TCS3448

Datasheet

Published by ams-OSRAM AG
Tobelbader Strasse 30, 8141 Premstaetten, Austria
Phone +43 3136 500-0
ams-osram.com

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TCS3448 14-Channel multi-spectral sensor

1 General description

The TCS3448 is a 14-channel highly versatile, multi-purpose spectral light sensor. It is optimized to sense spectral components of ambient light in the visible range. Such spectral information is used for camera enhancement (CCT, AWB, exposure time).

The spectral response is defined by individual channels covering approximately 380 nm to 1000 nm with 11 channels centered in the visible spectrum (VIS), plus one near-infrared (NIR) and a clear channel. Applications can be assisted to allow classification of ambient light and an integrated flicker detection channel that can automatically flag ambient light flicker at 50/60 Hz as well as buffer data for externally calculating other flicker frequencies.

TCS3448 integrates high-precision optical interference filters directly deposited on photodiodes which are embedded in CMOS silicon. A built-in aperture controls the light entering the sensor array to increase accuracy. A programmable digital GPIO and LED driver enable light source and trigger/sync control. Device control and spectral data access is implemented through a serial I²C 1.2 V/1.8 V interface. The device is available in an ultra-low profile package with dimensions of 3.1 mm x 2 mm x 1 mm.

1.1 Key benefits & features

The benefits and features of TCS3448, 14-Channel multi-spectral sensor are listed below:

Table 1: Added value of using TCS3448

Benefits	Features
Highly versatile multi-purpose spectral sensor	• 14 channels between 380 nm and 1000 nm • Reflective, transmissive and emissive applications
Highest sensitivity	• Enables ultra-low light operation • Enables operation behind dark glass
Low power consumption and minimum I²C traffic	• 1.8 V supply voltage • 1.2 V/1.8 V I²C bus voltage • Configurable sleep mode • Interrupt-driven device
Ultra-high integration	• On chip interference filter technology • Integrated LED driver and 6 ADCs • 3.1 mm x 2 mm x 1 mm package outline

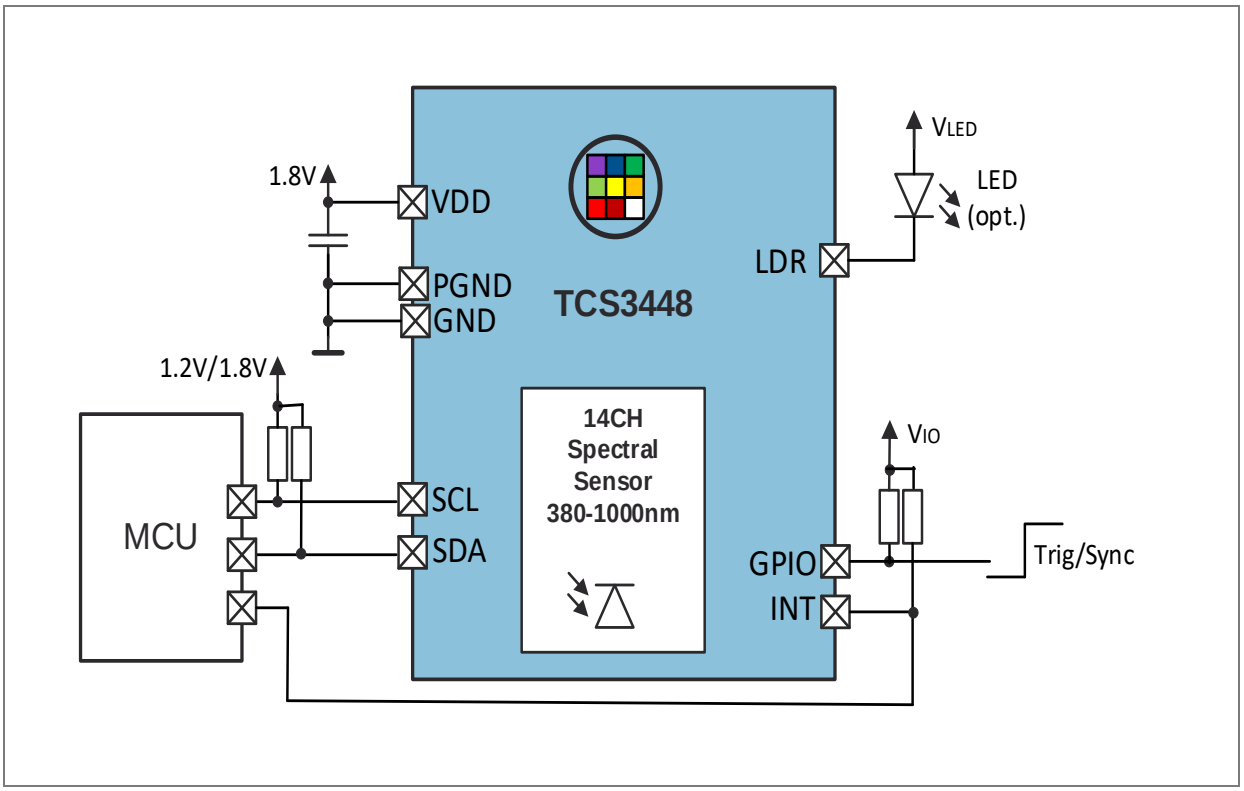
1.2 Applications

- Accurate ambient light measurement for camera enhancement.
- Calculation of reconstructed spectra, light source ID and ambient light flicker.
- Highly accurate CCT and LUX measurement.

1.3 Block diagram

The functional blocks of this device are shown below:

Figure 1: Functional blocks of TCS3448



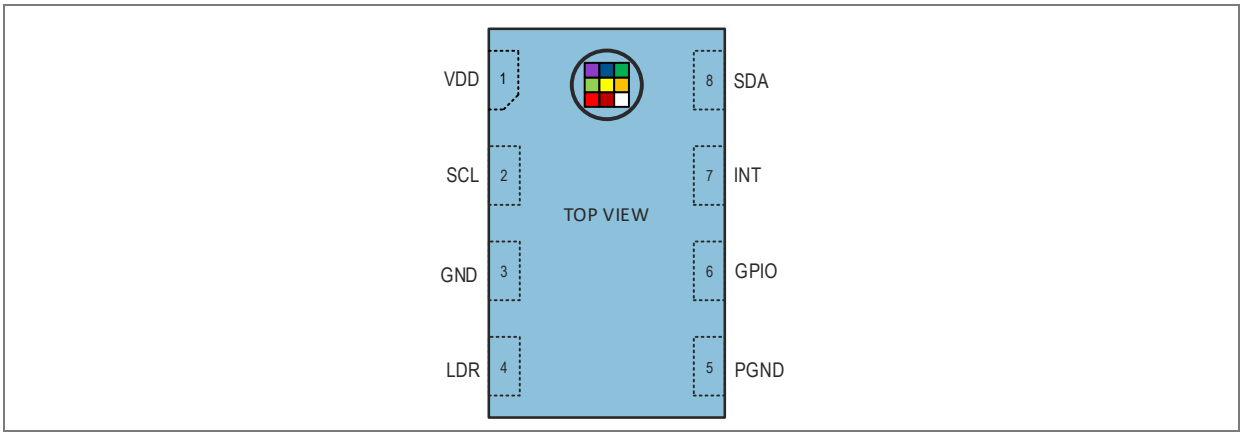
2 Ordering information

Ordering code	Package	Delivery form	Delivery quantity
TCS34488	OLGA-8	Tape & reel 13-inch	10000 pcs/reel
TCS34488M	OLGA-8	Tape & reel 7-inch	500 pcs/reel

3 Pin assignment

3.1 Pin diagram

Figure 2: Pin diagram of TCS3448 (Top View)



3.2 Pin description

Table 2: Pin description of TCS3448

Pin number	Pin name	Pin type(1)	Description
1	VDD	P	Positive supply voltage terminal.
2	SCL	DI	Serial interface clock signal line for I²C interface. Connect pull up resistor to 1.2 V or 1.8 V.
3	GND	P	Ground. All voltages referenced to GND.
4	LDR	A_I/O	LED current sink input. If not used leave pin open.
5	PGND	P	Ground. All voltages referenced to GND.
6	GPIO	D_I/O	General purpose input/output. Pin is used to select 1.2 V or 1.8 V I²C I/O voltage. Please refer to chapter “Selection of I²C bus interface voltage”.
7	INT	DO_OD	Interrupt. Open drain output active low. Connect pull up resistor to 1.8 V. If not used leave pin unconnected.
8	SDA	D_I/O	Serial interface data signal line for I²C interface. Connect pull up resistor to 1.2 V or 1.8 V.

(1) Explanation of abbreviations:
DI = Digital Input, D_I/O = Digital Input/Output, DO_OD = Digital output, Open drain, P = Power pin, A_I/O = Analog pin

4 Absolute maximum ratings

Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under “Operating Conditions” is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. All voltages with respect to GND/PGND. Device parameters are guaranteed at V_{DD}=1.8 V and T_A=25 °C unless otherwise noted.

Table 3: Absolute maximum ratings of TCS3448

Symbol	Parameter	Min	Max	Unit	Comments
Electrical parameters					
V_{DD} / V_{GND}	Supply voltage to ground	-0.3	1.98	V	Applicable for pin VDD
V_{ANA_MAX}	Analog pins	-0.3	3.6	V	Applicable for pin LDR
V_{IO}	Digital pins	-0.3	3.6	V	Applicable for pins GPIO and INT
V_{BUS}	Digital pins	-0.3	1.98	V	Applicable for pins SCL and SDA
I_{SCR}	Input current (latch-up immunity)	±100		mA	AEC-Q100-004E
I_O	Output terminal current	-1	20	mA	
Electrostatic discharge					
ESD_{HBM}	Electrostatic discharge HBM	±2000		V	JS-001-2017
ESD_{CDM}	Electrostatic discharge CDM	±500		V	JS-002-2018
Temperature ranges and storage conditions					
T_A	Operating ambient temperature	-30	85	°C	
T_{STRG}	Storage temperature range	-40	85	°C	
T_{BODY}	Package body temperature		260	°C	IPC/JEDEC J-STD-020(1)
R_{HNC}	Relative humidity (non-condensing)	5	85	%	
MSL	Moisture sensitivity level	3			Maximum floor life time of 168h

(1) The reflow peak soldering temperature (body temperature) is specified according to IPC/JEDEC J-STD-020 “Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices.” The lead finish for Pb-free leaded packages is “Matte Tin” (100 % Sn).

5 Electrical characteristics

All limits are guaranteed. The parameters with Min and Max values are guaranteed with production tests or SQC (Statistical Quality Control) methods. All voltages with respect to GND/PGND. Device parameters are guaranteed at V_{DD}=1.8 V and T_A=25 °C unless otherwise noted. While the device is operational across the temperature range, functionality will vary with temperature.

Table 4: Electrical characteristics of TCS3448

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DD}	Supply voltage		1.7	1.8	1.98	V
T_A	Operating free-air temperature(1)		-30	25	85	°C
Power consumption						
IDD	Supply current(2)	VDD=1.8 V; T_A =25 °C Active mode(3)		210	280	µA
		VDD=1.8 V; T_A =25 °C Idle mode(4)		40	60	µA
		VDD=1.8 V; T_A =25 °C Sleep mode(5)		0.7	5	µA
Digital pins						
Vbus1.2	Vbus I/O voltage	Vbus = 1.2 V	1.08	1.2	1.32	V
Vbus1.8	Vbus I/O voltage	Vbus = 1.8 V	1.62	1.8	1.98	V
VIL-INT/GPIO	INT and GPIO input low voltage				0.54	V
VIH-INT/GPIO	INT and GPIO input high voltage		0.84			V
VIL1-SCL/SDA	SCL, SDA input low voltage	Vbus = 1.2 V or 1.8 V	-0.1 x Vbus		0.3 x Vbus	V
VIH-SCL/SDA	SCL, SDA input high voltage	Vbus = 1.2 V or 1.8 V	0.7 x Vbus			V
VOL	INT, SDA output low voltage	6 mA sink current			0.4	V
CI	Input pin capacitance				10	pF
Ileak	Leakage current into SCL, SDA, INT pins		-5		5	µA
GPIO						
CLOAD	Maximum capacitive load GPIO				20	pF

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
LED driver						
V_LDR	LDR compliance voltage	I_LDR= 4 mA ; LED_HALF = “0”			240	mV
		I_LDR= 4 mA ; LED_HALF = “1”			130	
		I_LDR = 134 mA ; LED_HALF = “0”			280	mV
		I_LDR = 134 mA ; LED_HALF = “1”			180	

(1) While the device is operational across the temperature range, functionality will vary with temperature.
(2) Supply current values are shown at the VDD pin and do not include current through pin LDR.
(3) Active state occurs during active integration (PON = “1” ; ALS_EN = “1”). If wait is enabled (WEN = “1”), supply current is lower during the wait period.
(4) Idle state occurs when PON = “1” and all functions are disabled.
(5) Sleep state occurs when PON = “0” and I²C bus is idle. If I²C traffic is active device automatically enters idle mode.

6 Optical characteristics

Parameters listed under Test Level 4 are guaranteed with production tests and SQC (Statistical Quality Control). Parameters listed under Test Level 3 are measured in-line with transparent monitor glasses. Parameters listed under Test Level 2 are measured in lab bench characterization. Parameters listed under Test Level 1 are guaranteed by design. All Test Levels are measured with V_{DD} = 1.8 V and T_A = 25 °C unless otherwise noted. While the device is operational across the temperature range, functionality will vary with temperature.

