Product Document

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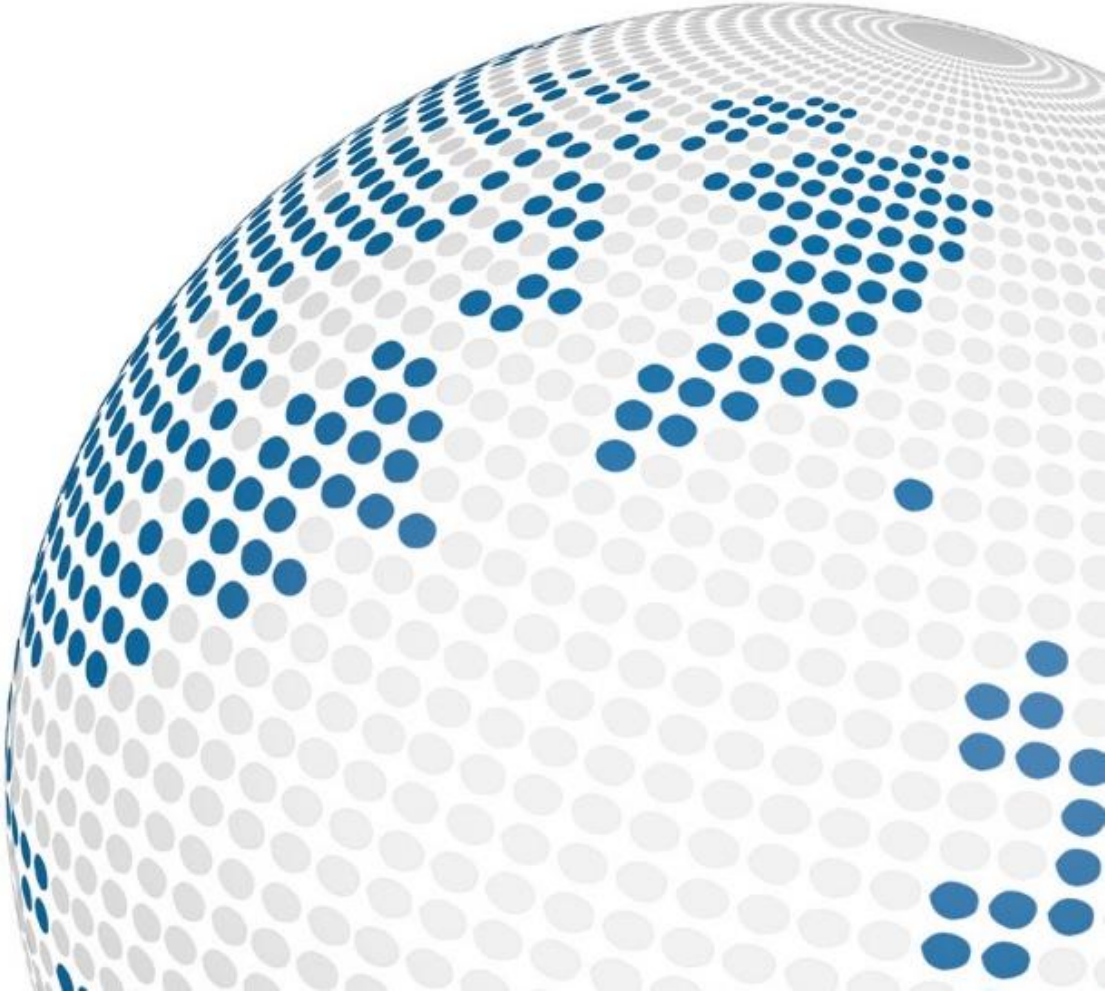
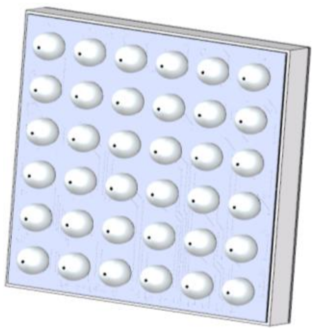


AS7050 Design-in Guidelines

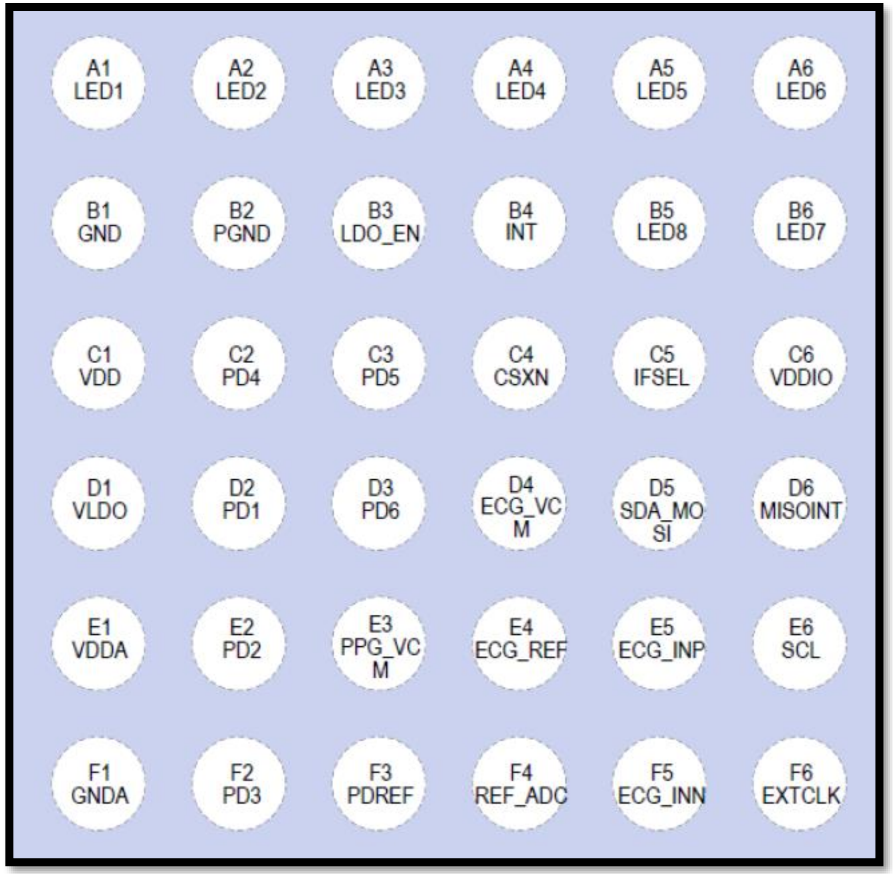
AS7050

Overview

Top View



Bottom View



AS7050 Pin Description

Fig. 1: AS7050 Overview

AS7050

System Overview

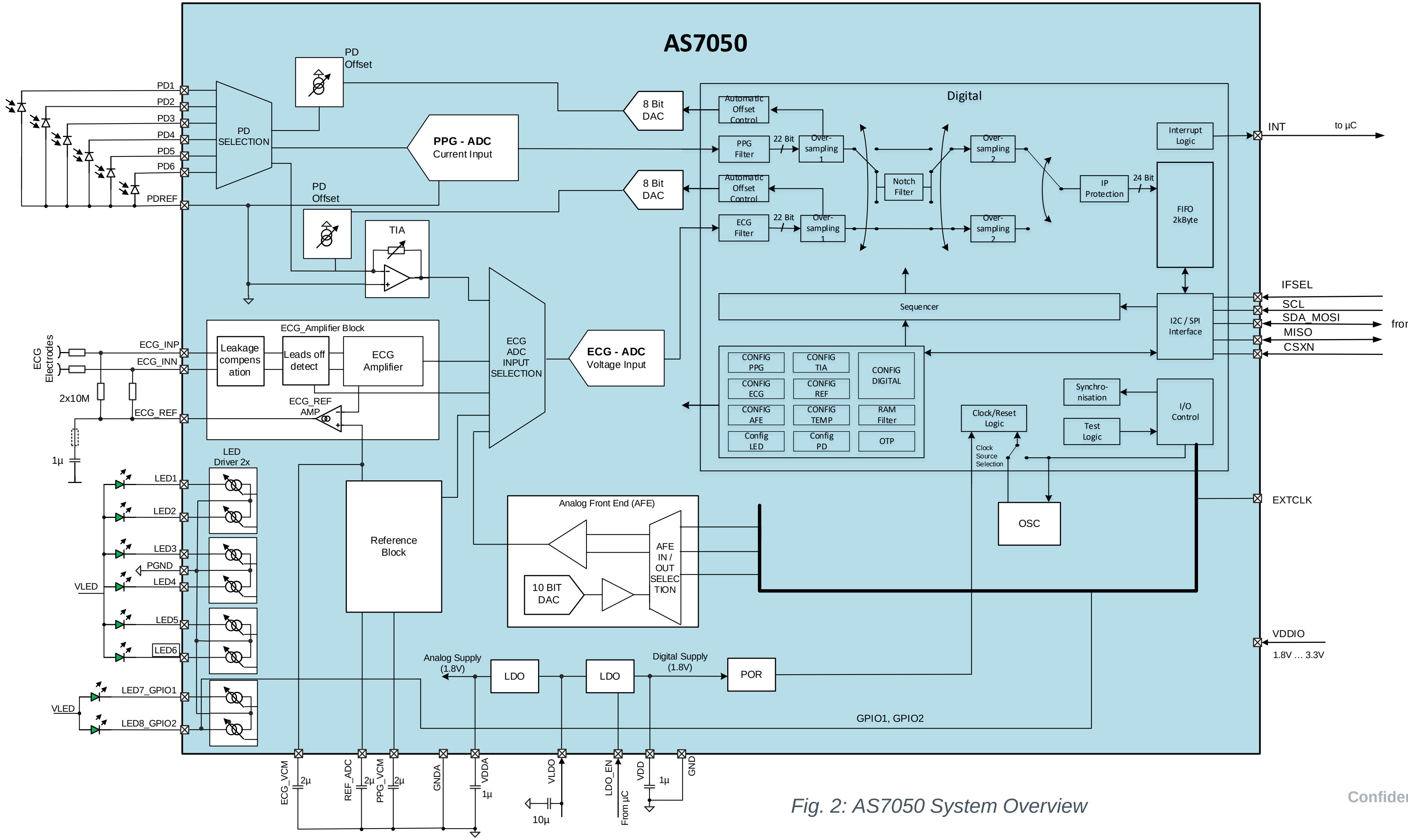
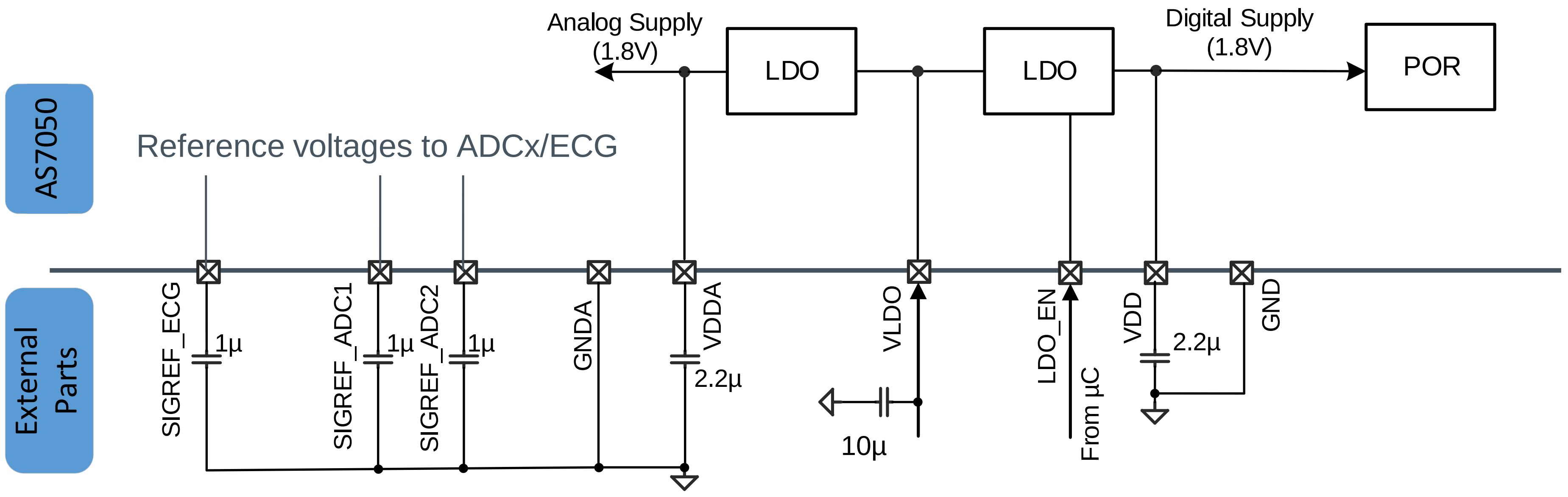


