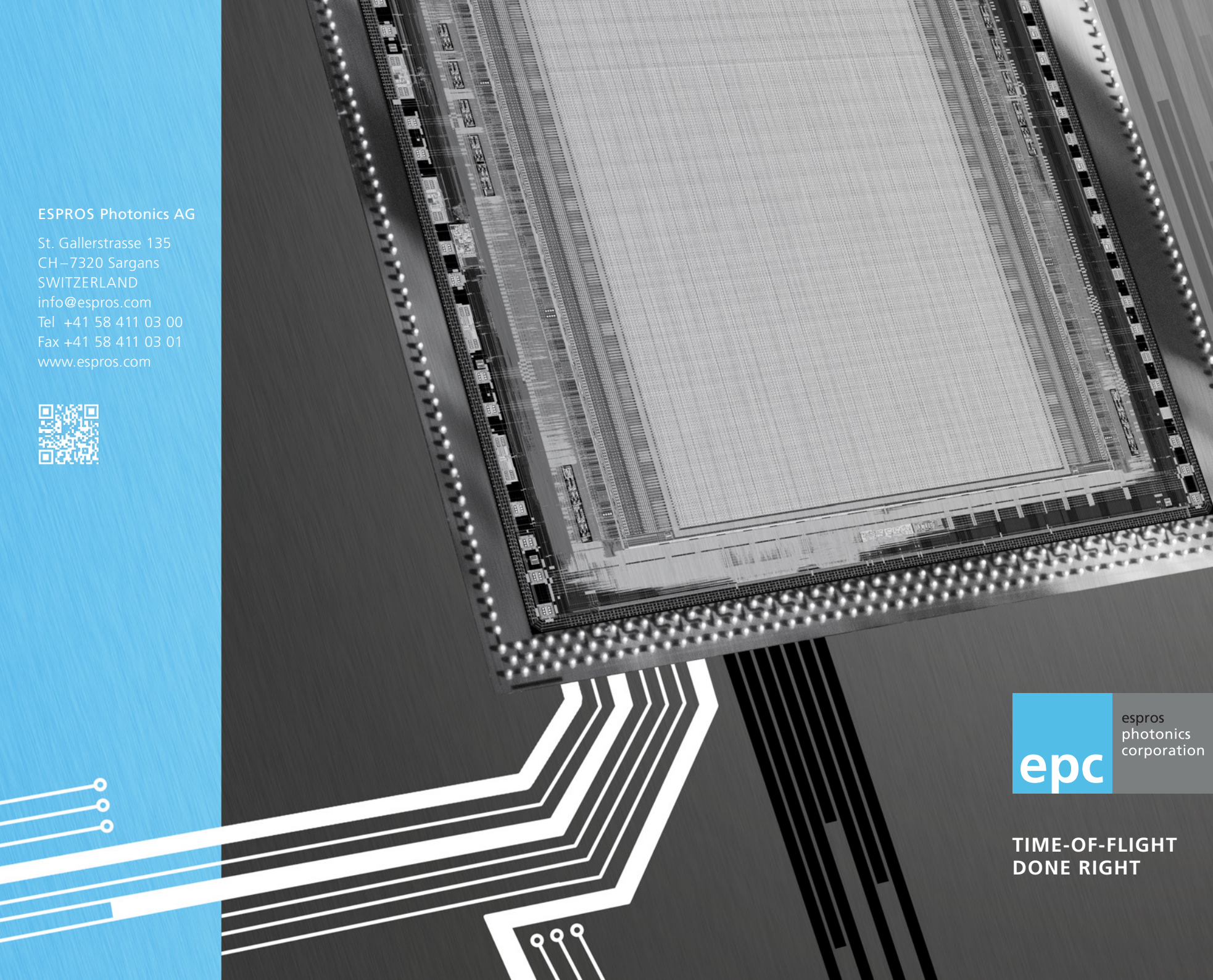


ESPROS Photonics AG

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TIME-OF-FLIGHT  
DONE RIGHT



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# about espros

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ESPROS Photonics AG is a privately owned company founded in 2006 by Beat De Coi. Today, ESPROS Photonics is a highly specialized IC (Integrated Circuit) design and production company.

We serve our customers with the only non-captive high performance CMOS process, with optical frontend, worldwide. Swiss quality and reliance combined with outstanding people and private investors guarantee long term availability of the process and compliance with the specifications.

Our own real estate property is located in Sargans, Switzerland. On 7000sqm floor space, we operate our production and office facilities, including a 600sqm cleanroom class ISO3 (1000), a 1000sqm class ISO1 (10) and a full featured quality lab.