Table 5: TCS3448 filter wavelength summary

Channel	Peak wavelength [nm](1)(2)			Full width half maximum [nm]	Test level
	(min)	λp (typ)	(max)	(typ)	
F1	397	407	417	28	2+3
F2	414	424	434	29	2+3
FZ	440	450	460	67	2+3
F3	463	473	483	38	2+3
F4	506	516	526	48	2+3
FY	550	560	570	123	2+3
F5	536	546	556	44	2+3
FXL	586	596	606	93	2+3

Channel	Peak wavelength [nm](1)(2)			Full width half maximum [nm]	Test level
	(min)	λp (typ)	(max)	(typ)	
F6	626	636	646	58	2+3
F7	677	687	697	63	2+3
F8	738	748	758	77	2+3
NIR	845	855	865	61	2+3

(1) Peak Wavelength and Full Width Half Max is validated by smoothed/averaged results from spectral scans under diffused light with a reference monochromator in ams OSRAM optical lab. Please observe that comparison measurements between two monochromators in different optical labs will first require correlation measurements between these two monochromators.
(2) Repeated temperature stress during e.g. soldering may alter measurements results and optical performance.

Table 6: TCS3448 irradiance responsivity of spectral channels, AGAIN: 1024x, int. time: 27.8 ms

Symbol	Parameter(1)(2)	Conditions	Min	Typ	Max	Unit	Test level
R_{e_F1}	Irradiance responsivity channel F1	LED_396 nm ; Ee= 155 mW/m² LED_408 nm ; Ee= 155 mW/m²	6108	8144	10180	counts	4
R_{e_F2}	Irradiance responsivity channel F2	LED_408 nm ; Ee= 155 mW/m² LED_448 nm ; Ee= 155 mW/m²	1871	2495	3118	counts	4
R_{e_FZ}	Irradiance responsivity channel FZ	LED_428 nm ; Ee= 155 mW/m² LED_480 nm ; Ee= 155 mW/m²	2122	2830	3536	counts	4
R_{e_F3}	Irradiance responsivity channel F3	LED_448 nm ; Ee= 155 mW/m² LED_500 nm ; Ee= 155 mW/m²	711	949	1185	counts	4
R_{e_F4}	Irradiance responsivity channel F4	LED_500 nm ; Ee= 155 mW/m² LED_534 nm ; Ee= 155 mW/m²	3002	4003	5003	counts	4
R_{e_FY}	Irradiance responsivity channel FY	LED_534 nm ; Ee= 155 mW/m² LED_593 nm ; Ee= 155 mW/m²	2989	3985	4981	counts	4
R_{e_F5}	Irradiance responsivity channel F5	LED_531 nm ; Ee= 155 mW/m² LED_594 nm ; Ee= 155 mW/m²	1238	1651	2063	counts	4
R_{e_FXL}	Irradiance responsivity channel FXL	LED_593 nm ; Ee= 155 mW/m² LED_628 nm ; Ee= 155 mW/m²	3905	5206	6508	counts	4
R_{e_F6}	Irradiance responsivity channel F6	LED_618 nm ; Ee= 155 mW/m² LED_665 nm ; Ee= 155 mW/m²	2768	3690	4613	counts	4
R_{e_F7}	Irradiance responsivity channel F7	LED_685 nm ; Ee= 155 mW/m² LED_715 nm ; Ee= 155 mW/m²	4403	5872	7339	counts	4

Symbol	Parameter[1][2]	Conditions	Min	Typ	Max	Unit	Test level
R_{e_F8}	Irradiance responsivity channel F8	LED_715 nm ; Ee= 155 mW/m² LED_766 nm ; Ee= 155 mW/m²	578	1095	1722	counts	4
R_{e_NIR}	Irradiance responsivity channel NIR	LED_849 nm ; Ee= 155 mW/m² LED_903 nm ; Ee= 155 mW/m²	6002	8002	10003	counts	4
R_{e_FD}	Irradiance responsivity channel Flicker	LED_593 nm ; Ee= 155 mW/m² LED_766 nm ; Ee= 155 mW/m² FD_GAIN=64x	3373	4497	5621	counts	4
R_{e_VIS}	Irradiance responsivity channel VIS	LED_396 nm ; Ee= 155 mW/m² LED_766 nm ; Ee= 155 mW/m² 2 VIS PDs read-out	847	1129	1411	counts	4

(1) Irradiance responsivity is measured under diffused light.
(2) Repeated temperature stress during e.g. soldering may alter measurements results and optical performance.

Table 7: Optical characteristics of TCS3448, AGAIN: 128x, integration time: 11 ms (unless otherwise noted)

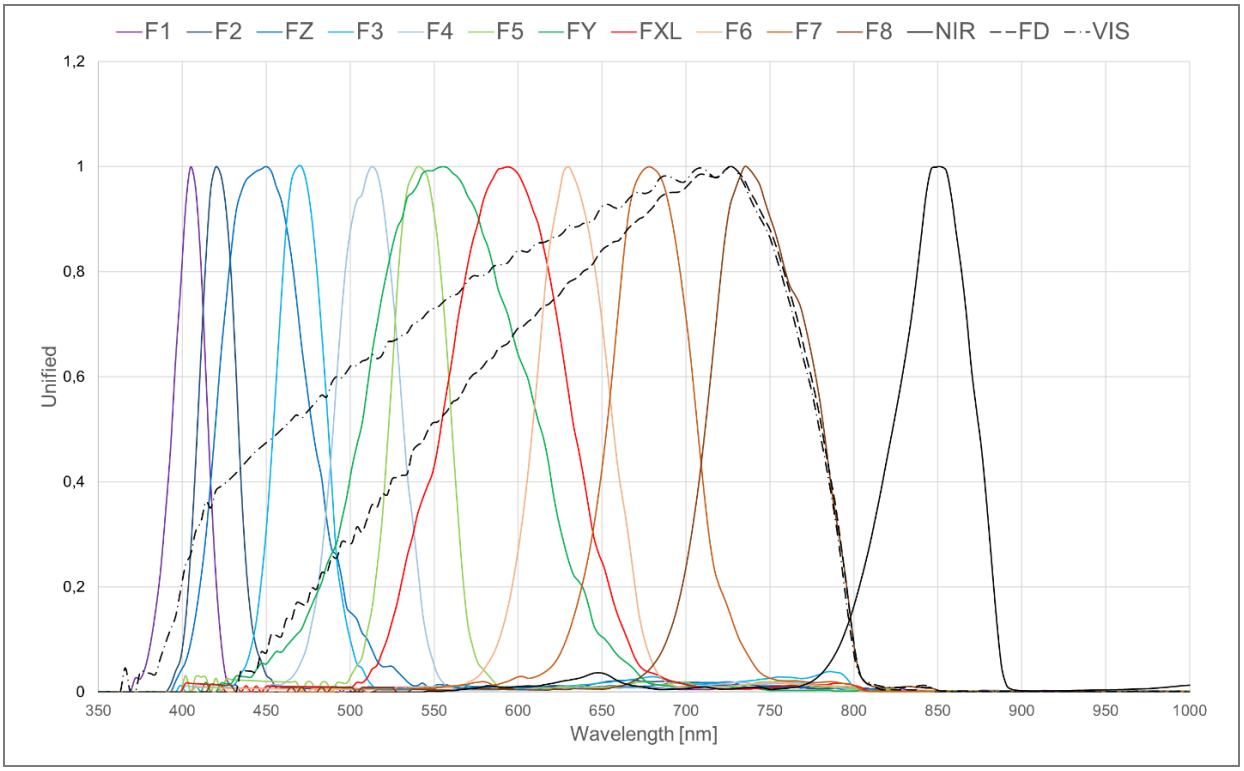
Symbol	Parameter	Conditions	Min	Typ	Max	Unit	Test level
Dark_1[2]	Dark ADC count value	Ee = 0 µW/cm² AGAIN: 512x Integration time: 98 ms		0	5	counts	4
Gain ratio[3]	Optical gain ratios, relative to 128x gain setting	AGAIN: 0.5x	2.71[1]	2.9	3.06[1]	See note[4]	2
		AGAIN: 1x	6.61[1]	7.05	7.41[1]		2
		AGAIN: 2x	14.49[1]	15.3	16.11[1]		2
		AGAIN: 4x	23.5	31.4	38.8		4
		AGAIN: 8x	53.4	61.05	68.4		4
		AGAIN: 16x	115.6	123.02	130.7		4
		AGAIN: 32x	1/4.16	1/4.04	1/3.89		4
		AGAIN: 64x	1/2.06	1/2	1/1.91		4
		AGAIN: 128x		1[3]			4
		AGAIN: 256x	1.91	2.05	2.19		4
		AGAIN: 512x	4.01	4.3	4.78		4
		AGAIN: 1024x	7.09	8.3	9.43		4
		AGAIN: 2048x	12.1	17.6	22.9		4
ADC noise[5]		White LED, 2700K Integration time: 100 ms		0.05		% full scale	1
t_{int}	Typical integration time[6]	ASTEP = 599 ATIME = 29		50		ms	1

Symbol	Parameter	Conditions	Min	Typ	Max	Unit	Test level
t_{ASTEP}	Integration time step size	ASTEP = 999		2.78		ms	1
h_{ca}	Half cone angle(7)	On the sensor		37		deg	1

(1) Test light irradiance of ATE too small for measurement of gain ratio variation. Variation has been measured during lab bench characterization.
(2) The typical 3-sigma distribution is between 0 and 1 counts for AGAIN setting of 16x.
(3) The gain ratios are relative to 128x gain setting. The ratio states the worst value measured over the 6 channels.
(4) AGAIN ratio 0.5x to 16x is multiplied by 1000 for easier readability.
(5) ADC noise is calculated as the standard deviation of relative to full scale.
(6) Integration time, in milliseconds, is equal to: (ATIME + 1) x (ASTEP + 1) x 2.78 µs.
(7) Simulated value for center photodiode.

7 Typical operating characteristics

Figure 3: Typical spectral responsivity

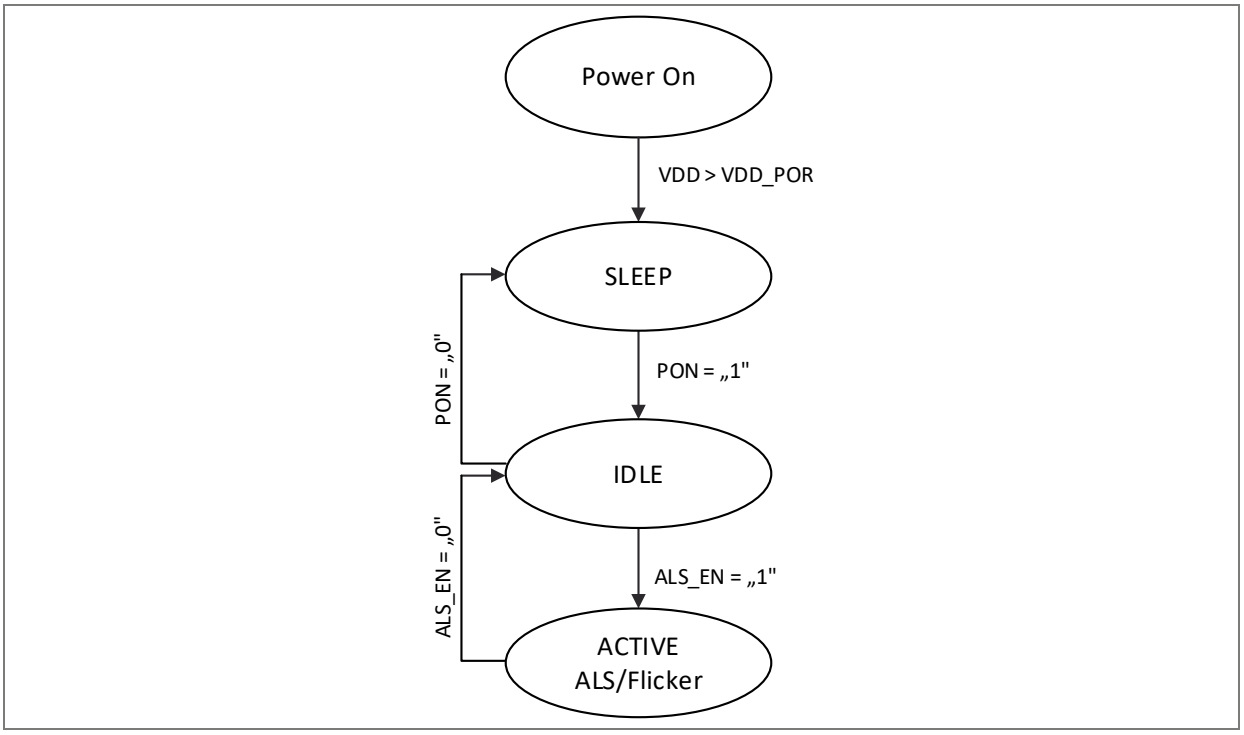


8 Functional description

Upon power-up (POR), the device initializes. During initialization (typically 200 µs), the device will deterministically send NAK on I²C and cannot accept I²C transactions. All communication with the device must be delayed and all outputs from the device must be ignored including interrupts. After initialization, the device enters the SLEEP state. In this operational state, the internal oscillator and other circuitry are not active, resulting in ultra-low power consumption. If an I²C transaction occurs during this state, the I²C core wakes up temporarily to service the communication. Once the Power ON bit, “PON”, is enabled, the device enters the IDLE state in which the internal oscillator and attendant circuitry are active, but power consumption remains low. Whenever the ALS measurement is enabled (ALS_EN = “1”), the device enters the ACTIVE state. If the ALS measurement is disabled (ALS_EN = “0”), the device returns to the IDLE state. The figure below describes a simplified state diagram and the typical supply currents in each state.