Fig. 2: AS7050 System Overview

Voltage Supply Scheme

Pin description

- Flexible voltage supply:
  - Supply Voltage = 1.8V with optional embedded LDO



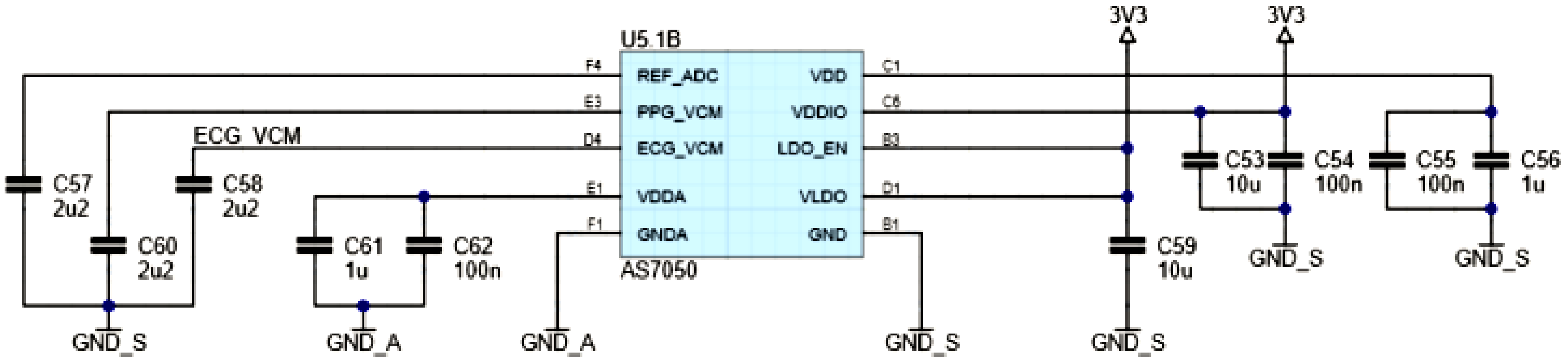
Symbol	Description	Min	Typ	Max	Unit
VDD	Digital power supply	1.7	1.8	1.98	V
VDDA	Analog power supply	1.7	1.8	1.98	V
VDDIO	IO power supply	VDD		3.3	V
VLDO	LDO input voltage	2.3		5.5	V

Fig. 3: Voltage supply scheme with pin description

Voltage Supply Scheme

Recommended power design for Internal LDO

- AS7050 can only be powered by a single 3.3V power rail.



Pin No.	Pin Name	Description
C6	VDDIO	Digital I/O supply. Connect to 3.3V power rail.
D1	VLDO	Input for internal LDOs. Connect to 3.3V power rail.
C1	VDD	Internal LDO output for digital supply, adding coupling capacitors to GND.
E1	VDDA	Internal LDO output for analog supply, adding coupling capacitors to GND.
B3	LDO_EN	Enable internal LDO.

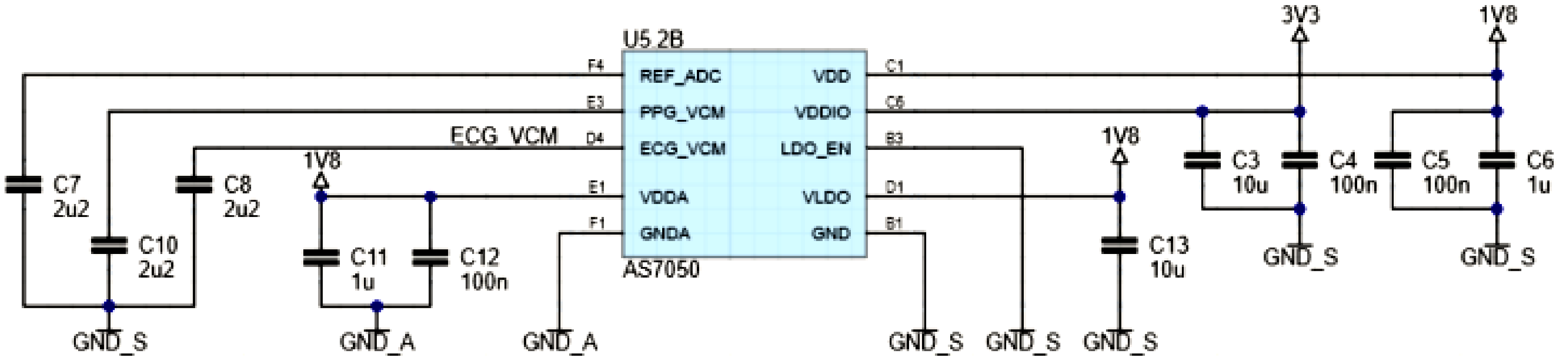
Fig. 4: Recommended power supply for internal LDO scheme with pin description

Voltage Supply Scheme

Recommended power design for External LDO

Sensing is life.

- AS7050 can only be powered by a single 3.3V power rail.



Pin No.	Pin Name	Description
C6	VDDIO	Digital I/O supply. Connect to 3.3V power rail.
D1	VLDO	Connecting to external 1.8V LDO output. Connect to 1.8V power rail.
C1	VDD	Connecting to external 1.8V LDO output, adding coupling capacitors to GND.
E1	VDDA	Connecting to external 1.8V LDO output, adding coupling capacitors to GND.
B3	LDO_EN	Disable internal LDO.

Fig. 5: Recommended power supply for External LDO scheme with pin description

Voltage Supply Scheme

System power rails

- AS7050 LED driver compliance voltage Max = 0.85V.
- For the Green LED, the max forward voltage is up to 3.4V.
- Need to power Green LED with another power rail in this case.

Forward voltage (I_F = 20 mA)	(typ. (max.))	V_F	3.0 (≤ 3.4)	V

LED forward voltage from LED datasheet

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{Compl_1}	Compliance Voltage	led_ictrl = 0 … 127			0.3	V
		led_ictrl = 128 … 255			0.85	V
LED Driver 7-8						
I_{LED}	Output current	led_ictrl = 128		50.00		mA
V_{Compl_1}	Compliance Voltage	led_ictrl = 0 … 127			0.3	V

LED driver compliance voltage

Fig. 6: LED forward voltage and driver compliance voltage

NOTE: *An extra power rail depends on the optical design. If the Green LED with max forward voltage is up to 3.4V, an extra power rail is needed. But on the market, a Green LED with max forward voltage below 3V is also available. In such cases, there is no need for an extra power rail.*

Digital IO Signals

Pin description

- A digital I2C/SPI slave interface is used for external control of the measurement setup and controls the function of all internal features. The transmission mode is selected via an external pin (IF_SEL). In both modes (I2C or SPI), the AS7050 works as a slave device.
- By connecting the IF_SEL pin to low or high, we can select an active interface connected to the host (MCU).

Pin assignment	Enable Interface
IF_SEL = 0	I2C
IF_SEL = 1	SPI

Fig. 7: AS7050 Digital IO Pin description

Digital IO Signals

Enable I2C interface

- The table below shows how to enable the I2C interface.
- The AS7050 includes an I2C slave using an I2C address of 0x55.
- Fast mode (400kHz) and standard mode (100kHz) support.

Pin number	Pin Name	Description and usage
C5	IF_SEL	Enable I2C interface, tie to GND.
D5	SDA	I2C data, pull up to VCC with a resistor.
E6	SCL	I2C clock, pull up to VCC with a resistor.

Fig. 8: AS7050 I2C interface

Digital IO Signals

Enable SPI interface

- The table below shows how to enable the SPI interface.
- SPI clock is 10MHz.

Pin number	Pin Name	Description and usage
C5	IF_SEL	Enable SPI interface, pull up to VCC with a resistor.
C4	CSXN	Chip select for SPI interface.
E6	SCL	SPI clock
D5	MOSI	Data input for SPI.
D6	MISO	Data output for SPI.

Fig. 9: AS7050 SPI interface

Digital IO Signals

Interrupt PIN

- The interrupt events are processed by the interrupt manager. These interrupt events must be released for processing via an interrupt enable register.
- The interrupt status is automatically reset when the register is read (auto-zero register).

