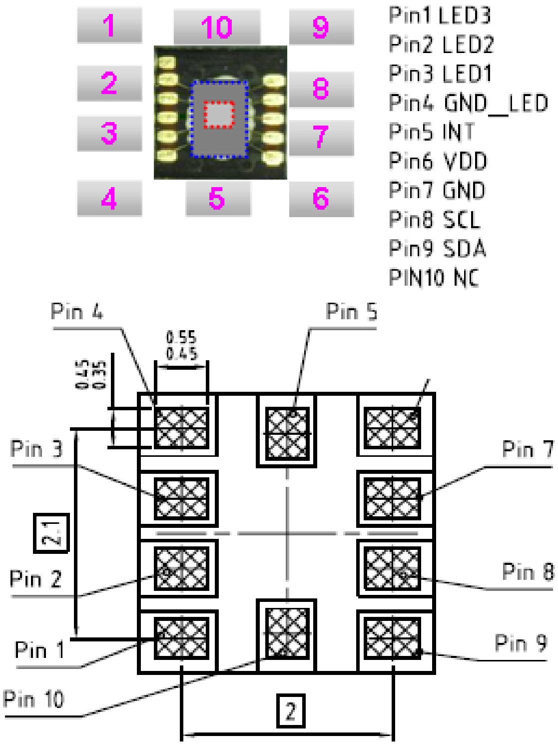


Figure 24: Application diagram for basic operation of SFH 7770

6.2 Supply voltage

The SFH 7770 is suitable for a supply voltage of 2.3 V to 3.1 V. A VDD bypass capacitor is strongly recommended to keep the supply voltage ripples below the specified limit, see [2]. Vdd ripples depend on the application and the power supply quality and can be measured with an oscilloscope. In any case, a capacitor of 100nF is recommended to suppress high frequency oscillations, see figure 23. The capacitor should be placed as close to the SFH7770 as possible. If the design only admits a large distance between the devices, the capacitance may have to be increased to 1 µF or more for proper operation.

6.3 LED connection and operation

The SFH 7770 is suitable to drive up to three LEDs. During driving the LEDs, the parasitic inductances and capacitances are very important, especially at LED currents >20mA.

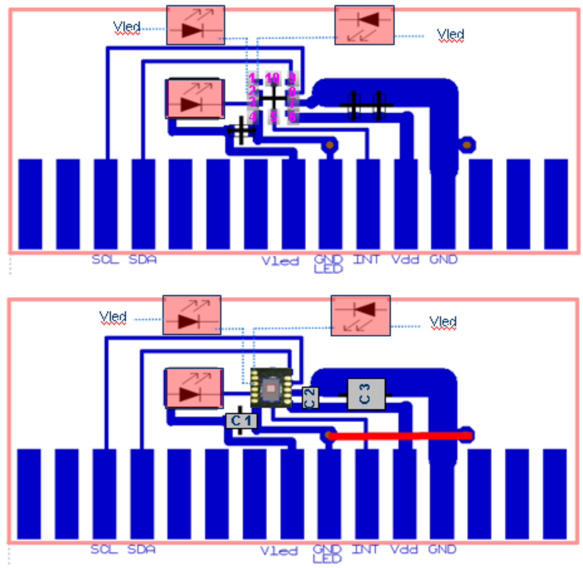


Figure 25: Sample PCB design (top) and component placement (bottom) for operating the SFH 7770 with up to 3 LEDs.

It is recommended to use a low-inductance layout for all LED connections. The parasitic LED wire inductances must be kept low (e.g. <20 nH for 200 mA LED current, <200nH for 20mA LED current). Special care has to be taken if the distance between the LED and the SFH7770 is in the range of several centimeters, as required for e.g. gesture recognition applications. In this case, a PCB design with low inductance paths has to be found for the connecting paths between SFH7770 and the LED.
Furthermore, a bypass capacitor between VddLED and GND_LED with >10µF is strongly recommended.

6.4 PCB design recommendations

As mentioned in the previous sections, the use of a low inductance wiring is advisable, especially for LED connections. A PCB with at least 2 layers is recommended, where one layer is used as a ground plane. The GND and the LED_GND pins of SFH7770 should be connected to the ground plane close to the device.

Figure 25 shows a sample PCB design for SFH7770 and one LED. The connections to 2 further LEDs are marked as dotted lines. As mentioned above, the design should include an additional ground plane (not shown). The VLED line is buffered with a single 10µF Tantalum capacitor (C1), while the VDD line is blocked by capacitors of size 100nF (C2) and 10µF (C3, Tantalum cap).

In addition, the PCB layout has to be designed in a way that the capacitance on SCL and SDA line fulfills the I²C bus specification [3]. The maximum clock frequency correlates with the bus frequency. The Highspeed mode (Hs) of 3.4 MHz requires a maximum bus line capacitance for SDA and SCL of 100pF. For the Hs mode with 1.7 MHz the bus capacitance can be increased up to 400pF.

6.5 Pull-up resistors

Pull-up resistors are used to reference the digital data lines SDA & SCL to the V_{IO} level. The maximum useable pull-up resistor depends on the overall bus capacitance (wires, connections and pins) due to the specified I²C bus rise time. Sink current needs to be calculated for each application. Details and instructions are provided at [3].

6.6 I²C bus master devices

In an I²C environment, the SFH7770 always acts as a *slave* device (see chapter 3). Therefore, the presence of an I²C *master* device is necessary for the operation.
During the design-in phase the SFH7770 usually needs to be operated in a laboratory environment, prior to sample builds. For this purpose, several PC based I²C driver tools are available, see table 6-1. Most of these adapters may be connected to the USB bus of the PC.

Manufacturer	Model	Max. I²C bus mode
Jupiter Instruments	JI-300	Hs
Corelis	busPro-I	Hs
Corelis	CAS-1000	Hs
AVIT Research	I²C Professional	Fm
demoboard.com	Win-I2CUSBDLL	Fm
FDI	USB-MPC	Fm
telos	TRACII 2.0	Hs
MCC	MIIC-204G	FM

Table 6-1: Examples of PC based development tools for I²C bus (Status: end/2009)

The complete control on the SFH7770 can be performed by a single (programmable) microcontroller IC. Table 6-2 shows several microcontrollers which contain an I²C Bus interface.

Manufacturer	Model	max Bit rate
MAXIM	MAXQ3108	Fm
MAXIM	MAXQ2010	Fm
NXP Semiconductors	LPC175X	Fm
NXP Semiconductors	LPC176X	Fm+
NXP Semiconductors	LPC2361/62	Fm

Table 6-2: Examples for I²C bus ICs (Status: end/2009)

Other microcontrollers with an I/O port might also be adapted to I²C bus communication.

7 List of literature:

[1] Application note can be downloaded from http://www.osram-os.com/osram_os/EN
[2] SFH 7770 Datasheet can be downloaded from http://www.osram-os.com/osram_os/EN
[3] UM10204 I²C bus specification and user manual" from NXP Rev.03 --- 19 June 2007

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