If Sleep after Interrupt is enabled (SAI = “1” in register 0xC7), the state machine will enter SLEEP when an interrupt occurs. Entering SLEEP does not automatically change any of the register settings (e.g. PON bit is still high, but the normal operational state is over-ridden by SLEEP state). SLEEP state is terminated when the SAI_ACTIVE bit is cleared (the status bit is in register 0xBC and the clear status bit is in register 0xFA).

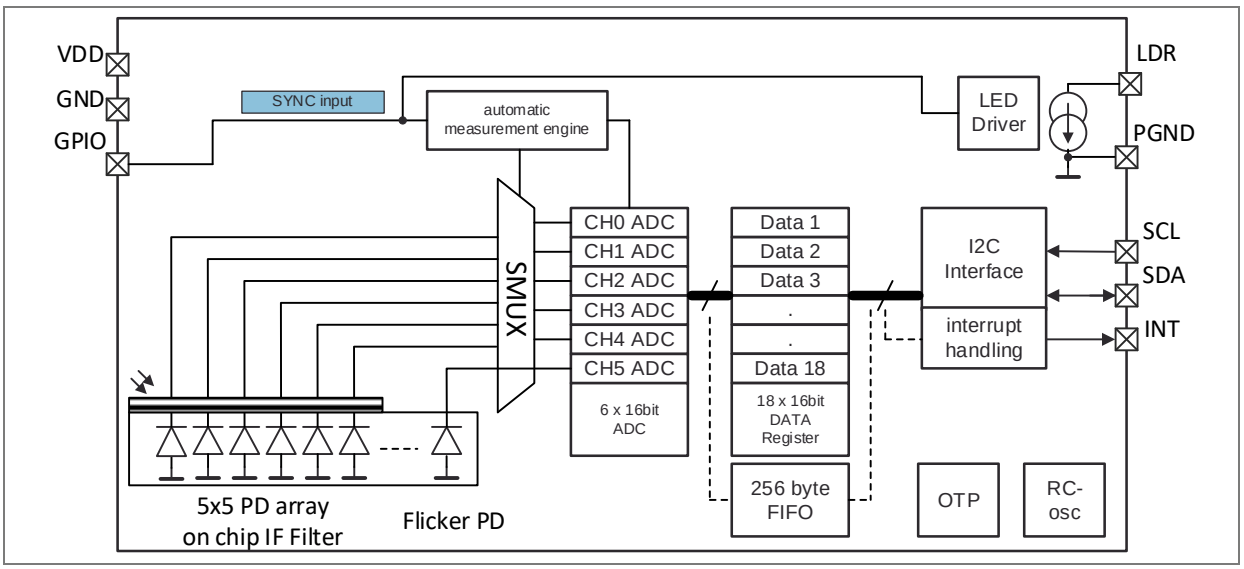
Figure 4: Simplified state diagram



8.1 Device architecture

The device features six independent 16-bit ADCs. Gain and integration time of the six ADCs can be adjusted with the I²C interface. A wait time can be programed to automatically set a delay between two consecutive ALS measurements and to reduce overall power consumption. Once a measurement is started, the device is automatically processing the channels and storing the measurement data on chip in the corresponding data registers.

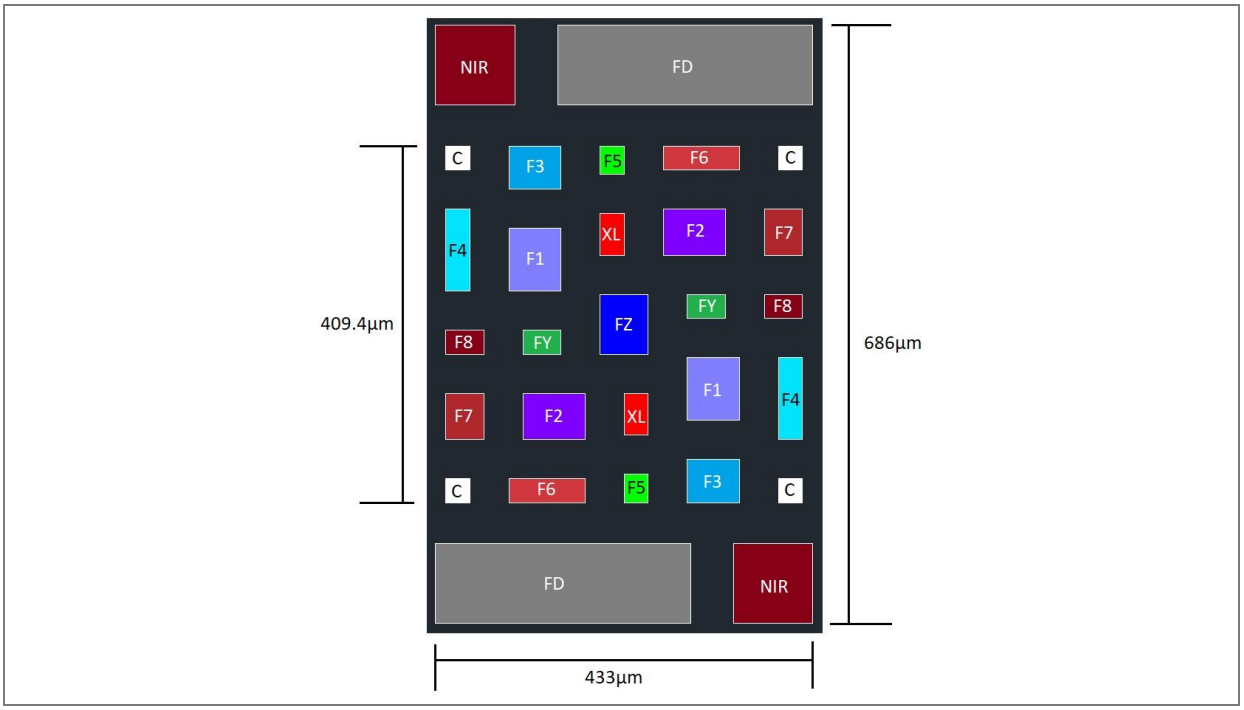
Figure 5: Simplified block diagram



8.2 Sensor array

The device features a 5 x 5-photodiode array. On top and below the photodiode array there are two photodiodes with dedicated functions such as flicker detection (“FD”) and near-infrared response (“NIR”). The photodiode “C” represents a photodiode without filter and is responsive in the visible spectral range (“VIS”).

Figure 6: Sensor array



8.3 GPIO

The GPIO can be used synchronization input to start/stop the ALS measurement. It also allows synchronizing the LED driver (LDR) with an external start/stop signal. Default state of the GPIO is “output”.

8.4 Interrupt (INT)

The interrupt (INT) can be used to define thresholds and read-out the device only when the channel threshold has been reached. The pin is active low.

8.5 LED driver (LDR)

The LED driver is programmable and can be used to drive external LEDs. It is also possible to synchronize the LED driver with an external start/stop signal via pin GPIO.

9 I²C interface

The device uses I²C serial communication protocol for communication. The device supports 7-bit chip addressing and both standard and full-speed clock frequency modes. Read and Write transactions comply with the standard set by Philips (now NXP). Internal to the device, an 8-bit buffer stores the register address location of the desired byte to read or write. This buffer auto-increments upon each byte transfer and is retained between transaction events (i.e. valid even after the master issues a STOP command and the I²C bus is released). During consecutive Read transactions, the future/repeated I²C Read transaction may omit the memory address byte normally following the chip address byte; the buffer retains the last register address +1. All 16-bit fields have a latching scheme for reading and writing. In general, it is recommended to use I²C bursts whenever possible, especially in this case when accessing two bytes of one logical entity. When reading these fields, the low byte must be read first, and it triggers a 16-bit latch that stores the 16-bit field. The high byte must be read immediately afterwards. When writing to these fields, the low byte must be written first, immediately followed by the high byte. Reading or writing to these registers without following these requirements will cause errors.

9.1 I²C address

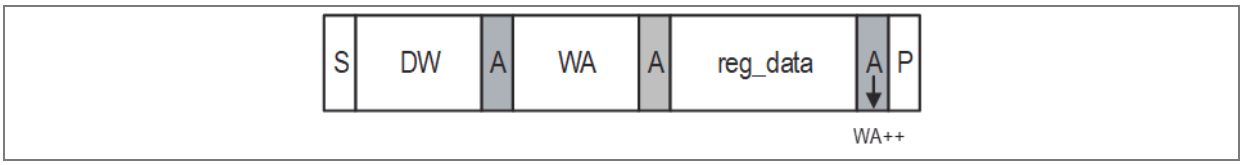
Table 8: TCS3448 I²C slave address

Device	I²C address
TCS3448	0x59

9.2 I²C write transaction

A Write transaction consists of a START, CHIP-ADDRESSWRITE, REGISTER-ADDRESS WRITE, DATA BYTE(S), and STOP (P). Following each byte (9th clock pulse) the slave places an ACKNOWLEDGE/NOT- ACKNOWLEDGE (A/N) on the bus. If the slave transmits N, the master may issue a STOP.

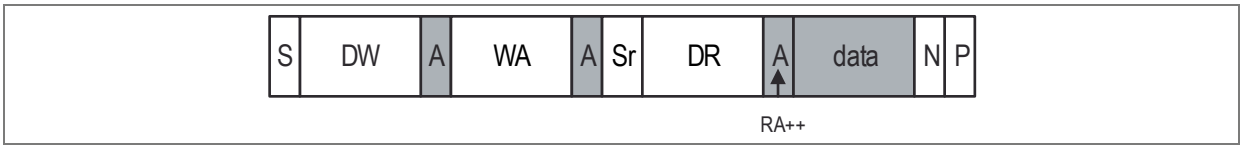
Figure 7: I²C byte write



9.3 I²C read transaction

A Read transaction consists of a START, CHIP-ADDRESSWRITE, REGISTER-ADDRESS, RESTART, CHIP-ADDRESSREAD, DATA BYTE(S), and STOP. Following all but the final byte the master places an ACK on the bus (9th clock pulse). Termination of the Read transaction is indicated by a NACK being placed on the bus by the master, followed by STOP.

Figure 8: I²C read



9.4 Timing characteristics

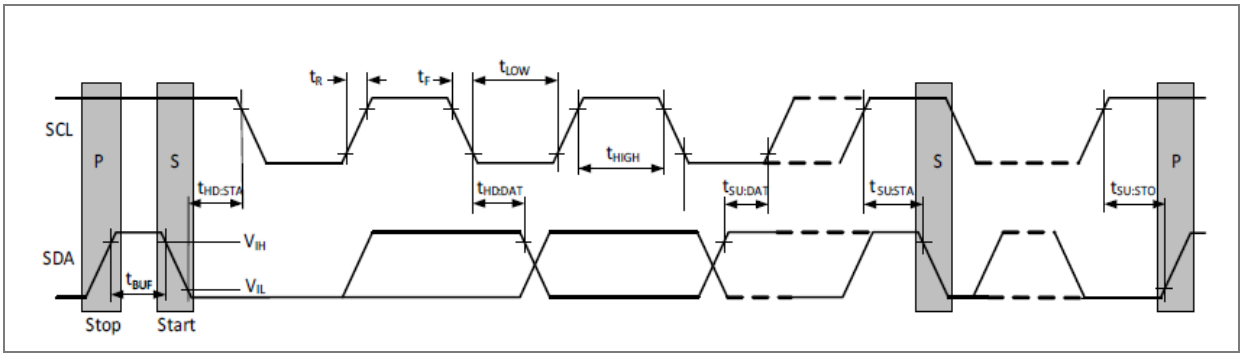
Parameters listed under Test Level 4 are guaranteed with production tests and SQC (Statistical Quality Control). Parameters listed under Test Level 3 are measured in-line with transparent monitor glasses. Parameters listed under Test Level 2 are measured in lab bench characterization. Parameters listed under Test Level 1 are guaranteed by design. All Test Levels are measured with VDD = 1.8 V and T_A = 25°C unless otherwise noted.

Table 9: I²C timing characteristics

Symbol	Parameter	Min	Typ	Max	Unit	Test level
f_{SCL}	I²C clock frequency			1	MHz	4
t_{BUF}	Bus free time between start and stop condition	1.3			µs	1
$t_{HD;STA}$	Hold time after (repeated) start condition. After this period, the first clock is generated.	0.6				1
$t_{SU;STA}$	Repeated start condition setup time	0.6				1
$t_{SU;STO}$	Stop condition setup time	0.6				1
t_{LOW}	SCL clock low period	1.3				1
t_{HIGH}	SCL clock high period	0.6				1
$t_{HD;DAT}$	Data hold time	0			ns	1
$t_{SU;DAT}$	Data setup time	100				1
t_F	Clock/data fall time			300		1
t_R	Clock/data rise time			300		1

9.5 Timing diagrams

Figure 9: I²C slave timing diagram



9.6 Selection of I²C bus interface voltage[1]

Only once, 600 µs after startup, the voltage level at the GPIO pin will be measured. There is no I²C communication possible before 600 µs. “Startup” is determined by a “Power on Reset” at the VDD pin.