Pin number	Pin Name	Description and usage
B4	INT	Interrupt pin, pull up to VCC with a resistor.

Fig. 10: AS7050 interrupt pin description

IO Signals

Pin description – LED Drivers and Photodiodes

- The AS7050 provides a high amount of LED driver output and photodiode input pins. This enables the highest flexibility for several LED and photodiode arrangements in different applications.
- It can drive external LEDs and support additional photodiodes.

Pin No.	Pin Name	Description
A1	LED1	Output LED driver 1
A2	LED2	Output LED driver 2
A3	LED3	Output LED driver 3
A4	LED4	Output LED driver 4
A5	LED5	Output LED driver 5
A6	LED6	Output LED driver 6
B6	LED7 (GPIO1)	Output LED driver 7 or General purpose I/O (analog & digital)
B5	LED8 (GPIO2)	Output LED driver 8 or General purpose I/O (analog & digital)
D2	PD1	Photodiode input
E2	PD2	Photodiode input
F2	PD3	Photodiode input
C2	PD4	Photodiode input
C3	PD5	Photodiode input
D3	PD6	Photodiode input

Fig. 11: AS7050 Pin description – LED drivers & Photodiodes

PPG Design

LED drivers

- The AS7050 controls up to as many as eight LED drivers.
- LED1 to LED6 have a maximum output current of 300mA.
- LED7 to LED8 have a maximum output current of 50mA.
- Make sure the total average current ≤ 35mA @ DC, with all the LEDs on during all 8-time slots.
- *Fig 11* shows a basic idea of the LED connections.

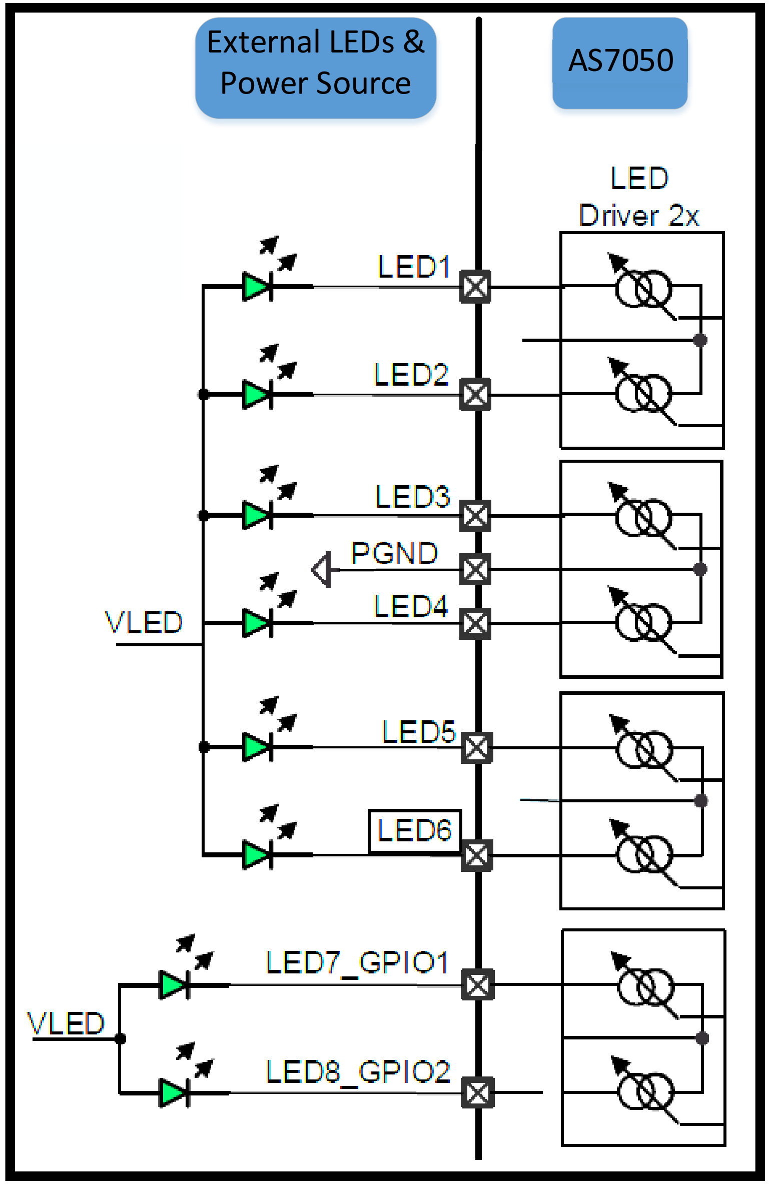


Fig. 12: AS7050 LED drivers

PPG Design

PD inputs

- The AS7050 has six photodiode input pins.
- The maximum allowed photodiode capacitance connected to PPG ADC is 300pF.
- *Fig 12* shows a basic idea of the PD connections.

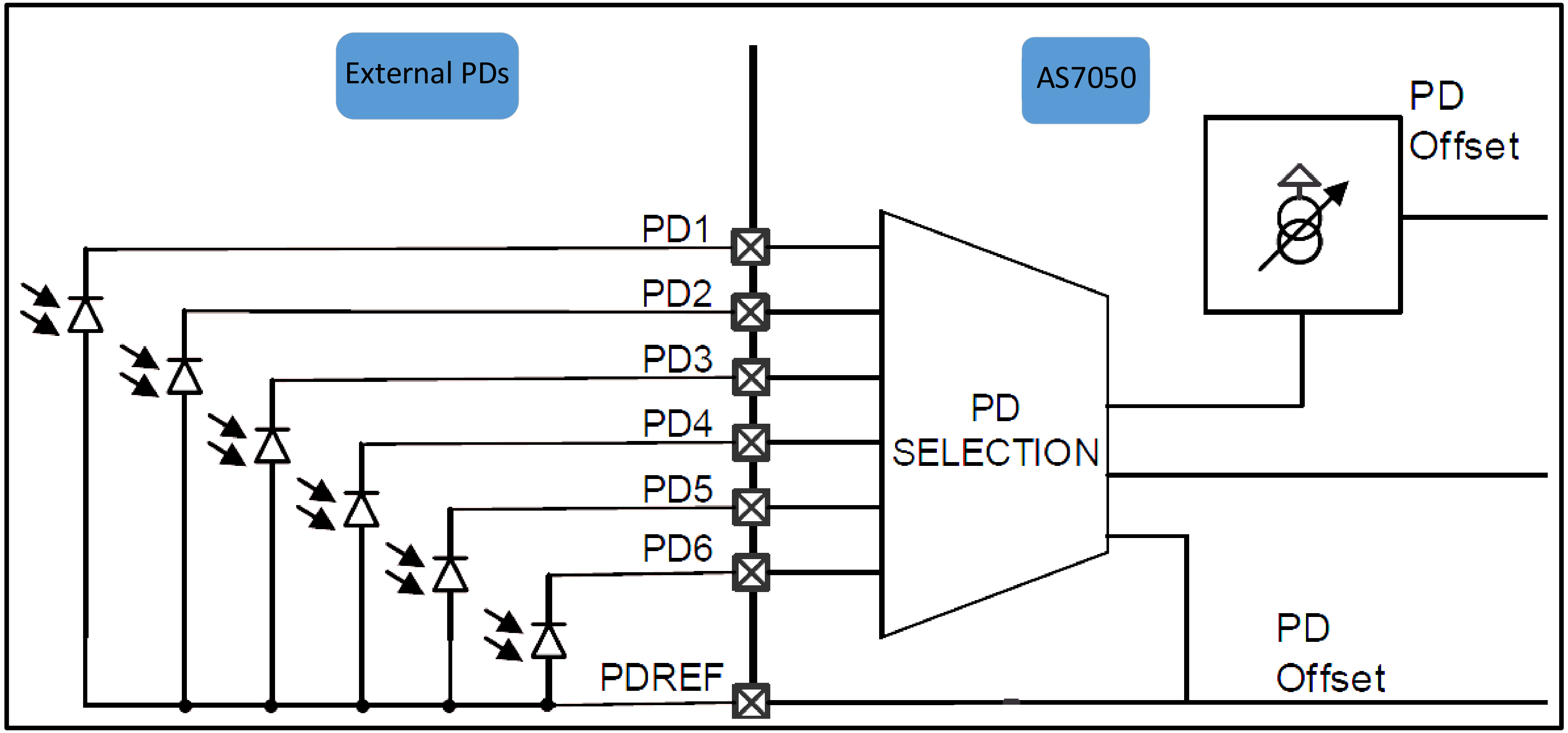


Fig. 13: AS7050 PPG Input

PPG Signal

General Information

- Make sure your fingers are warm. -> A pulse signal cannot be detected on cold fingers.
- Do not press too hard on the sensor with your finger. -> If pressed too hard, the blood flow my be disrupted and no signal can be detected.

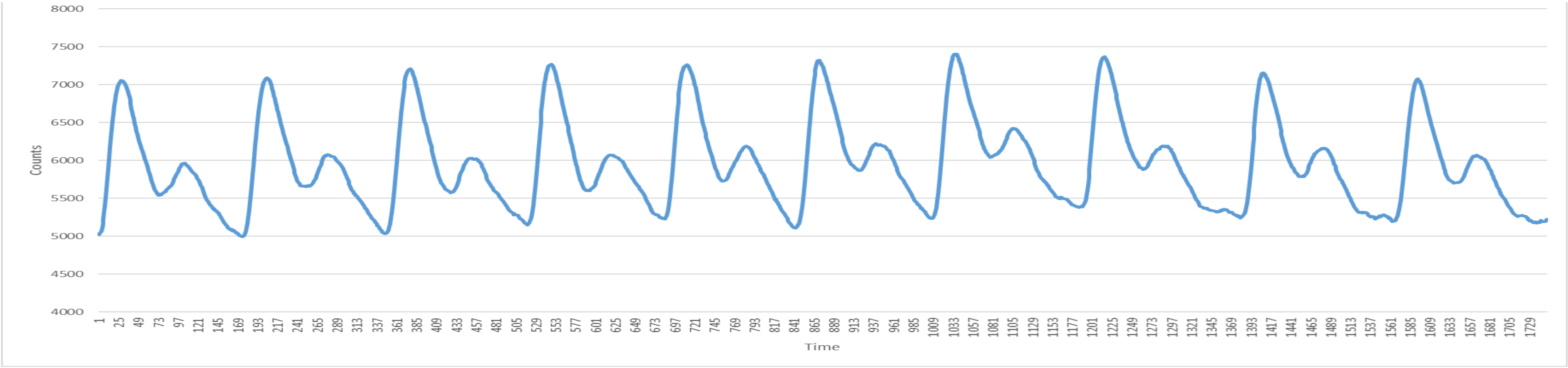
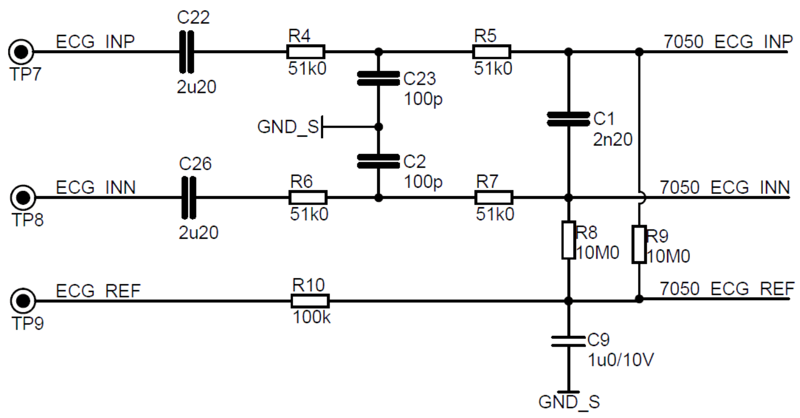