Our technology, and also our facilities are unique. Our wafer fab is built deep inside a Swiss mountain. Perfect mechanical isolation from the outside world guarantees a vibration free cocoon for the highest quality standards in IC manufacturing. A constant climate and total radiation shielding allow us to control operation of the fab inside in a most efficient and cost effective way.

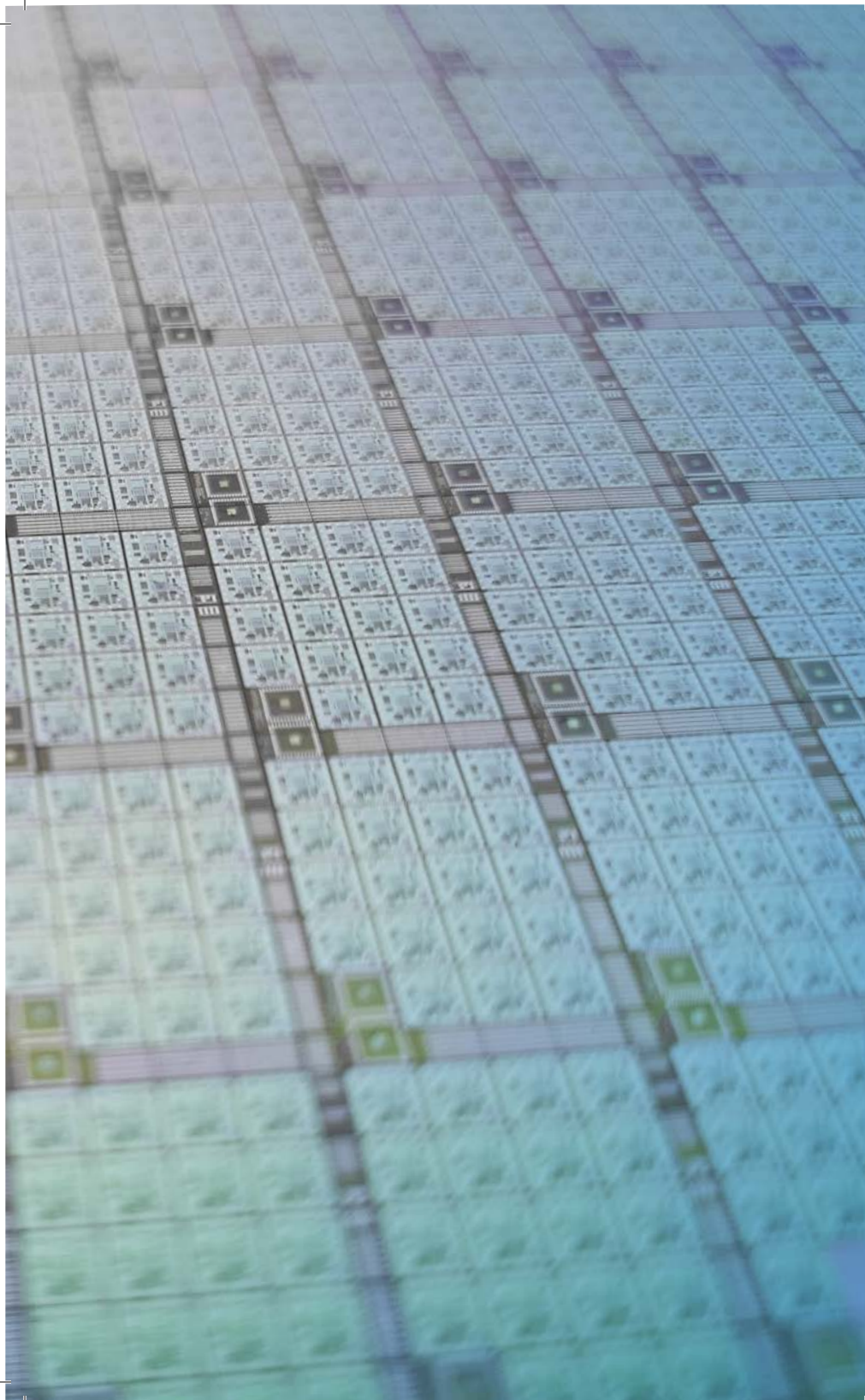
We strive to be your reliable partner when it comes to your optoelectronic IC needs. Swiss precision quality and innovation are core driving forces of our company, and all our employees.