If the voltage level at the GPIO pin is higher than 1.5 V (±0.15 V), 1.8 V is selected as I/O voltage for SCL and SDA pins. If the voltage level at the GPIO pin lower than 1.5 V (±0.15 V), 1.2 V is selected as I/O voltage for SCL and SDA pins.

If the GPIO pin is connected to VSS, the I/O voltage for SCL and SDA pins will always be 1.2 V.

After Startup and GPIO pin scan (which takes 600 µs) the GPIO pin is configured as open drain I/O as known from pin-compatible earlier products.

It is NOT allowed to leave the GPIO pin floating. It shall always be connected to VSS or VBUS. VBUS is usually identical to VDD of the host processor but can also be a separate supply rail for the I²C bus.

For exact I/O voltage levels please refer to Electrical characteristics.

[1] ams OSRAM patents pending.

10 Register description

The device is controlled and monitored by registers accessed through the I²C serial interface. These registers provide device control functions and can be read to determine device status and acquire device data.

The register set is summarized below. The values of all registers and fields that are listed as reserved or are not listed must not be changed at any time. Two-byte fields are always latched with the low byte followed by the high byte. The “Name” column illustrates the purpose of each register by highlighting the function associated to each bit. The bits are shown from MSB (D7) to LSB (D0). GRAY fields are reserved and their values must not be changed at any time.

In order to access registers from 0x58 to 0x66 bit REG_BANK in register CFG0 (0xBF) needs to be set to “1”.

10.1 Register overview

Table 10: Register overview

Addr	Name	<D7>	<D6>	<D5>	<D4>	<D3>	<D2>	<D1>	<D0>
0x58	AUXID					AUXID [3:0]			
0x59	REVID						REVID [2:0]		
0x5A	ID	ID [7:0]							
0x66	CFG12						ALS_TH_CH [2:0]		
0x80	ENABLE		FDEN		SMUXEN	WEN		ALS_EN	PON
0x81	ATIME	ATIME [7:0]							
0x83	WTIME	WTIME [7:0]							
0x84	ALS_TH_L	ALS_TH_L_LSB [7:0]							
0x85		ALS_TH_L_MSB [7:0]							
0x86	ALS_TH_H	ALS_TH_H_LSB [7:0]							
0x87		ALS_TH_H_MSB [7:0]							
0x93	STATUS	ASAT				AINT	FINT		SINT
0x94	ASTATUS	ASAT_ STATUS				AGAIN_STATUS [3:0]			
0x95	ADATA0	ADATA0_L [7:0]							
0x96		ADATA0_H [7:0]							
0x97	ADATA1	ADATA1_L [7:0]							
0x98		ADATA1_H [7:0]							
0x99	ADATA2	ADATA2_L [7:0]							
0x9A		ADATA2_H [7:0]							

Addr	Name	<D7>	<D6>	<D5>	<D4>	<D3>	<D2>	<D1>	<D0>
0x9B	ADATA3	ADATA3_L [7:0]							
0x9C		ADATA3_H [7:0]							
0x9D	ADATA4	ADATA4_L [7:0]							
0x9E		ADATA4_H [7:0]							
0x9F	ADATA5	ADATA5_L [7:0]							
0xA0		ADATA5_H [7:0]							
0xA1	ADATA6	ADATA6_L [7:0]							
0xA2		ADATA6_H [7:0]							
0xA3	ADATA7	ADATA7_L [7:0]							
0xA4		ADATA7_H [7:0]							
0xA5	ADATA8	ADATA8_L [7:0]							
0xA6		ADATA8_H [7:0]							
0xA7	ADATA9	ADATA9_L [7:0]							
0xA8		ADATA9_H [7:0]							
0xA9	ADATA10	ADATA10_L [7:0]							
0xAA		ADATA10_H [7:0]							
0xAB	ADATA11	ADATA11_L [7:0]							
0xAC		ADATA11_H [7:0]							
0xAD	ADATA12	ADATA12_L [7:0]							
0xAE		ADATA12_H [7:0]							
0xAF	ADATA13	ADATA13_L [7:0]							
0xB0		ADATA13_H [7:0]							
0xB1	ADATA14	ADATA14_L [7:0]							
0xB2		ADATA14_H [7:0]							
0xB3	ADATA15	ADATA15_L [7:0]							
0xB4		ADATA15_H [7:0]							
0xB5	ADATA16	ADATA16_L [7:0]							
0xB6		ADATA16_H [7:0]							
0xB7	ADATA17	ADATA17_L [7:0]							
0xB8		ADATA17_H [7:0]							
0x90	STATUS 2		AVALID		ASAT_DIG	ASAT_ANA		FDSAT_ANA	FDSAT_DIG
0x91	STATUS 3			INT_ALS_H	INT_ALS_L				
0xBB	STATUS 5					SINT_FD	SINT_SMUX		
0xBC	STATUS 4	FIFO_OV		OVTEMP	FD_TRIG		ALS_TRIG	SAI_ACT	INT_BUSY
0xBF	CFG 0			LOW_POWER	REG_BANK		WLONG		

Addr	Name	<D7>	<D6>	<D5>	<D4>	<D3>	<D2>	<D1>	<D0>
0xC6	CFG1				AGAIN[4:0]				
0xC7	CFG3				SAI				
0xF5	CFG6				SMUX_CMD [4:3]				
0xC9	CFG8	FIFO_TH [7:6]							
0xCA	CFG9		SIEN_FD		SIEN_SMUX				
0x65	CFG10						FD_PERS [2:0]		
0xCF	PERS					APERS [3:0]			
0x6B	GPIO					GPIO_INV	GPIO_IN_EN	GPIO_OUT	GPIO_IN
0xD4	ASTEP	ASTEP [7:0]							
0xD5		ASTEP [15:8]							
0xD6	CFG20	FD_FIFO_8b	auto_SMUX						
0xCD	LED	LED_ACT	LED_DRIVE [6:0]						
0xD7	AGC_GAIN_MAX	AGC_FD_GAIN_MAX [7:4]							
0xDE	AZ_CONFIG	AT_NTH_ITERATION [7:0]							
0xE0	FD_TIME_1	FD_TIME [7:0]							
0xE2	FD_TIME_2	FD_GAIN [7:3]					FD_TIME [10:8]		
0xDF	FD_CFG0	FIFO_WRITE_FD							
0xE3	FD_STATUS			FD_VALID	FD_SAT	FD_120Hz_VALID	FD_100Hz_VALID	FD_120Hz	FD_100Hz
0xF9	INTENAB	ASIEN				ALS_IEN	FIEN		SIEN
0xFA	CONTROL					SW_RESET	ALS_MAN_AZ	FIFO_CLR	CLEAR_SAI_ACT
0xFC	FIFO_MAP		FIFO_WRITE_CH5_DATA – FIFO_WRITE_CH0_DATA [6:1]						ASTATUS
0xFD	FIFO_LVL	FIFO_LVL [7:0]							
0xFE	FDATA	FDATA_L [7:0]							
0xFF		FDATA_H [15:8]							

10.2 Detailed register description

For easier readability, the detailed register description is done in groups of registers related to dedicated device functions. This is not necessarily related to its register address.

Explanation of register access abbreviations:
RW = Read or write
R = Read only
W = Write only
SC = Self-clearing after access

10.2.1 Enable and configuration registers

Table 11: ENABLE register

Addr: 0x80		ENABLE		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7	Reserved	0	RW	Reserved
6	FDEN	0	RW	**Flicker Detection Enable.** 0: Flicker Detection disabled. 1: Flicker Detection enabled.
5	Reserved	0	RW	Reserved
4	SMUXEN	0	RW	**SMUX Enable.** 1: Starts SMUX command. **Note:** This bit gets cleared automatically as soon as SMUX operation is finished.
3	WEN	0	RW	**Wait Enable.** 0: Wait time between two consecutive ALS measurements disabled. 1: Wait time between two consecutive ALS measurements enabled.
2	Reserved	0	RW	Reserved
1	ALS_EN	0	RW	**ALS Measurement Enable.** 0: ALS measurement disabled. 1: ALS measurement enabled.
0	PON	0	RW	**Power ON.** 0: TCS3448 disabled. 1: TCS3448 enabled. **Note:** When bit is set, internal oscillator is activated, allowing timers and ADC channels to operate.

10.2.1.1 GPIO register (Address 0x6B)

Table 12: GPIO register

Addr: 0x6B		GPIO		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:4	Reserved	0		Reserved
3	GPIO_INV	0	RW	**GPIO Invert.** If set, the GPIO output is inverted.
2	GPIO_IN_EN	0	RW	**GPIO Input Enable.** If set, the GPIO pin accepts a non-floating input.
1	GPIO_OUT	1	RW	**GPIO Output.** If set, the output state of the GPIO is active directly.
0	GPIO_IN	0	R	**GPIO Input.** Indicates the status of the GPIO input if GPIO_IN_EN is set.

10.2.1.2 LED register (Address 0xCD)

Table 13: LED register

Addr: 0xCD		LED		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7	LED_ACT	0	RW	**LED Control.** 0: External LED connected to pin LDR off. 1: External LED connected to pin LDR on.
6:0	LED_DRIVE	000 0100	RW	**LED Driving Strength.** 000 0000: 4 mA 000 0001: 6 mA 000 0010: 8 mA 000 0011: 10 mA **000 0100:** 12 mA …… 111 1110: 256 mA 111 1111: 258 mA

10.2.1.3 INTENAB register (Address 0xF9)

Table 14: INTENAB register

Addr: 0xF9		INTENAB		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7	ASIEN	0	RW	**ALS and Flicker Detect Saturation Interrupt Enable.** When asserted permits saturation interrupts to be generated.
6:4	Reserved			Reserved
3	ALS_IEN	0	RW	**ALS Interrupt Enable.** When asserted permits interrupts to be generated, subject to the ALS thresholds and persistence filter. Bit is mirrored in the ENABLE register.
2	F_IEN	0	RW	**FIFO Buffer Interrupt Enable.** When asserted permits interrupt to be generated when FIFO_LVL exceeds the FIFO threshold condition.
1	Reserved	0		Reserved
0	SIEN		RW	**System Interrupt Enable.** When asserted permits system interrupts to be generated. Indicates that flicker detection status has changed or SMUX operation has finished.

10.2.1.4 CONTROL register (Address 0xFA)

Table 15: CONTROL register

Addr: 0xFA		CONTROL		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:4	Reserved	0		Reserved
3	SW_RESET	0	RW	**Software Reset** When set the device will force a power on reset.
2	ALS_MAN_AZ	0	RW	**ALS Engine Manual Autozero.** Starts a manual autozero of the ALS engines. Set ALS_EN = 0 before starting a manual autozero for it to work.
1	FIFO_CLR	0	RW	**FIFO Buffer Clear.** Clears all FIFO data, FINT, FIFO_OV, and FIFO_LVL.
0	CLEAR_SAI_ACT	0	RW	**Clear Sleep-After-Interrupt Active.** Clears SAI_ACTIVE, ends sleep, and restarts device operation.

10.2.2 ADC timing configuration / integration time

The integration time is set using the ATIME (0x81) and ASTEP (0xD4, 0xD5) registers. The integration time, in milliseconds, is equal to:

Equation 1: Setting the integration time

$$t_{int} = (ATIME + 1) \times (ASTEP + 1) \times 2.78\ \mu s$$

It is not allowed that both settings –ATIME and ASTEP – are set to “0”.

The integration time also defines the full-scale ADC value, which is equal to:

Equation 2: ADC full scale value[2]

$$ADC_{fullscale} = (ATIME + 1) \times (ASTEP + 1)$$

10.2.2.1 ATIME register (Address 0x81)

Table 16: ATIME register

Addr: 0x81		ATIME		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	ATIME	0x00	RW	**Integration Time.** Sets the number of integration steps from 1 to 255.

Value	**Integration Time**
0	ASTEP
n	ASTEP x (n+1)
255	ASTEP x 256

[2] The maximum ADC count is 65535. Any ATIME/ASTEP field setting resulting in higher ADC full-scale values would result in a full-scale of 65535.

10.2.2.2 ASTEP register (Address 0xD4, 0xD5)

Table 17: ASTEP register

Addr: 0xD4, 0xD5		ASTEP		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0 0xD4	ASTEP LOW ASTEP HIGH	0xE7	RW	**Integration Time Step Size.** Sets the integration time per step in increments of 2.78 µs. The default value is 999 (0x03E7). **VALUE** **STEP SIZE** 0 (0x0000) 2.78 µs n 2.78 µs x (n+1) 599 (0x0257) 1.67 ms 999 (0x03E7) 2.78 ms(default) 17999 (0x464F) 50 ms 65534 (0xFFFE) 182 ms 65535 (0xFFFE) Reserved, do not use.
15:8 0xD5	ASTEP HIGH	0x03		

10.2.2.3 WTIME register (Address 0x83)

If wait is enabled (WEN = “1” register 0x80), each new measurement is started based on WTIME. It is necessary for WTIME to be sufficiently long for ALS integration and any other functions to be completed within the period. The device will warn the user if the timing is configured incorrectly. If WTIME is too short, then ALS_TRIG in register STATUS6 (ADDR: 0xBC) will be set to “1”.