Fig. 13: PPG signal (Count vs Time)

ECG

Circuit design

- The ECG (electrocardiogram) amplifier is a high impedance, low noise instrumentation amplifier, with analog circuitry to band-pass filter the signal and amplify it before converting it with the ADC.
- The ECG lead OFF detection can be used for detection if the user touches the leads. It is circuitry to measure the capacitor and/or resistance between the two lead inputs ECG_INP and ECG_INN.



Pin No.	Pin Name	Description	Capacitors [F]	Resistors [Ohm]
D4	ECG_VCM	ECG amplifier reference voltage	2.2u to GND	
E4	ECG_REF	ECG amplifier reference output	1u to GND	
E5	ECG_INP	ECG amplifier input	2.2u in series 100p to GND 2.2n to ECG_INN	51k + 51k in series 100M to ECG_REF
F5	ECG_INN	ECG amplifier input	2.2u in series 100p to GND	51k + 51k in series 100M to ECG_REF

Fig. 14: Recommended ECG Frontend Filter

NOTE*: As the ECG signal lines are very sensitive to noise, it is very important to pay attention to the layout. The ECG frontend filter might be changed based on the application and noise sensitivity.*

ECG Signal

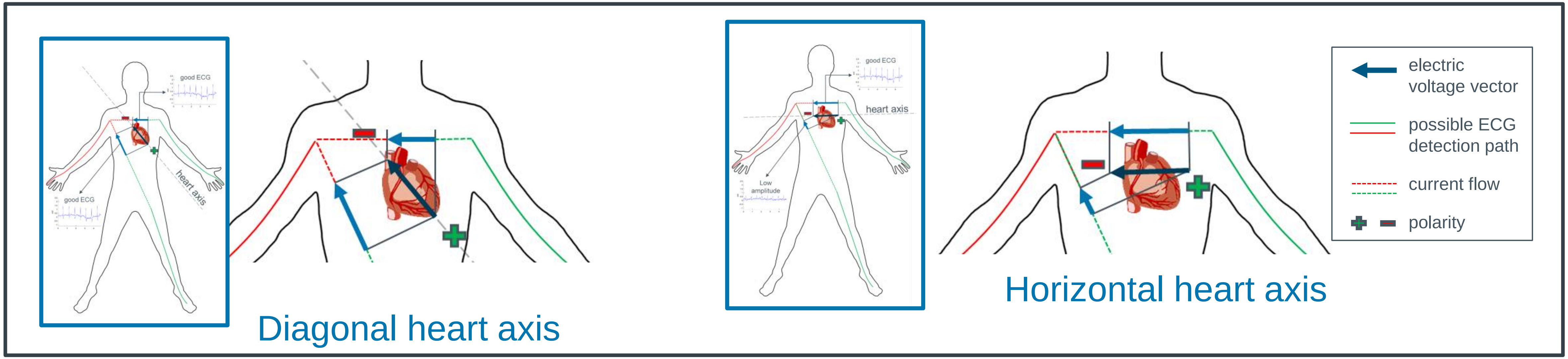


Fig. 15: Diagonal & horizontal heart axis

- An ECG recording is similar to voltage measurement in batteries.
- The recorded amplitude depends highly on the orientation of the electrical heart axis relative to the recording axis of the electrodes.
- There is a considerable variation of the axis orientation even in healthy people.
- A reference electrode is used to filter out noise pickup (common-mode rejection).
- Make sure the electrodes are clean and do not have any film of fat on them.
- The ECG signal may be too weak to be detected due to dry skin.
- The signal strength of the ECG signal depends on the orientation of the heart axis, which varies from individual to individual and may not be detectable in some cases.

Signals

- Weak signals ranging from 0.5mV to 5.0mV.
- High DC component of up to +/- 300mV (electrode skin contact).
- Common-mode component up to 1.5V (potential electrodes – ground).

Noise

- Power-line interference: 50-60 Hz.
- Electrode contact noise (baseline drift).
- Motion artifacts (shifts in the baseline).
- Muscle contraction.
- Electromagnetic interference from other electronic devices (higher frequencies).

Electrode Properties

Recommendations

Electrodes

- Based on our measurements with twenty subjects, a skin-to-electrode resistance up to 350-400kΩ is recommended.
- Based on this, we recommend a round electrode of >14mm for each ECG contact.
- A differently shaped electrode with equivalent surface area is also possible.
- A typical material to use would be stainless steel sheet electrodes (material 1.4301).

Electrode Cables

- For longer electrode cables (>20cm) or in EMC polluted environments, a shielded cable is highly recommended.
- The shield should be connected to GND.

Electrode Connections

- Positive and negative electrodes detect ECG signal (across the heart).
- Reference electrode for common-mode rejection.

- ‘ECG INN’ should be connected to the right hand of the user.
- ‘ECG INP’ and ‘ECG REF’ should be connected to the left hand of the user.
- ‘ECG INP’ and ‘ECG REF’ should not share an electrode but rather have individual electrodes that connect to different parts of the left hand.

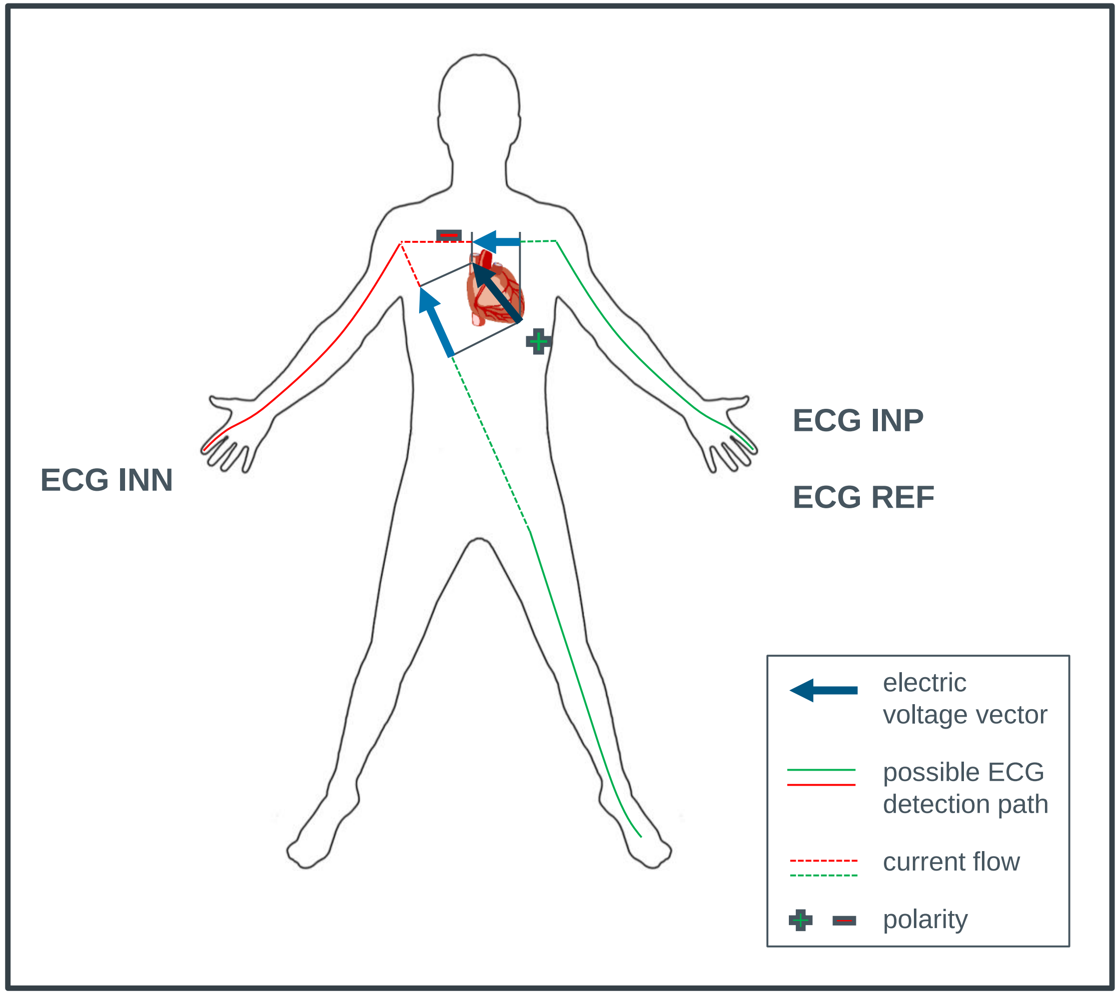
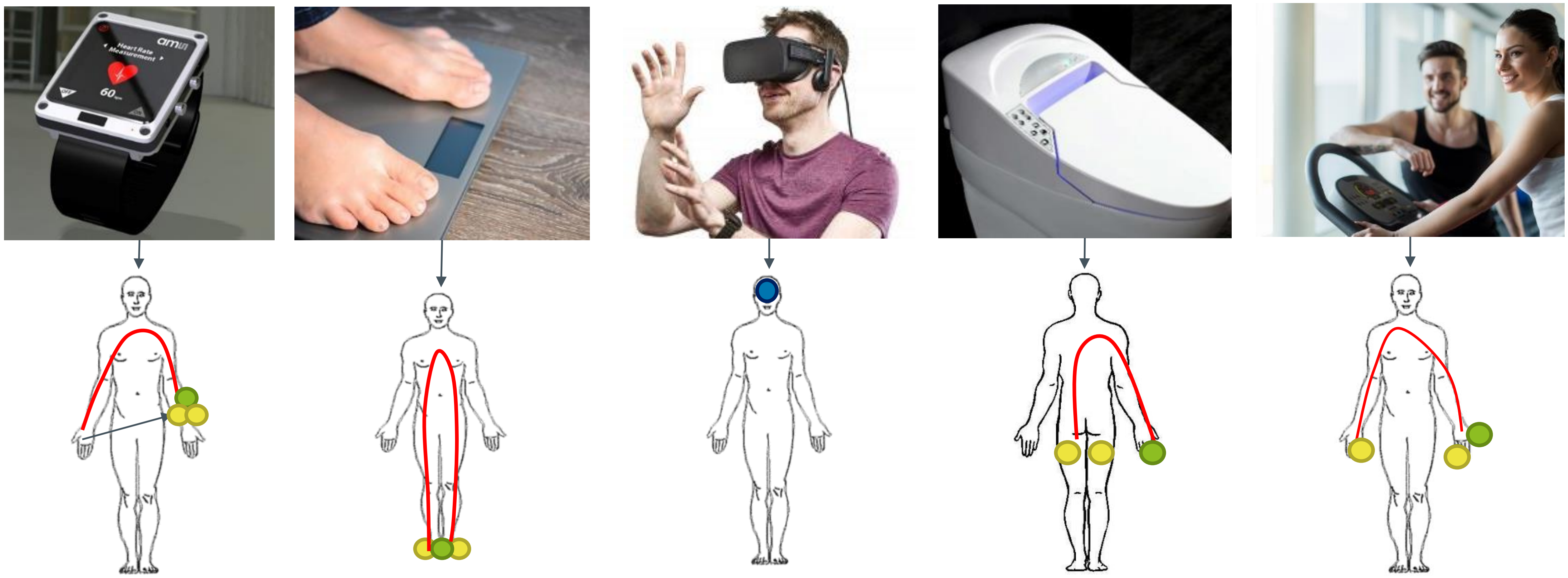