espros  
photonics  
corporation

**epc**



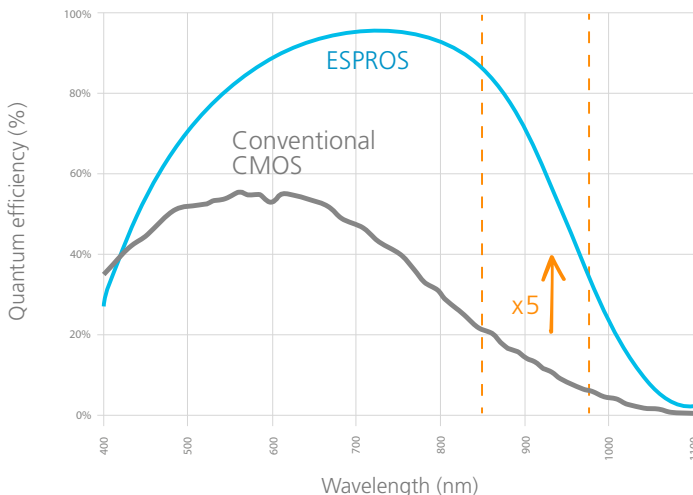
# about our technology

Image detector manufacturing was limited by various boundary conditions. CCD technology provides very good sensitivity over a wide wavelength range, has an excellent charge handling capability, but high-density CMOS mixed signal processing is rarely available. PIN photodiodes are well established due to their superior absorption characteristic and capability of high-speed response, especially for detection in the near infrared (NIR), but they are discrete devices. Photo diodes integrated in CMOS however have a very poor NIR sensitivity due to its thin absorption layer.

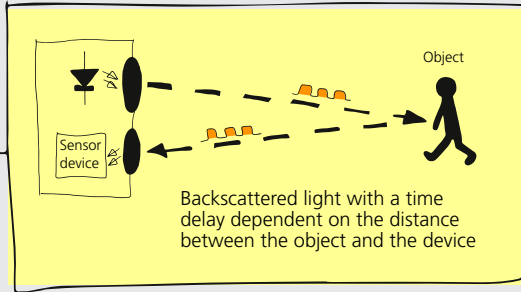
Today the majority of imagers are built using slightly modified CMOS processes resulting in mediocre

optical performance, e.g. low quantum efficiency (QE). Our technology breaks with these limitations in optical performance in the NIR range. This makes it highly suitable for a broad range of optical sensor systems.

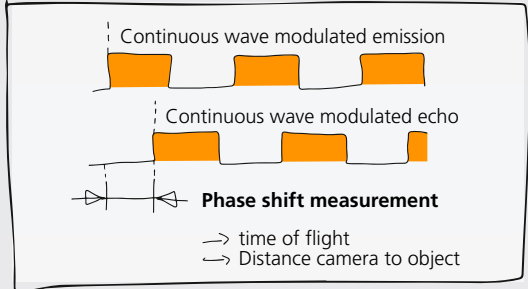
The key to ESPROS' outstanding optical detector performance is our own dedicated CMOS process OHC15L. It is based on an industry standard, 150 nm CMOS process, well established and reliable. This process is tailored to incorporate the necessary new devices for optical detectors, while keeping the impact on the available devices as low as possible. Available IP of the baseline process can be easily reused in the ESPROS Photonic CMOS™ environment.



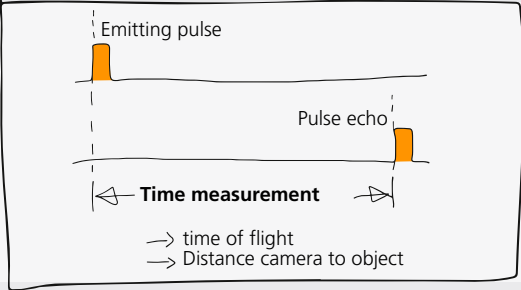
## Time-of-flight (TOF)



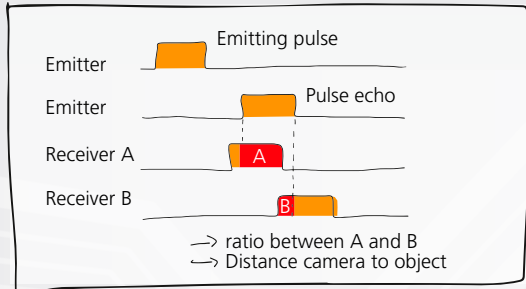
### cwTOF Continuous wave modulated



### pTOF Pulse modulated



### Gated Imaging TOF Pulse modulated




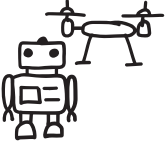
## why TOF

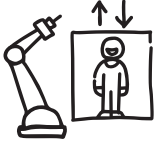

A time-of-flight camera (TOF camera) is a range imaging camera system measuring the time-of-flight of a light signal between the camera and the subject for each point of the image. Compared to 3D laser scanning methods for capturing

3D images, TOF cameras operate very quickly, providing up to 250 images per second or more. In addition, they offer much higher spatial resolution than radar, ultrasonic sensors or stereo cams.