Table 18: WTIME register

Addr: 0x83		WTIME		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	WTIME	0x00	RW	**ALS Measurement Wait Time.** 8-bit value to specify the delay between two consecutive ALS measurements. **Value** **Wait Cycles** **Wait Time** 0x00 1 2.78 ms 0x01 2 5.56 ms n n 2.78 ms x (n+1) 0xff 256 711 ms

10.2.2.4 FD_TIME register (Address 0xE0, 0xE2)

The register FD_Time_1 and FD_Time_2 can be used to configure the integration time and gain (ADC 5) of the flicker detection independently from the other ADCs. The FD_TIME register is an 11-bit register with the MSB in register 0xDA (bit 10:8) and the LSB in register 0xD8 (bit 7:0). The bit FDEN (register 0x80) must be set to “1” in order to use the FD_TIME registers. If the bit FDEN is not set, ADC5 runs automatically with the same gain and integration time as ADC0 to ADC4.

Equation 3: Calculating the flicker detection integration time

$$t_{int\_FD} = FD\_TIME \times 2.78\ \mu s$$

Table 19: FD_Time_1 register

Addr: 0xE0		**FD_TIME_1**		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	FD_TIME [7:0]	0110 0111	RW	LSB of flicker detection integration time. **Note:** Must not be changed during FDEN = 1 and PON = 1.

Table 20: FD_Time_2 register

Addr: 0xE2		FD_TIME_2		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:3	FD_GAIN	9	RW	**Flicker Detection Gain Setting (ADC5)** **VALUE** / **GAIN** 0 / 0.5x 1 / 1x 2 / 2x 3 / 4x 4 / 8x 5 / 16x 6 / 32x 7 / 64x 8 / 128x 9 / 256x 10 / 512x 11 / 1024x 12 / 2048x
2:0	FD_TIME [10:8]	1	RW	MSB of flicker detection integration time. Note: Must not be changed during FDEN = 1 and PON = 1.

10.2.3 ADC configuration

The following registers provide configuration for the 6 integrated ADCs (CH0 to CH5). It is possible to adjust the gain and setup the auto zero compensation for the ADCs.

10.2.3.1 CFG1 register (Address 0xC6)

Addr: 0xC6		CFG1		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:5	Reserved	0		Reserved
4:0	AGAIN	9	RW	**ALS Engines Gain Setting.** Sets the ALS sensitivity.

VALUE	GAIN
0	0.5x
1	1x
2	2x
3	4x
4	8x
5	16x
6	32x
7	64x
8	128x
9	256x
10	512x
11	1024x
12	2048x

10.2.3.2 CFG10 register (Address 0x65)

Table 21: CFG10 register

Addr: 0x65		CFG10		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:3	Reserved	Reserved	Reserved	Reserved
2:0	FD_PERS	2	RW	**Flicker Detect Persistence.** Sets the number of consecutive flicker detect results that must be different before the flicker detect status will be changed. Flicker detection interrupts on SINT are affected by this setting. Flicker detect persistence is equal to $2^{(FD_{PERS}-1)}$ Setting “0” equals to every time.

10.2.3.3 AZ_CONFIG register (Address 0xDE)

The following register configures how often the ALS engine offsets are reset (auto zero) to compensate for changes of the device temperature. The typical time auto zero needs to be completed is 15 ms.

Table 22: AZ_CONFIG register

Addr: 0xDE		**AZ_CONFIG**		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	AZ_NTH_ITERATION	255	RW	**AUTOZERO FREQUENCY.** Sets the frequency at which the device performs auto zero of the ALS engines. **Note:** If FDEN = "1" auto zero is also done for ADC 5. The flicker detection measurement will be interrupted and restarted in this case.

VALUE	**AUTOZERO FREQUENCY**
0	Never (not recommended)
1	Every integration cycle
2	Every 2 cycles
…	Every "AZ_NTH_ITERATION" cycle
254	Every 254 cycles
255	Only before first measurement cycle

10.2.3.4 AGC_GAIN_MAX register (Address 0xD7)

Table 23: AGC_GAIN_MAX register

Addr: 0xD7		**AGC_GAIN_MAX**		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:4	AGC_FD_GAIN_MAX	9	RW	**Flicker Detection AGC Gain Max.** Sets the maximum gain for flicker detection to $2^{AGC\_FD\_GIAN\_MAX}$ Default value is 9 (256x). The range can be set from 0 (0.5x) to 10 (2048x).
3:0	Reserved	9	Reserved	**Reserved**

10.2.3.5 CFG8 register (Address 0xC9)

Table 24: CFG8 register

Addr: 0xC9		CFG8			
Bit	**Bit name**	**Default**	**Access**	**Bit description**	
7:6	FIFO_TH	2	RW	**FIFO Threshold.** Sets a threshold on the FIFO level that triggers the first FIFO buffer interrupt (FINT).	
				VALUE	**FIFO_LVL**
				0	1
				1	4
				2	8
				3	16
5:0	Reserved	0		Reserved	

10.2.4 Device identification

The following registers provided device identification. Device ID, revision ID and auxiliary ID are read only.

10.2.4.1 AUXID register (Address 0x58)

Table 25: AUXID register

Addr: 0x58		AUXID		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:4	Reserved			Reserved
3:0	AUXID	0000	R	**Auxiliary Identification TCS3448**

10.2.4.2 REVID register (Address 0x59)

Table 26: REVID register

Addr: 0x59		REVID		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:3	Reserved			Reserved
2:0	REV_ID	000	R	**Revision Number Identification**

10.2.4.3 ID register (Address 0x5A)

Table 27: ID register

Addr: 0x5A		ID		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	ID	10000001	R	**Part Number Identification** Value 10000001

10.2.5 ALS interrupt configuration

The ALS interrupt threshold registers provide 16-bit values to be used as the high and low thresholds for comparison to the 16-bit CH0_DATA values (ADC CH0). If ALS_IEN (register 0xF9) is enabled and CH0_DATA is not between the two thresholds for the number of consecutive measurements specified in APERS (register 0xBD) an interrupt is set.

10.2.5.1 ALS_TH_L_LSB register (Address 0x84)

Table 28: ALS_TH_L_LSB register

Addr: 0x84		ALS_TH_L_LSB		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	ALS_TH_L_LSB	0x00	RW	**ALS Low Threshold LSB** This register provides the low byte of the low interrupt threshold (CH0).

10.2.5.2 ALS_TH_L_MSB register (Address 0x85)

Table 29: ALS_TH_L_MSB register

Addr: 0x85		ALS_TH_L_MSB		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	ALS_TH_L_MSB	0x00	RW	**ALS Low Threshold MSB** This register provides the high byte of the low interrupt threshold (CH0). Both ALS_TH_L registers are combined to a 16-bit threshold. If the value captured by channel 0 is below the low threshold and the APERS value is reached the bit ALS_IEN is set and an interrupt is generated. There is an 8-bit data latch implemented that stores the written low byte until the high byte is written. Both bytes will be applied at the same time to avoid an invalid threshold. **Note:** The LSB register cannot be changed without writing to the MSB register. It is recommended to write to ALS_TH_L_LSB and ALS_TH_L_MSB within one I²C command.

10.2.5.3 ALS_TH_H_LSB Register (Address 0x86)

Table 30: ALS_TH_H_LSB register

Addr: 0x86		ALS_TH_H_LSB		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	ALS_TH_H_LSB	0x00	RW	**ALS High Threshold LSB** This register provides the low byte of the high interrupt threshold (CH0).

10.2.5.4 ALS_TH_H_MSB register (Address 0x87)

Table 31: ALS_TH_H_MSB register

Addr: 0x87		ALS_TH_H_MSB		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	ALS_TH_H_MSB	0x00	RW	**ALS High Threshold MSB** This register provides the high byte of the high interrupt threshold (CH0). Both ALS_TH_H registers are combined to a 16-bit threshold. If the value captured by channel 0 is above the high threshold and the APERS value is reached the bit ALS_IEN is set and an interrupt is generated.

10.2.5.5 CFG12 register (Address 0x66)

Table 32: CFG12 register

Addr: 0x66		CFG12		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:3	Reserved	0		Reserved
2:0	ALS_TH_CH	0	RW	**ALS Threshold Channel.** Sets the channel used for interrupts and persistence, if enabled, to determine device status and gain settings.

VALUE	**CHANNEL**
0	CH0
1	CH1
2	CH2
3	CH3
4	CH4
5	CH5

10.2.6 Device status registers

The following registers provide status of the device and indicate details about saturation, interrupts, over temperature, device execution and ambient light flicker detection.

10.2.6.1 STATUS register (Address 0x93)

The primary status register for TCS3448 indicates if there are saturation or interrupt events that need to be handled by the user. This register is self-clearing, meaning that writing a “1” to any bit in the register clears that status bit. In this way, the user should read the STATUS register, handle all indicated event(s) and then write the register value back to STATUS to clear the handled events. Writing “0” will not clear those bits if they have a value of “1”, which means that new events that occurred since the last read of the STATUS register will not be accidentally cleared. In case channel saturation has happened (ASAT or FDSAT) it is recommended to discard the measurement results and re-configure device configuration such as AGAIN and Integration Time to avoid saturation.

Table 33: STATUS register

Addr: 0x93		STATUS		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7	ASAT	0	R, SC	**ALS and Flicker Detect Saturation.** If ASIEN is set, indicates ALS saturation. Check STATUS2 register to distinguish between analog or digital saturation.
6:4	Reserved	0	R	Reserved
3	AINT	0	R, SC	**ALS Channel Interrupt.** If ALS_IEN is set, indicates that a ALS event that met the programmed thresholds and persistence (APERS) occurred.
2	FINT	0	R, SC	**FIFO Buffer Interrupt.** If FIEN is set, indicates that the FIFO_LVL fulfills the threshold condition. If cleared by writing 1, the interrupt will be asserted again as more data is collected. To fully clear this interrupt, all data must be read from the FIFO buffer.
1	Reserved	0	R	**Reserved**
0	SINT	0	R, SC	**System Interrupt.** If SIEN is set, indicates that system interrupt is set. Refer to Status5 register**.**

10.2.6.2 STATUS 2 register (Address 0x90)

Table 34: STATUS 2 register

Addr: 0x90		STATUS 2		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7	Reserved	0		Reserved
6	AVALID	0	R	**ALS Valid**. Indicates that the ALS measurement has been completed.
5	Reserved	0		Reserved
4	ASAT_DIGITAL	0	R	**Digital Saturation**. Indicates that the maximum counter value has been reached. Maximum counter value depends on integration time set in the ATIME register.
3	ASAT_ANALOG	0	R	**Analog Saturation**. Indicates that the intensity of ambient light has exceeded the maximum integration level for the ALS analog circuit.
2	Reserved	0	R	Reserved
1	FDSAT_ANALOG	0	R	**Flicker Detect Analog Saturation**. Indicates that the intensity of ambient light has exceeded the maximum integration level for the analog circuit for flicker detection.
0	FDSAT_DIGITAL	0	R	**Flicker Detect Digital Saturation**. Indicates that the maximum counter value has been reached during flicker detection.

10.2.6.3 STATUS 3 register (Address 0x91)

Table 35: STATUS 3 register

Addr: 0x91		STATUS 3		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:6	Reserved	0		Reserved
5	INT_ALS_H	0	R	**ALS Interrupt High.** Indicates that a ALS interrupt occurred because the data exceeded the high threshold.
4	INT_ALS_L	0	R	**ALS Interrupt Low**. Indicates that a ALS interrupt occurred because the data is below the low threshold.
3:0	Reserved	0		Reserved

10.2.6.4 STATUS 5 register (Address 0xBB)

Table 36: STATUS 5 register

Addr: 0xBB		STATUS 5		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:4	Reserved	0		Reserved
3	SINT_FD	0	R	**Flicker Detect Interrupt.** If SIEN_FD is set, indicates that the FD_STATUS register status has changed.
2	SINT_SMUX	0	R	**SMUX Operation Interrupt.** Indicates that SMUX command execution has finished.
1:0	Reserved	0		Reserved

10.2.6.5 STATUS 4 register (Address 0xBC)

Table 37: STATUS 4 register

Addr: 0xBC		STATUS 4		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7	FIFO_OV	0	R	**FIFO Buffer Overflow.** Indicates that the FIFO buffer overflowed and information has been lost. Bit is automatically cleared when the FIFO buffer is read
6	Reserved	0	R	Reserved
5	OVTEMP	0	R	**Over Temperature Detected.** Indicates the device temperature is too high. Write 1 to clear this bit.
4	FD_TRIG	0	R	**Flicker Detect Trigger Error.** Indicates that there is a timing error that prevents flicker detect from working correctly.
3	Reserved	0		Reserved
2	ALS_TRIG	0	R	**ALS Trigger Error.** Indicates that there is a timing error. The WTIME is too short for the selected ATIME.
1	SAI_ACTIVE	0	R	**Sleep after Interrupt Active.** Indicates that the device is in SLEEP due to an interrupt. To exit SLEEP mode, clear this bit.
0	INT_BUSY	0	R	**Initialization Busy.** Indicates that the device is initializing. This bit will remain 1 for about 300 µs after power on. Do not interact with the device until initialization is complete.