Fig. 16: Front view of the human body

Electrode Positions

For various use cases



Key: Electrode PPG Electrode + PPG

Fig. 17: Electrode positions for different use cases

SpO2 algorithm

For AS7050 reflective mode

Basic description of SpO2 algorithm

- The **ams** algorithm provide as an output, the ratio of R:
  - $R = \frac{AC_{red}/DC_{red}}{AC_{ir}/DC_{ir}}$
- SpO2 value is calculated based on:
  - SpO2 (%) = a*R2 + b*R + c
- An algorithm converting the PPG and ECG readings into a digital SpO2 value, supports the AS7050.

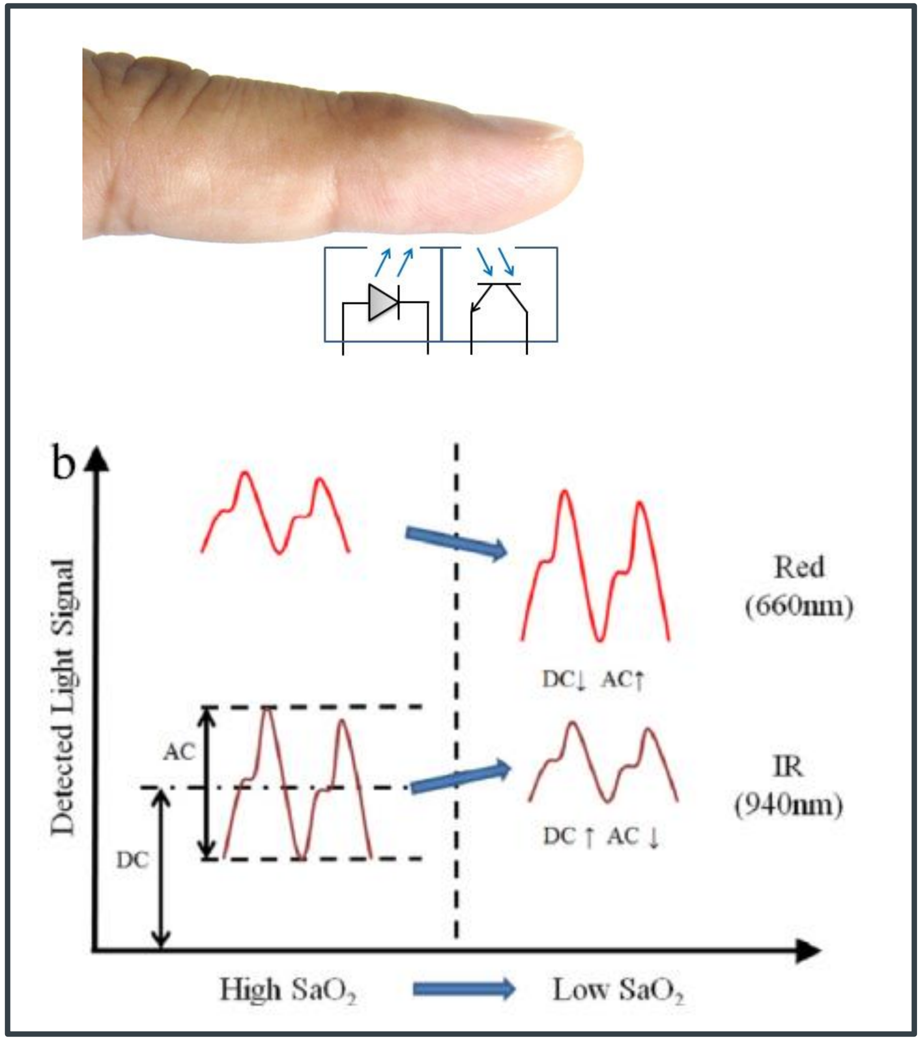


Fig. 18: Reflective mode

Proposal for Optical Design

Simple Design

- **ams** provides two Osram optical designs to evaluate all the functions on the AS7050 Biosensor and test various applications.
- Simple & Advanced designs to increase activities towards measuring HRM, SpO2, and PS.
- High-end arrangement for higher accuracy and medical grade.