Parameter	Requirement	Radar	Ultra-sonic	Stereo cam	scan-ning LiDAR	cwTOF	pTOF (Imaging LiDAR)
Long Range	$\geq 100$ m	✓			✓	✓	✓
Short Range	0 ... 2 m		✓	✓	✓	✓	✓
Spatial resolution	$\leq 0.1^\circ$			✓		✓	✓
FOV horizontal	360°		✓	✓	✓	✓	✓
FOV vertical	$\geq 25^\circ$		✓	✓	✓	✓	✓
Distance resolution	cm		✓		✓	✓	✓
Weather condition	all weather	✓	✓		✓		✓
Daytime	day & night	✓	✓	✓		✓	✓
Surface independent	all surfaces (incl. non-structured)	✓	✓		✓	✓	✓
Response time	> 50 fps	✓	✓	✓		✓	✓
Safety	eye safe, ASIL	✓	✓	✓	✓	✓	✓
Multiple sensors	no interference	✓	✓		✓	✓	✓
Cost	low	✓	✓	✓		✓	✓

# key markets

Market	 Automotive	 Mobile Robotics
<b>Product and Technology Capabilities</b>	<ul style="list-style-type: none"> <li>• Long range LiDAR: pTOF &gt; 250 m</li> <li>• High resolution: better than 0.1°</li> <li>• High frame rate: more than hundreds of frames per second</li> <li>• High sensitivity at full sunlight and night</li> <li>• QE &gt; 70% at 905 nm</li> </ul>	<ul style="list-style-type: none"> <li>• cwTOF</li> <li>• pTOF/LiDAR</li> <li>• Low power</li> <li>• Flash and scanning</li> <li>• SLAM</li> </ul>
<b>Applications</b>	<ul style="list-style-type: none"> <li>• Long range LiDAR ADAS solutions at full sunlight</li> <li>• Mid range/high resolution or object classification</li> <li>• Night vision</li> <li>• In-cabin monitoring</li> <li>• Gesture control</li> <li>• Face ID</li> <li>• 360° surround view</li> <li>• Driver/passenger behavior monitoring</li> </ul>	<ul style="list-style-type: none"> <li>• Obstacle collision avoidance</li> <li>• Step sensing</li> <li>• Face ID</li> <li>• Landing and constant height hover control</li> <li>• Auto-focus for built in camera</li> <li>• Hospitality and retail robots</li> <li>• Household robots</li> <li>• Consumer and security drones</li> <li>• Delivery robots and drones</li> </ul>

 <p><b>Industrial and Building Automation</b></p>	 <p><b>Consumer Electronics</b></p>
<ul style="list-style-type: none"> <li>• cwTOF</li> <li>• CCD technology</li> <li>• Imaging with up to 20Mfps</li> <li>• Very high near infrared sensitivity</li> <li>• High sensitive photodiode amplifiers</li> <li>• Low cost photodiode arrays</li> </ul>	<ul style="list-style-type: none"> <li>• cwTOF with 100 % fill factor</li> <li>• Low power</li> <li>• High sensitivity</li> <li>• Low cost spectral sensing</li> </ul>
<ul style="list-style-type: none"> <li>• Rotary and linear encoder</li> <li>• Triangulation</li> <li>• Surface scan</li> <li>• Hyperspectral imaging</li> <li>• TDI imaging</li> <li>• High accuracy spectral sensing</li> <li>• Automatic door sensors</li> <li>• Elevator door sensors</li> <li>• ATM face Id.</li> <li>• People counting</li> </ul>	<ul style="list-style-type: none"> <li>• Miniature spectral sensor</li> <li>• Smart watch sensing</li> <li>• VR/AR TOF solutions</li> <li>• Gesture control TOF</li> <li>• 3D room scan</li> </ul>

# products

[www.espros.com/products](http://www.espros.com/products)



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epc901	31
epc200/epc3xx	35

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epc70x	41

**asic and foundry 43**

Our standard portfolio consists of a full range of cwTOF imagers from 8x8 to 320x240 pixel resolution. They all use the same architecture, the same pixel design and the same optical key parameters, e.g. high QE. Thus, once a design is implemented, it can be ported quite smoothly to applications which need a different resolution. Additional products are photodiodes and amplifiers.