10.2.6.6 FD_STATUS Register (Address 0xE3)

Table 38: FD STATUS register

Addr: 0xE3		FD_STATUS		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:6	Reserved			Reserved
5	FD_MEASUREMENT_VALID	0	R	**Flicker Detection Measurement Valid.** Indicates that flicker detection measurement is complete. Write 1 to this bit to clear this field.
4	FD_SATURATION_DETECTED	0	R	**Flicker Saturation Detected.** Indicates that saturation occurred during the last flicker detection measurement, and the result may not be valid. Write 1 to this bit to clear this field.
3	FD_120Hz_FLICKER_VALID	0	R	**Flicker Detection 120 Hz Flicker Valid.** Indicates that the 120 Hz flicker detection calculation is valid. Write 1 to this bit to clear this field.
2	FD_100Hz_FLICKER_VALID	0	R	**Flicker Detection 100 Hz Flicker Valid.** Indicates that the 100 Hz flicker detection calculation is valid. Write 1 to this bit to clear this field.
1	FD_120Hz_FLICKER	0	R	**Flicker Detected at 120 Hz.** Indicates if an ambient light source is flickering at 120 Hz.
0	FD_100Hz_FLICKER	0	R	**Flicker Detected at 100 Hz.** Indicates if an ambient light source is flickering at 100 Hz.

10.2.7 ALS data and status

The ASTATUS register provides saturation and gain status associated to each set of ALS data. Reading the ASTATUS register (0x94) latches all 36 ALS data bytes to that status read. Reading these bytes consecutively (0x94 to 0xB8) ensures that the data is concurrent. All ALS data are stored as 16-bit values. If flicker detection is enabled, ALS channel five (CH5 ADC) is used for the flicker detection function. The ASTATUS and ALS data registers are read only.

10.2.7.1 ASTATUS register (Address 0x94)

Table 39: ASTATUS register

Addr: 0x94		ASTATUS		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7	ASAT_STATUS	0	R, SC	**Saturation Status.** Indicates if the latched data is affected by analog or digital saturation.
6:4	Reserved	0	R	Reserved
3:0	AGAIN_STATUS	0	R, SC	**Gain Status.** Indicates the gain applied for the ALS data latched to this ASTATUS read.

10.2.7.2 DATA register (Address 0x95/0xB8)

Table 40: DATA_L register

Addr: 0x95/97/99..B7		DATA_L		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	DATA_L	0	R	ALS Data – low byte

Table 41: DATA_H register

Addr: 0x96/98/9A..B8		DATA_H		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	DATA_H	0	R	ALS Data – high byte

10.2.8 Miscellaneous configuration

10.2.8.1 CFG0 register (Address 0xBF)

Table 42: CFG0 register

Addr: 0xBF		CFG0		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:6	Reserved	0		Reserved
5	LOW_POWER	0	RW	**Low Power Idle.** When asserted, the device will automatically run in a low power mode whenever all functions are in wait states or disabled.
4	REG_BANK	0	RW	**Register Bank Access** 0: Register access to register 0x80 and above. 1: Register access to register 0x20 to 0x7F. Note: Bit needs to be set to access registers 0x20 to 0x7F. If registers 0x80 and above needs to be accessed bit needs to be set to “0”.
3	Reserved	0		Reserved
2	WLONG	0	RW	**Trigger Long.** Increases the WTIME setting by a factor of 16.
1:0	Reserved	0		Reserved

10.2.8.2 CFG3 register (Address 0xC7)

Table 43: CFG3 register

Addr: 0xC7		CFG3		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:5	Reserved	0		Reserved
4	SAI	0	RW	**Sleep After Interrupt.** If set, the oscillator is turned off whenever an interrupt is active. SAI_ACTIVE is set in this event. To activate the oscillator again, clear all interrupts and clear the SAI_ACTIVE bit.
3:0	Reserved	0xC		Reserved

10.2.8.3 CFG6 register (Address 0xF5)

Table 44: CFG6 register

Addr: 0xF5		CFG6		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
4:3	SMUX_CMD	2	RW	**SMUX Command.** Selects the SMUX command to execute when setting SMUXEN gets set. Do not change during ongoing SMUX operation. **VALUE** / **SMUX_CMD** 0 – ROM code initialization of SMUX 1 – Read SMUX configuration to RAM from SMUX chain 2 – Write SMUX configuration from RAM to SMUX chain 3 – Reserved, do not use

10.2.8.4 CFG9 register (Address 0xCA)

Table 45: CFG9 register

Addr: 0xCA		CFG9		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7	Reserved	0		Reserved
6	SIEN_FD	0	RW	**System Interrupt Flicker Detection.** Enables system interrupt when flicker detection status change has occurred.
5	Reserved			Reserved
4	SIEN_SMUX	0	RW	**System Interrupt SMUX Operation.** Enables system interrupt when SMUX command has finished
3:0	Reserved			Reserved

10.2.8.5 CFG20 register (Address 0xD6)

Table 46: CFG20 register

Addr: 0xD6		CFG20		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7	FD_FIFO_8b	0	RW	**Enable 8-bit FIFO mode for Flicker Detection.** 0: Disabled 1: Enabled **Note:** FD_TIME must be smaller than 256, else flicker data might be larger than 8 bits. In that case flicker data gets saturated to 0xFF.
6:5	auto_smux	0	RW	**Automatic channel read-out** **0:** 6 Channel FZ, FY, FXL, NIR, 2xVIS, FD **1:** Reserved **2:** Automatic 12 channel Cycle 1: FZ, FY, FXL, NIR, 2xVIS, FD Cycle 2: F2, F3, F4, F6, 2xVIS, FD **3:** Automatic 18 channel Cycle 1: FZ, FY, FXL, NIR, 2xVIS, FD Cycle 2: F2, F3, F4, F6, 2xVIS, FD Cycle 3: F1, F7, F8, F5, 2xVIS, FD **Note:** The bit “auto_smux” should only be changed before a measurement is started. Once a measurement is started, the device is automatically processing the channels as per definition above and storing the measurement results in the eighteen data registers. 2xVIS: Per default the “Top Left” and “Both Right” VIS/CLEAR PD is read-out.
4:0	Reserved			Reserved

10.2.8.6 PERS Register (Address 0xCF)

Table 47: PERS register

Addr: 0xCF		PERS		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:4	Reserved	0		Reserved

Addr: 0xCF		PERS		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
3:0	APERS	0	RW	**ALS Interrupt Persistence.** Defines a filter for the number of consecutive occurrences that ALS data must remain outside the threshold range between ALS_TH_L and ALS_TH_H before an interrupt is generated. The ALS data channel used for the persistence filter is set by ALS_TH_CHANNEL. Any sample that is inside the threshold range resets the counter to 0.

VALUE	**CHANNEL**
0	Every ALS cycle generates an interrupt
1	1
2	2
3	3
4	5
5	10
…	5 x (APERS – 3)
14	55
15	60

10.2.9 FIFO buffer data and status

The FIFO buffer is used to poll ALS data with fewer I²C read and write transactions. The FIFO buffer is 256 bytes of RAM containing 128 two-byte datasets. If the FIFO overflows (i.e. 129 datasets before host reads data from the FIFO buffer), an overflow flag will be set and new data will be lost. The Host acquires data by reading addresses: 0xFE – 0xFF. The register address pointer automatically wraps from 0xFF to 0xFE as data are read. Data can be read one byte at a time or in blocks, (there is no block-read length limit). When reading single bytes, the internal FIFO read pointer and the FIFO Buffer Level, FIFO_LVL, are updated each time register 0xFF is read. For block-reads, the internal FIFO read pointer and the FIFO Buffer Level, FIFO_LVL update for each two-byte entry. If the FIFO continues to be accessed after FIFO_LVL = 0, the device will return 0 for all data. The FINT interrupt indicates when there is valid data in the FIFO buffer. The amount of unread data is indicated by the FIFO_LVL.

10.2.9.1 FIFO_MAP register (Address 0xFC)

Table 48: FIFO_MAP register

Addr: 0xFC		FIFO_MAP		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7	Reserved	0		Reserved
6	FIFO_WRITE_CH5_DATA	0	RW	**FIFO Write CH5 Data.** If set, CH5 data is written to the FIFO Buffer. (two bytes per sample) **Note:** If flicker detection is enabled, this bit is ignored. Refer to register 0xD7 for FDEN=”1”.
5	FIFO_WRITE_CH4_DATA	0	RW	**FIFO Write CH4 Data.** If set, CH4 data is written to the FIFO Buffer. (two bytes per sample).
4	FIFO_WRITE_CH3_DATA	0	RW	**FIFO Write CH3 Data.** If set, CH3 data is written to the FIFO Buffer. (two bytes per sample).
3	FIFO_WRITE_CH2_DATA	0	RW	**FIFO Write CH2 Data.** If set, CH2 data is written to the FIFO Buffer. (two bytes per sample).
2	FIFO_WRITE_CH1_DATA	0	RW	**FIFO Write CH1 Data.** If set, CH1 data is written to the FIFO Buffer. (two bytes per sample).
1	FIFO_WRITE_CH0_DATA	0	RW	**FIFO Write CH0 Data.** If set, CH0 data is written to the FIFO Buffer. (two bytes per sample).
0	FIFO_WRITE_ASTATUS	0	RW	**FIFO Write Status.** If set, ASTATUS (one byte per sample) is written to the FIFO Buffer.

10.2.9.2 FIFO_CFG0 register (Address 0xDF)

Table 49: FIFO_CFG0 register

Addr: 0xDF		FIFO_CFG0		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7	FIFO_WRITE_FD	0	RW	**FIFO Write Flicker Detection** If set flicker raw data is written into FIFO (one byte per sample). **Note:** This bit is ignored if flicker detection is disabled. Refer to register 0xFC for FDEN=”0”.
6:0	Reserved	0100001		Reserved, do not change.

10.2.9.3 FIFO_LVL register (Address 0xFD)

Table 50: FIFO_LVL register

Addr: 0xFD		FIFO_LVL		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	FIFO_LVL	0	R	**FIFO Buffer Level.** Indicates the number of entries (each are 2 bytes) available in the FIFO buffer waiting for readout. The FIFO RAM is 256 byte, the FIFO_LVL range is from 0 entries to 128 entries.

10.2.9.4 FDATA register (Address 0xFE and 0xFF)

Table 51: FDATA_L register

Addr: 0xFE		FDATA_L		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
7:0	FDATA	0	R	FIFO Buffer Data

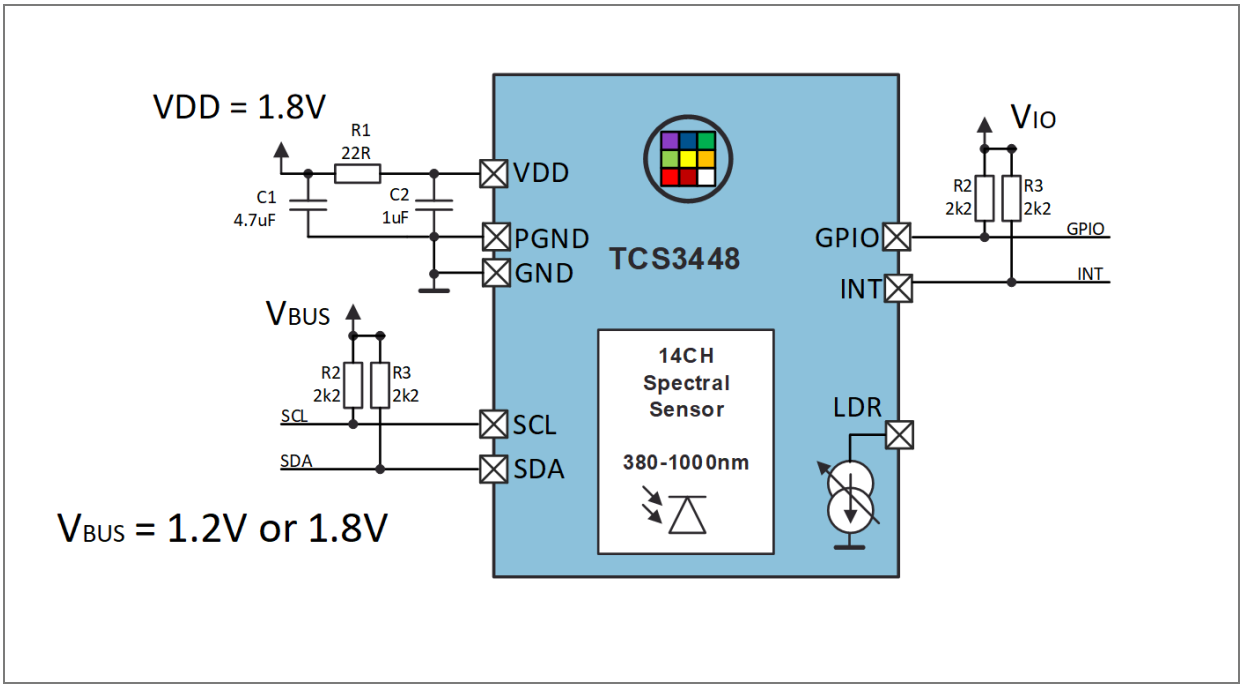
Table 52: FDATA_H register

Addr: 0xFF		FDATA_H		
Bit	**Bit name**	**Default**	**Access**	**Bit description**
15:8	FDATA	0	R	FIFO Buffer Data

11 Application information

11.1 Schematic

Figure 10: Application example



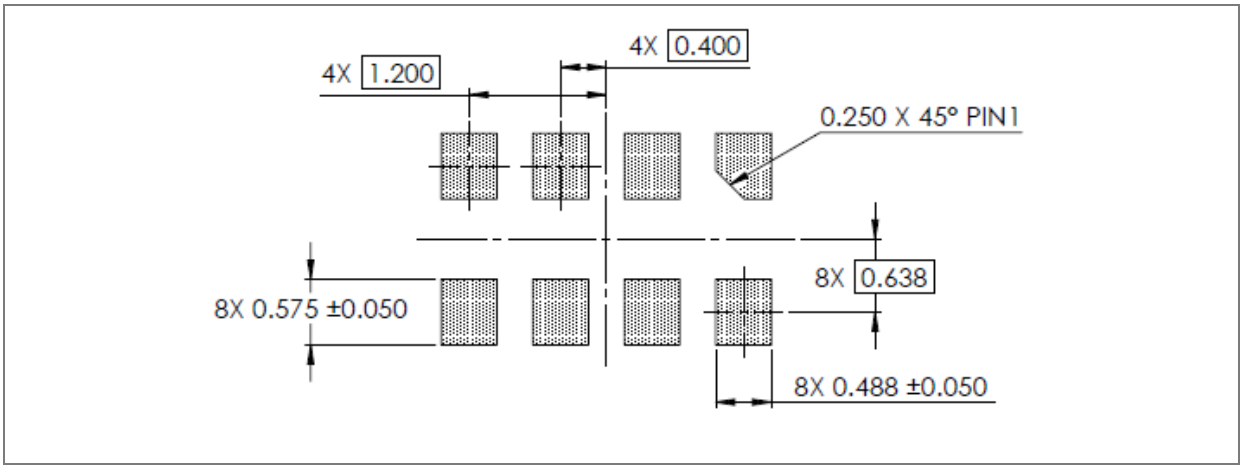
Pin GPIO is used to select the I²C bus interface voltage during start-up of the device. Please refer to chapter “Selection of I²C bus interface voltage” for details.