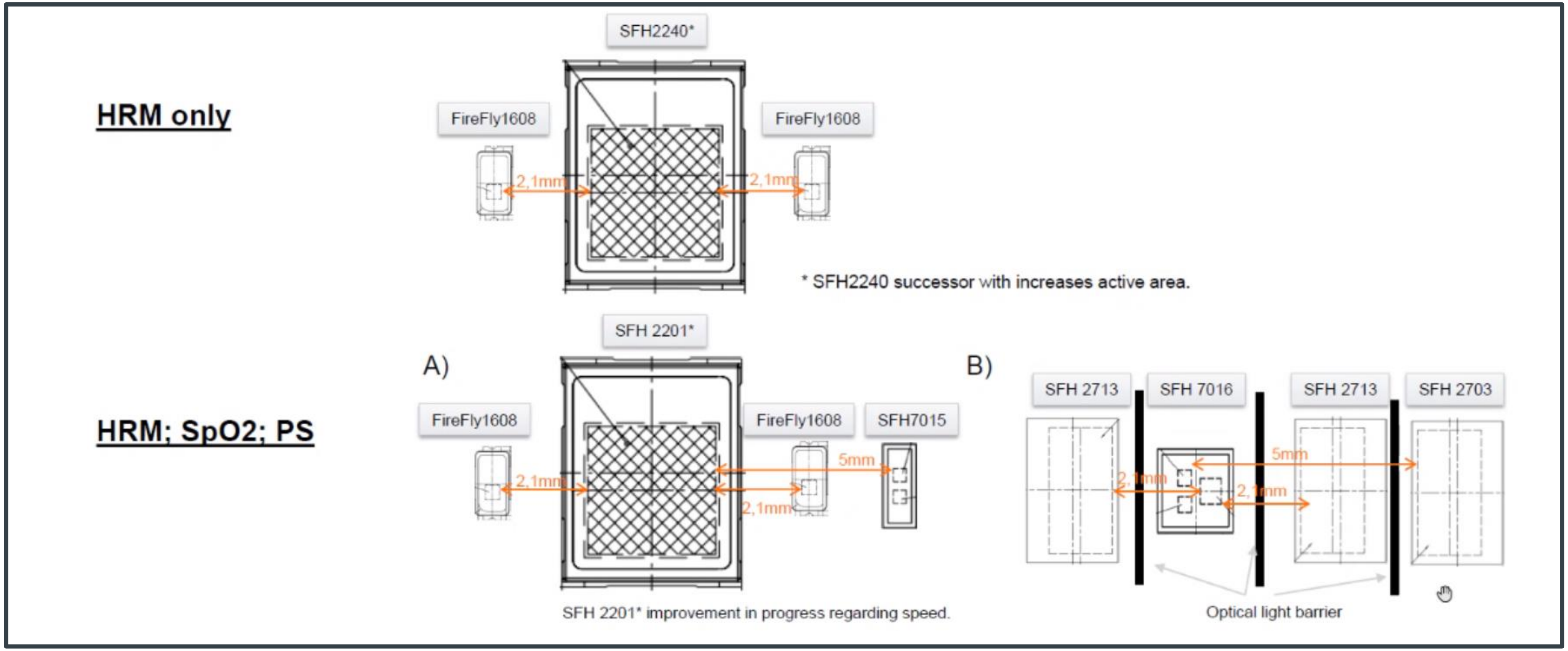


Fig. 19: Simple Design

Proposal for Optical Design

Advanced Design

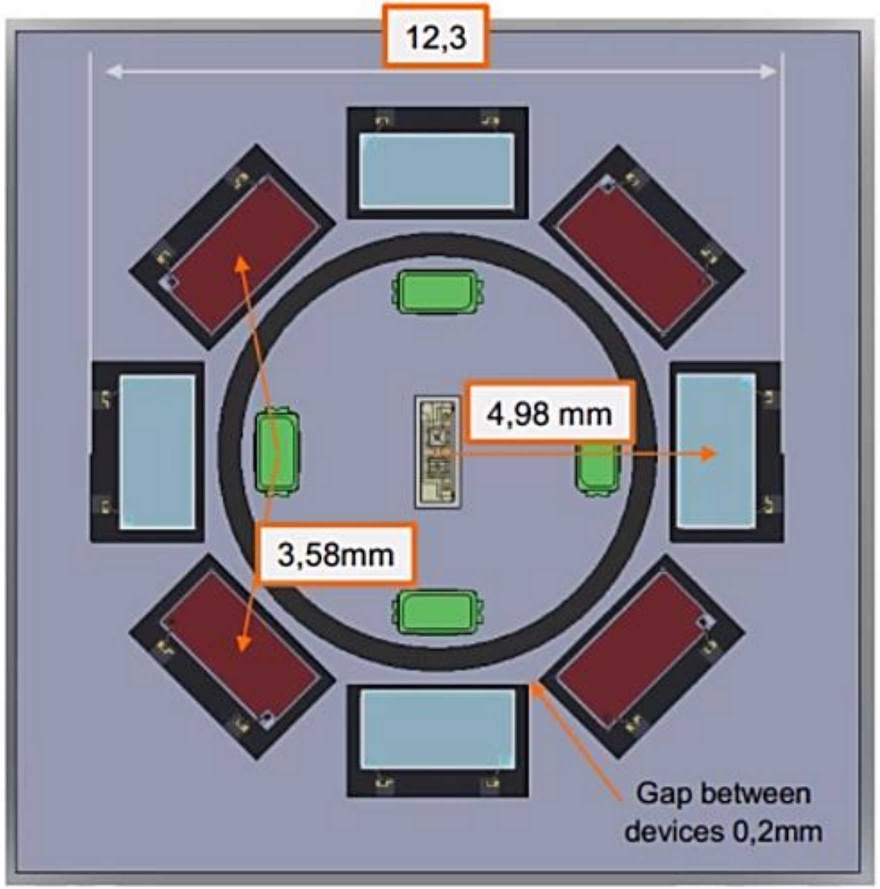


Fig. 20: Advanced design

<u>High End arrangement:</u>

- HRM: Center Firefly 1608 to SFH2713 center PD distance: 3,58mm
- SpO2/PS: Center SFH 7015 to SFH2703 center PD distance: 4,98mm
- Outer dimension for shown arrangement: 12,3mm

Optional: a) increase SFH 7015 to SFH2703 to further improve SpO2 measurement;

b) replace some Firefly 1608 with SFH7016 distance at ~ 6,3mm

- Gap between Photodiodes: 0,2mm → cross-check with assembler

Optical system components

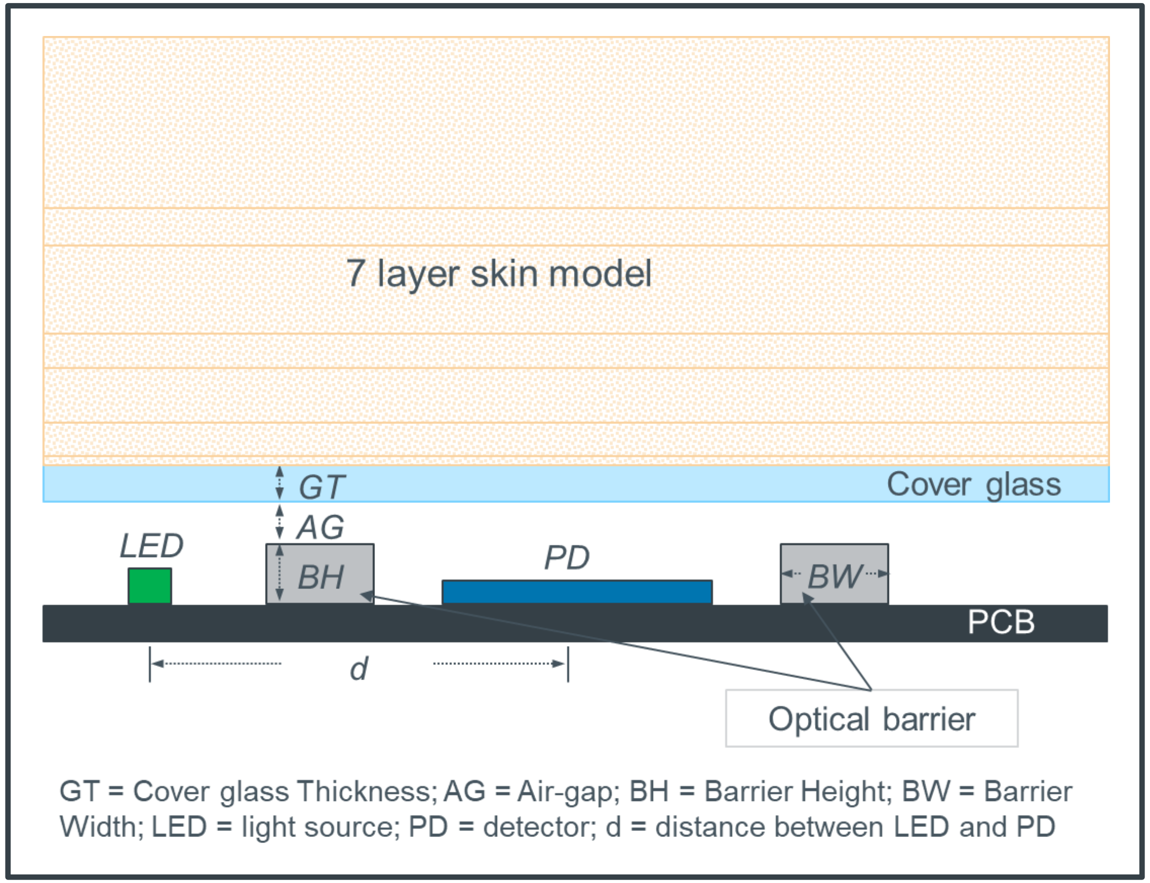


Fig. 21: Components of optical system

- The optical system consists of an AS7038 placed on a PCB, along with the LED and the 1 mm high optical barrier that surrounds the photodiode.
- A cover glass is placed in between the source and detector and the 7-layer skin model.
- The optical properties of each optical component are provided in the table in the next slide.
- Assuming a symmetrical system, only one LED was used as a light source.
- Optical simulations were carried out using Zemax ray tracing software.
- The signal is defined as the optical power detected on the surface of the PD when the skin is in contact with the cover glass.
- Crosstalk is defined as the detected optical power without the skin. This represents the light rays reaching the detector without hitting the skin's surface.
- A ratio of signal to crosstalk (SXR) is used for comparing the effect of parameters such as d, GT, AG, and BW for different LEDs.

Optical properties of the system components

*Table 1: Skin Parameters**

Skin Layer	Layer thickness (mm)	Refractive Index (generic)	skin reflectivity generic (diffused)	Absorption coefficient (1/mm)			Scattering coefficients	
				at 525 nm	at 660 nm	at 940 nm	generic	*g*
1 - Stratum corneum	0.02	1.5	0.07	0.4493	0.5488	0.7408	1.00	0.86
2 - Living epidermis	0.09	1.34	0.00	0.1353	0.4493	0.6065	1.00	0.8
3 - Papillary dermis	0.175	1.4	0.00	0.7788	0.8869	0.4966	1.00	0.9
4 - Upper blood net dermis	0.09	1.39	0.00	0.6376	0.8958	0.4966	1.00	0.95
5 - Reticular dermis	1.5	1.4	0.00	0.8607	0.8869	0.4966	1.00	0.8
6 - Deep blood net dermis	0.105	1.38	0.00	0.5488	0.9048	0.4966	1.00	0.95
7 - Subcutaneiuous fat	6.25	1.44	0.00	0.8607	0.9048	0.4966	1.00	0.75

* Reference for skin parameters: I.V. Meglinski and S.J. Matcher, Computer Methods and Programs in Biomedicine 70 (2):179-186, 2003.

Table 2: Optical properties of PCB and Barrier

System Component	Reflectivity		Absorption	Transmission	Remarks
	Diffused	Specular			
PCB	0.5 of 50%	0.5 of 50%	50%	0	PCB is considered to be 50% reflective.
Optical Barrier	0.5 of 20%	0.5 of 20%	80%	0	Barrier is considered to be 20% reflective.
Cover glass	As per Fresnel equations		0%		

LEDs used for the simulations

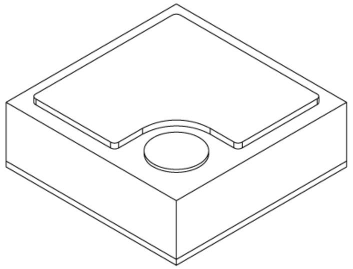
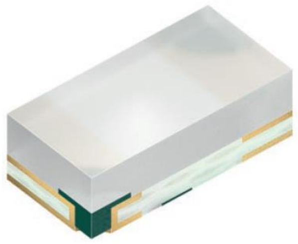
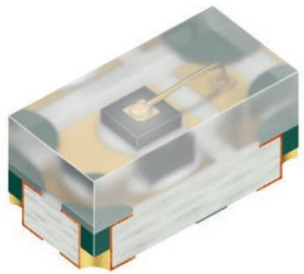
				
ODT1313UX3.A3 OS-CORE UX:3	CT DELSS1.12 FIREFLY E1608	LT QH9G CHIPLED 0402	CH DELSS1.12 FIREFLY E1608	SFH 4053 CHIPLED
- True green (λ_{dom} = 530 nm) LED chip - 13 mil x 13 mil - 0.335 mm x 0.335 mm x 0.12 mm - Used in AS7030	- True green (λ_{dom} = 530 nm) LED module in white SMT package and colorless clear resin - 0.8 mm x 1.6 mm x 0.6 mm - Used in AS7038G EVKs	- True green (λ_{dom} = 530 nm) LED module in SMT package, colorless diffused resin - 0.6 mm x 1.1 mm x 0.4 mm	- Hyper red ($\lambda_{centroid}$ = 657 nm) LED module in white SMT package and colorless clear resin - 0.8 mm x 1.6 mm x 0.6 mm - Used in AS7038R EVKs	- Infrared ($\lambda_{centroid}$ = 850 nm) LED module in SMT package and clear resin - 1.0 mm x 0.5 mm x 0.45 mm - Used in AS7038R EVKs

Fig. 22: LEDs used for the simulations

- Each LED is assumed to emit 1 W optical power.
- Ray-files corresponding to each LED was available and used for simulating the source characteristics.