Configuration examples:
V_{GPIO} = GND : V_{BUS} = 1.2 V
V_{GPIO} = 1.2 V : V_{BUS} = 1.2 V
V_{GPIO} = 1.8 V : V_{BUS} = 1.8 V
V_{GPIO} = 3.3 V : V_{BUS} = 1.8 V

Pins GPIO and INT are both 3 V compliant (3.6 V abs max) and do not have to be connected to the same V_{IO} voltage.

11.2 PCB pad layout

Figure 11: Recommended PCB pad layout

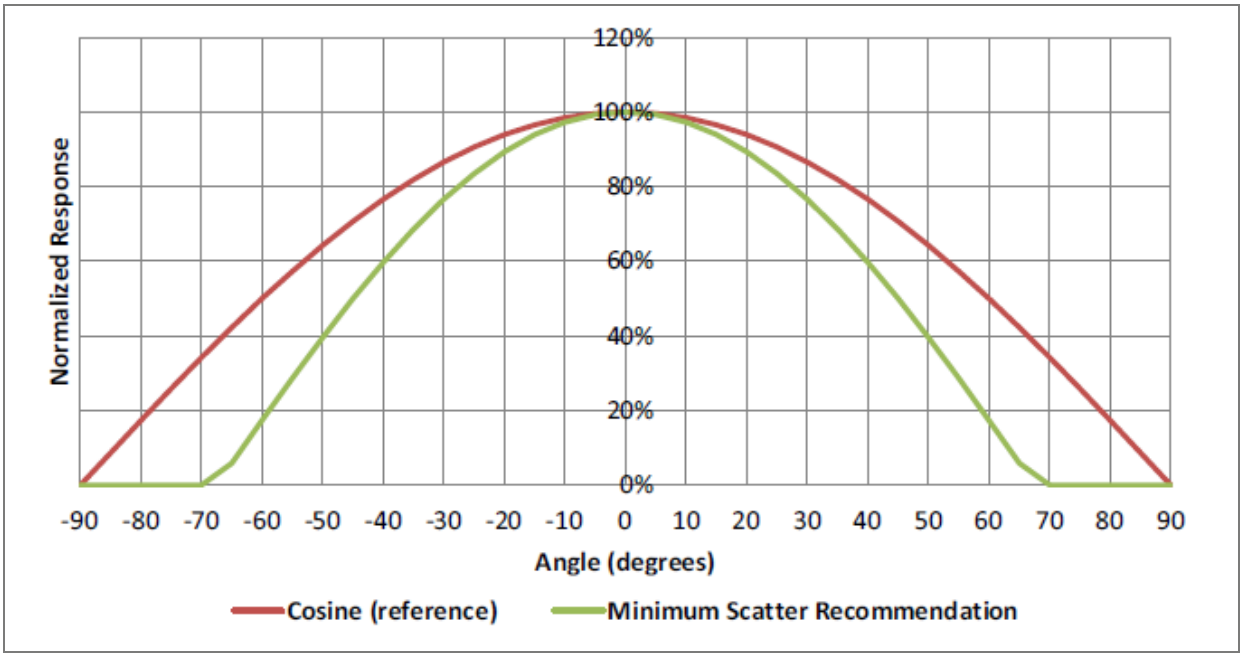


(1) All dimensions are in millimeters.
(2) Dimension tolerances are 0.05 mm unless otherwise noted.
(3) This drawing is subject to change without notice.

11.3 Application optical requirements

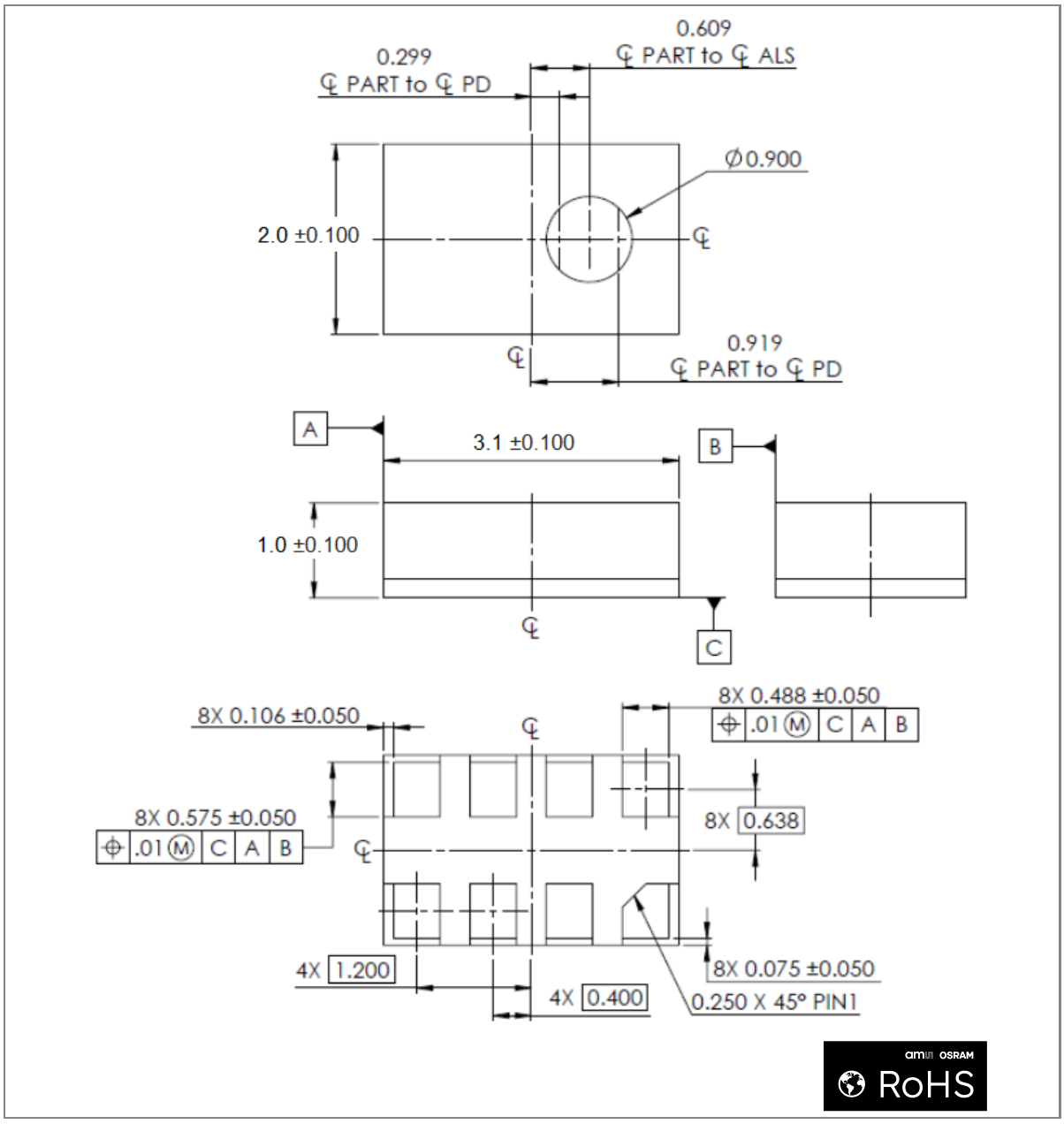
For stable performance, an achromatic diffuser shall be placed above the device aperture. The recommended solution is a bulk diffuser that meets the minimum recommended scattering characteristic shown below. For more details refer to the optical design guide or contact ams OSRAM.

Figure 12: Diffuser characteristics



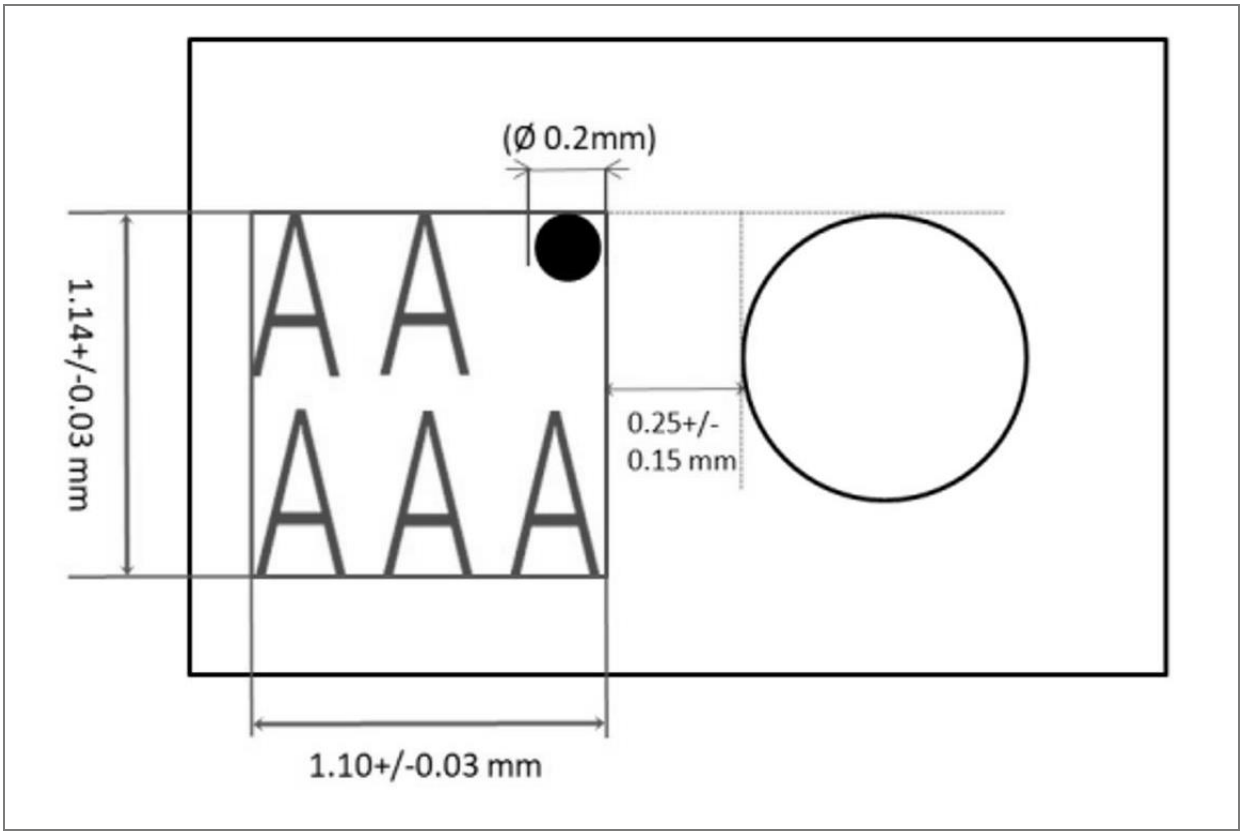
12 Package drawings & markings

Table 53: OLGA8 package outline drawing



(1) All dimensions are in millimeters. Angles in degrees.
(2) Dimensioning and tolerance conform to ASME Y14.5M-1994.
(3) This package contains no lead (Pb).
(4) This drawing is subject to change without notice.