PD-LED distance dependence of SXR

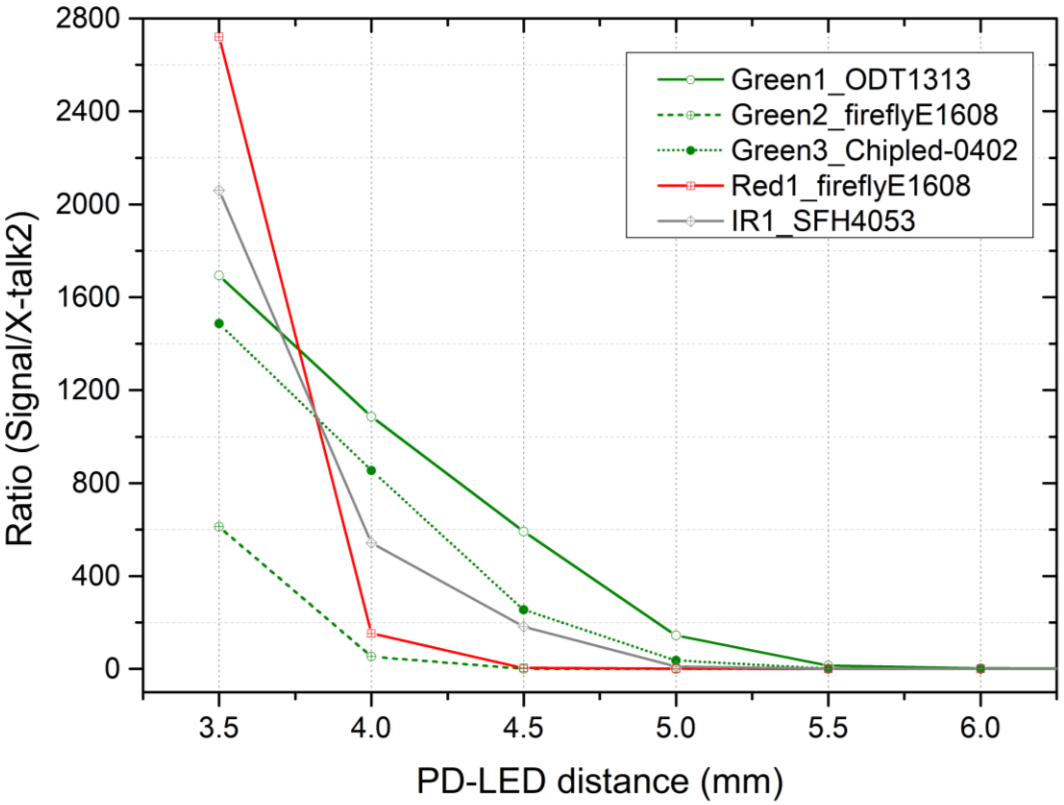


Fig. 23: Graph of SXR against PD-LED distance

- In this graph, SXR values are presented for various LEDs as a function of PD-LED distance.
- System: AG = 0.1 mm; CT = 0.3 mm; BW = 1 mm
- The minimum simulated distance is 3.5 mm.
- It is clear that the SXR values decrease rapidly with increasing PD-LED distance.

Effect of air gap on SXR

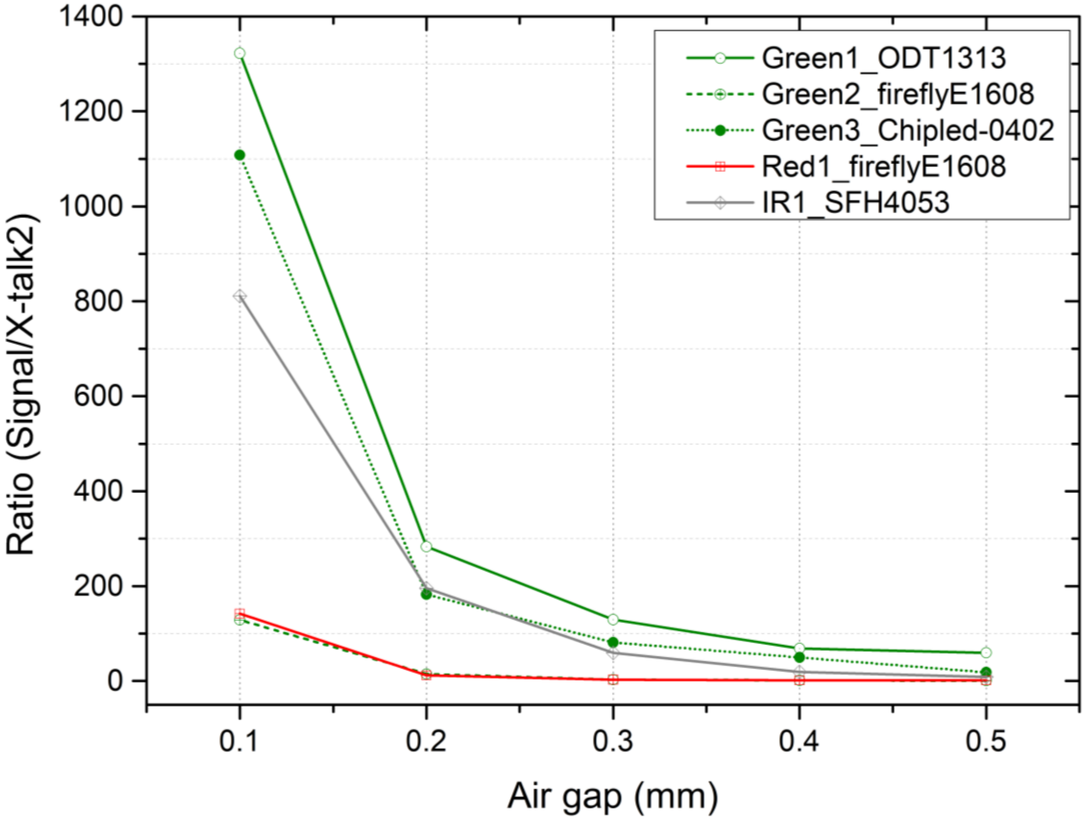


Fig. 24: Graph of SXR against Air gap

- In this graph, SXR values are presented for various LEDs as a function of air gap.
- System: d = 0.4 mm; CT = 0.3 mm; BW = 1 mm
- The minimum simulated air gap (AG = 0 mm) results in an X-talk value of 0. Hence, the SXR values for AG starting at 0.1 mm is presented.
- It is clear that the SXR values decrease rapidly with increasing AG value.

Effect of barrier width on SXR

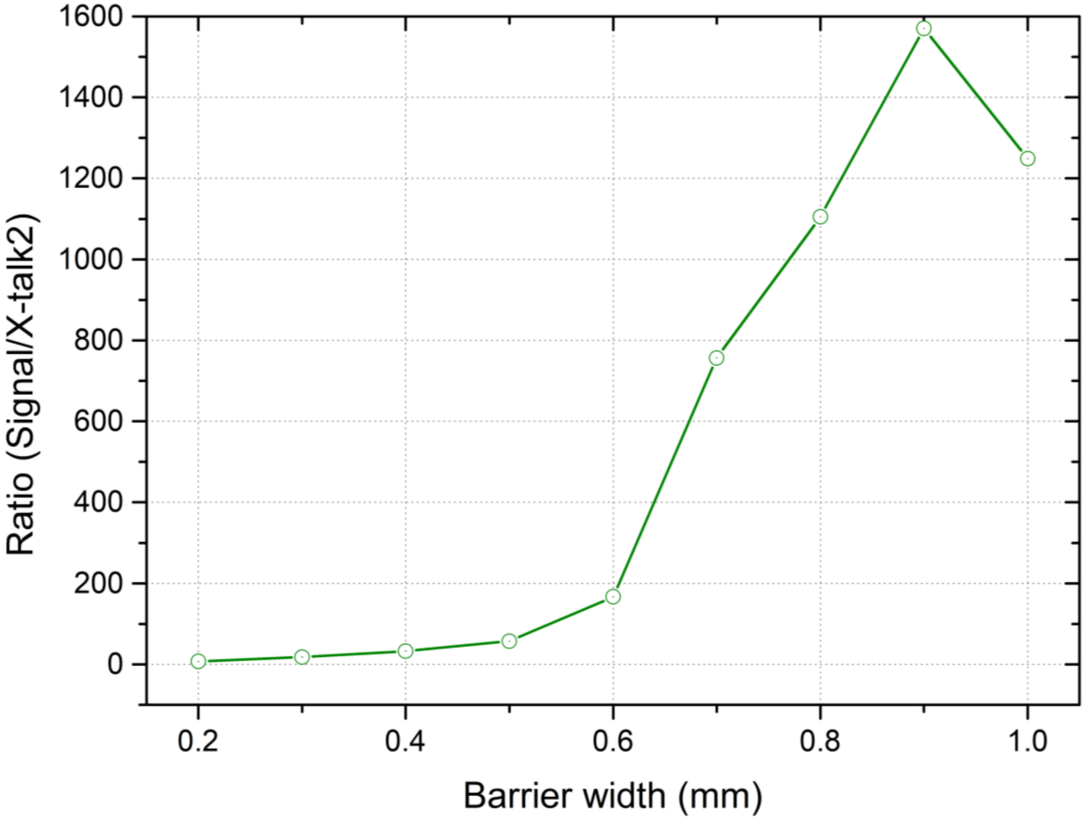


Fig. 26: Barrier width dependence of SXR

- In this graph, SXR values are presented for the green LED chip as a function of optical barrier width.
- System: d = 0.4 mm; AG = 0.1 mm; CT = 0.3 mm
- The minimum simulated BW is 0.2 mm.
- The SXR values increase with increasing optical barrier width until BW = 0.9 mm. A further increase in BW results in a decrease in the SXR value.