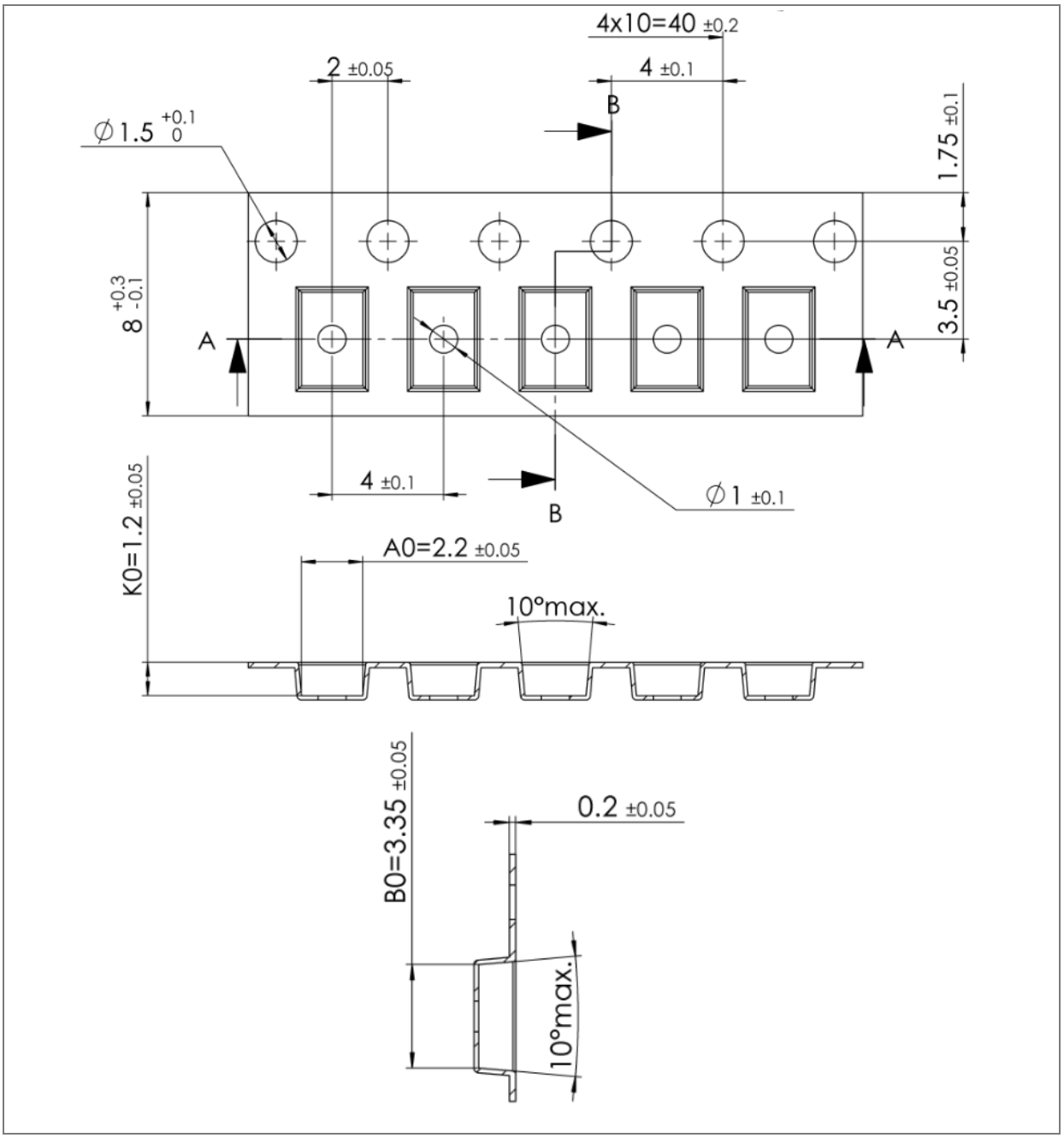
Figure 13: OLGA8 package marking



(1) Marking code consists of random characters or digits. Placeholder is indicated with “AAAAA” in drawing.
(2) All dimensions are in millimeters. Angles in degrees.
(3) Dimensioning and tolerance conform to ASME Y14.5M-1994.
(4) This package contains no lead (Pb).
(5) This drawing is subject to change without notice.

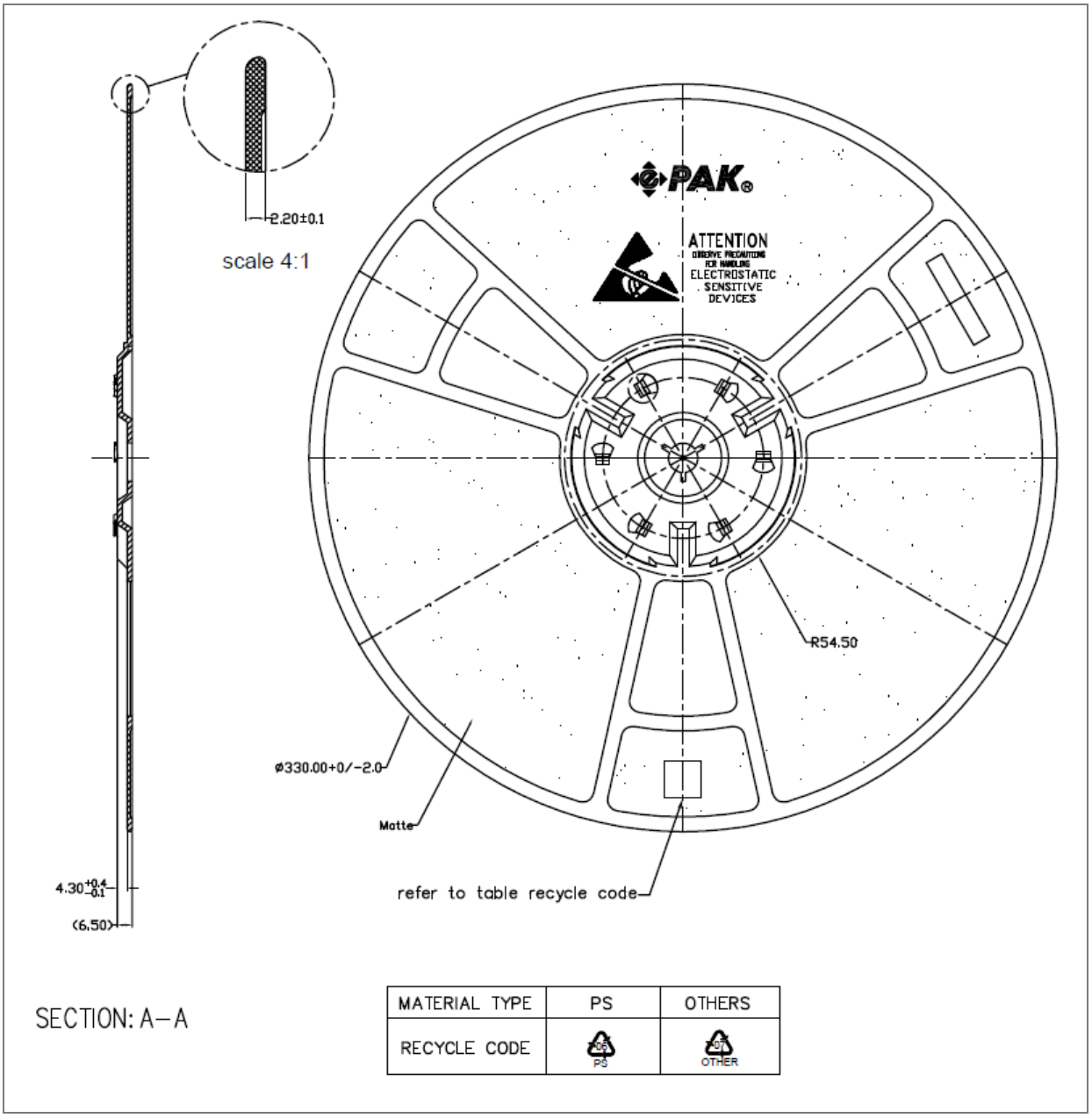
13 Tape & reel information

Figure 14: TCS3448 OLGA8 tape dimensions



(1) All dimensions are in millimeters. Angles in degrees.
(2) This drawing is subject to change without notice.

Figure 15: TCS3448 OLGA8 reel dimensions



(1) All dimensions are in millimeters. Angles in degrees.
(2) This drawing is subject to change without notice.

14 Soldering & storage information

The module has been tested and has demonstrated an ability to be reflow-soldered to a PCB substrate. Please observe, however, that such repeated temperature stress may alter measurements results and optical performance and will influence color measurement accuracy. The solder reflow profile describes the expected maximum heat exposure of components during the solder reflow process of product on a PCB. Temperature is measured on top of component. The components should be limited to a maximum of three passes through this solder reflow profile.

Figure 16: Solder reflow profile graph

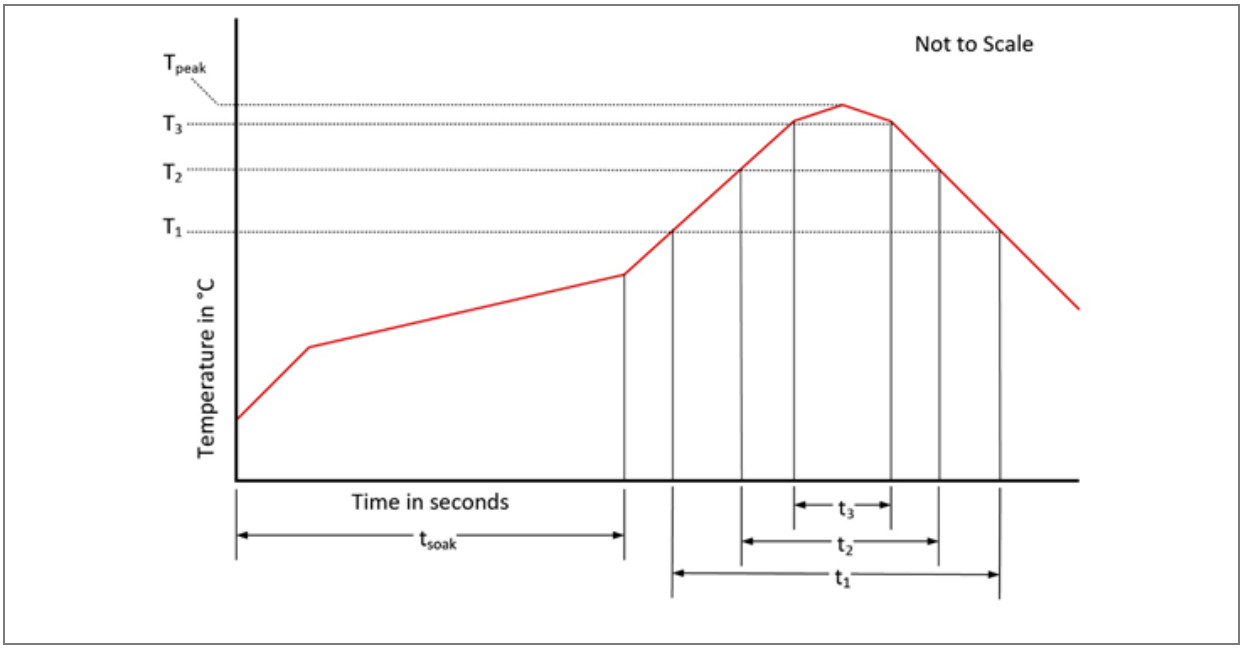


Table 54: Solder reflow profile

Parameter	Reference	Device
Average temperature gradient in preheating		2.5 °C/s
Soak time	t_{soak}	2 to 3 minutes
Time above 217 °C (T1)	t_1	Max 60 s
Time above 230 °C (T2)	t_2	Max 50 s
Time above T_{peak} – 10 °C (T3)	t_3	Max 10 s
Peak temperature in reflow	T_{peak}	260 °C
Temperature gradient in cooling		Max −5 °C/s

14.1 Storage information

14.1.1 Moisture sensitivity

Optical characteristics of the device can be adversely affected during the soldering process by the release and vaporization of moisture that has been previously absorbed into the package.

To ensure the package contains the smallest amount of absorbed moisture possible, each device is baked prior to being dry packed for shipping. Devices are dry packed in a sealed aluminized envelope called a moisture-barrier bag with silica gel to protect them from ambient moisture during shipping, handling, and storage before use.

14.1.2 Shelf life

The calculated shelf life of the device in an unopened moisture barrier bag is 24 months from the date code on the bag when stored under the following conditions:

- Shelf Life: 24 months
- Ambient Temperature: <40 °C
- Relative Humidity: <90%

Re-baking of the devices will be required if the devices exceed the 24 months shelf life or the Humidity Indicator Card shows that the devices were exposed to conditions beyond the allowable moisture region. Please observe, however, that such repeated temperature stress may alter measurements results and optical performance and will influence color measurement accuracy.

14.1.3 Floor life

The module has been assigned a moisture sensitivity level of MSL 3. As a result, the floor life of devices removed from the moisture barrier bag is 168 hours from the time the bag was opened, provided that the devices are stored under the following conditions:

- Floor Life: 168 hours
- Ambient Temperature: <30 °C
- Relative Humidity: <60%

If the floor life or the temperature/humidity conditions have been exceeded, the devices must be re-baked prior to solder reflow or dry packing. Please observe, however, that such repeated

temperature stress may alter measurements results and optical performance and will influence color measurement accuracy.

14.1.4 Re-baking instructions

When the shelf life or floor life limits have been exceeded, re-bake at 50 °C for 12 hours.

15 Revision information

Document status	Product status	Definition
Product Preview	Pre-development	Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice
Preliminary Datasheet	Pre-production	Information in this datasheet is based on products in the design, validation or qualification phase of development. The performance and parameters shown in this document are preliminary without any warranty and are subject to change without notice
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Changes from previous released version to current revision v1-01	Page
Document security class is updated to “PUBLIC” in the footer	

- 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.

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Headquarters
ams-OSRAM AG
Tobelbader Strasse 30
8141 Premstaetten
Austria, Europe
Tel: +43 (0) 3136 500 0

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