Effect of barrier type on optical power

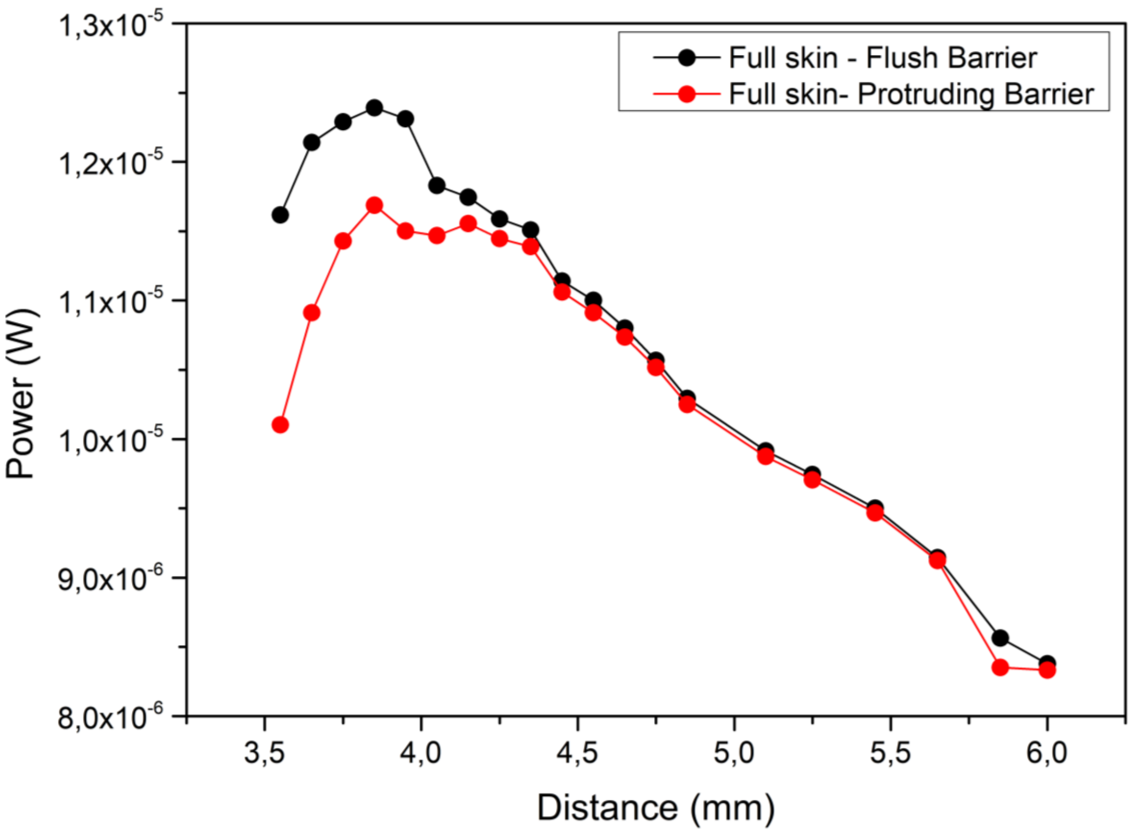


Fig. 27: Graph of Power against Distance

Optical power received on the photodiode at various LED-PD separation for the two types of optical barriers. LED: green (CT DELSS1.12), cover glass thickness: 0.3 mm, Air gap: 0 mm.

- Two sets of simulations were done to understand the effect of the optical barrier type on the optical power received on the detector.
- Barrier types:
  - Flushed barrier – This barrier type ends just below the cover glass.
  - Protruding barrier – This barrier type separates the cover glass into multiple segments.
- Thus, by design, the protruding barrier is taller than the flushed barrier.
- It is seen from the simulation results that for smaller PD-LED separation, the optical power received on the photodiode is higher with flushed type barrier. For distances larger than 4 mm, the difference in power reduces gradually.
- The crosstalk on the other hand is expected to be higher with the flushed barrier type.

Effect of barrier type on optical power

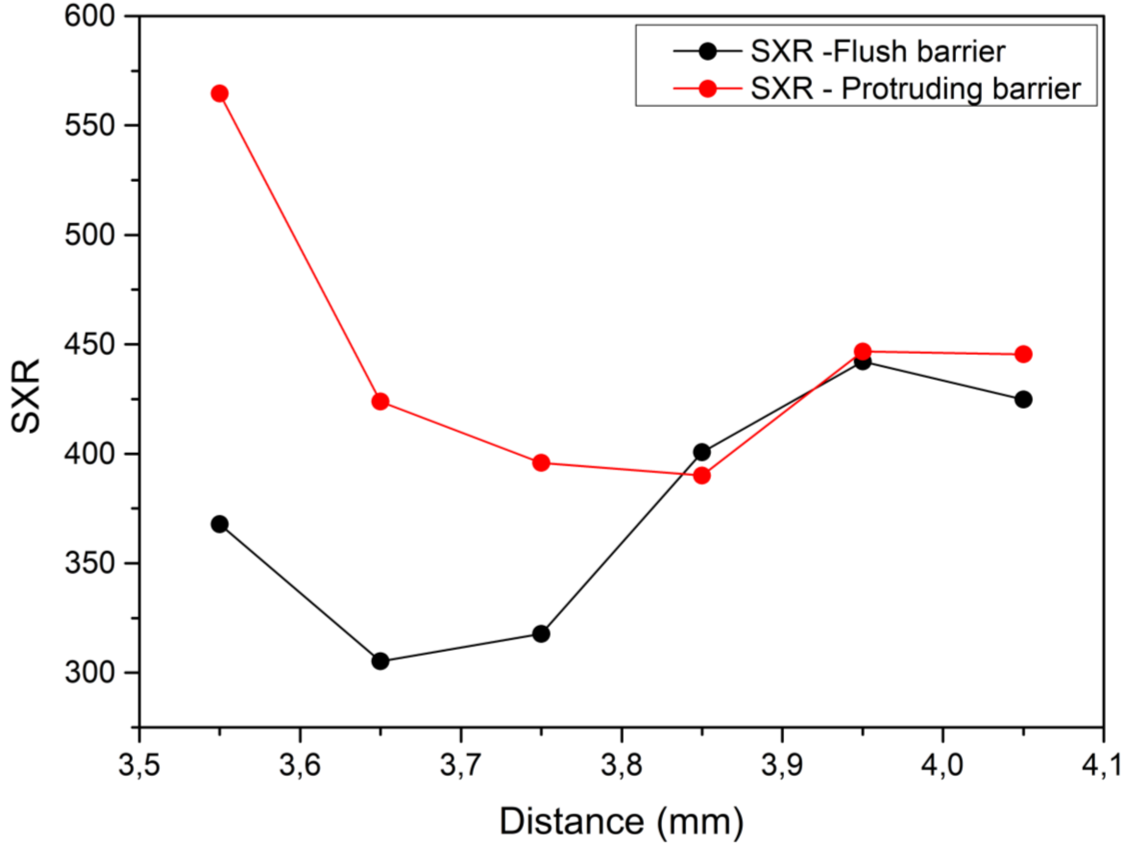


Fig. 28: Graph of SXR against Distance

The plot of SXR values for flushed and protruding barrier shows that at smaller LED-PD separation distances, the protruding barrier would result in better SXR values.

Ray tracing

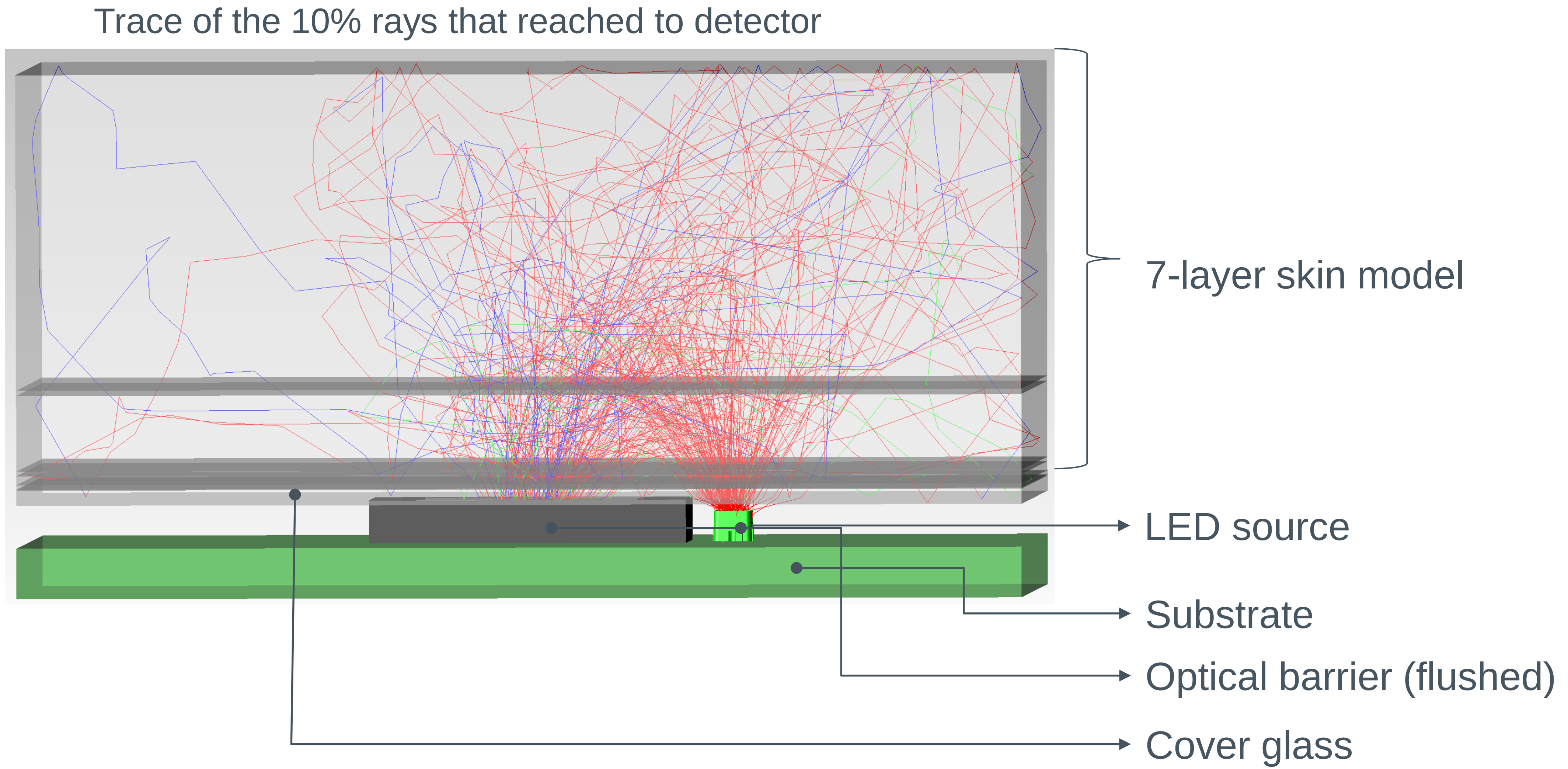


Fig. 29: Ray tracing

Sensing is life.

Thank you!

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