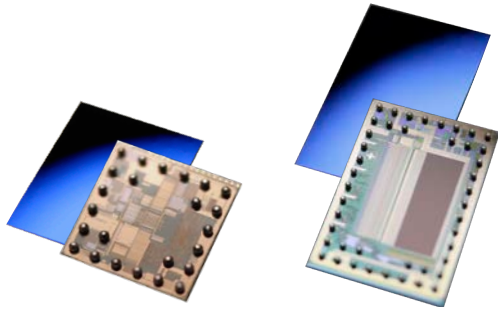
ESPROS' capabilities are to design and manufacture application specific imager chips (ASIC). A range of products have already been implemented and are in mass production. We are happy to discuss your specific requirements to find the best possible solution for your application.

**modules 47**

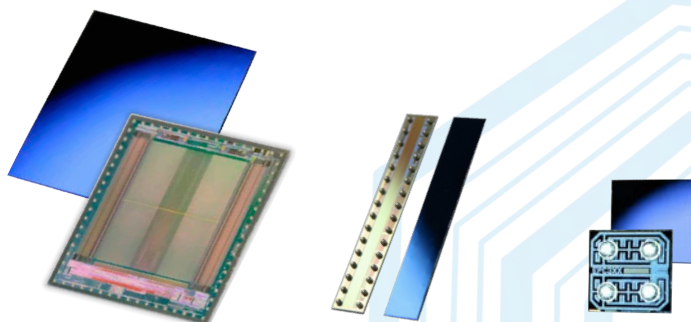
TOF>frame 611	49
TOF>range 611	51
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TOFcam 660	55

ESPROS' modules are designed to meet the requirements of system integrators. They are typically used in mobile robotics, industrial and building automation systems as well as sensors in infrastructure; for example in public transport systems. They come with a high level data interface and with the required ROS drivers. The modules are also used as reference designs for our TOF imagers. We share these designs with our chip customers to reduce their time-to-market.

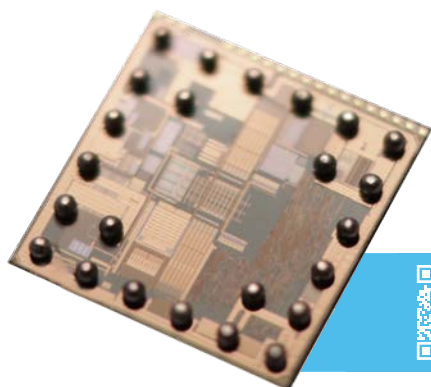
# standard chips



Product	epc611	epc635
Operating principle	cwTOF	cwTOF
Pixel field	8×8 pixel	160×60 pixel
Pixel pitch	20×20 μm	20×20 μm
Photosensitive area	0.16×0.16 mm	3.2×1.2 mm
Packaging	CSP24	CSP44
Size	2.7×2.8×0.25 mm	6.3×4.2×0.25 mm
Frame rate	up to 8000 fps	up to 512 fps
Output data	up to 18 bit DCS	12 bit DCS
Data interface	SPI up to 16 MHz	TCMI up to 80 MHz
Control interface	SPI	I2C
Power consumption	155 mW	300 mW



epc660	epc901	epc200 epc3xx
cwTOF	Line imager	Photodiode Photodiode arrays
320 × 240 pixel	1024 × 1 pixel 4 frames store buffers	1 × 1 pixel up to several hundred
20 × 20 μm	7.5 μm	0.5 × 1.0 mm
6.4 × 4.8 mm	7.68 × 0.120 mm	1.65 × 1.65 mm multiples of 0.4 × 0.9 mm
CSP68	CSP32	CSP5 multiples of CSP4
9.7 × 8.7 × 0.25 mm	8.0 × 1.3 × 0.23 mm	1.75 × 1.75 mm multiples of 0.5 × 1 mm
up to 158 fps	500 kfps burst 50 kfps continuous	n/a
12 bit DCS	Analog voltage	Analog photo-current
TCMI up to 80 MHz	Analog video, singlended or differential	n/a
I2C	I2C or hardware	n/a
750 mW	36 mW	Reverse voltage up to 20V



original size

STANDARD CHIPS



epc611

 **Size**  
2.7 × 2.8 × 0.25 mm

 **Pixel Pitch**  
20 × 20 μm

 **Pixel Field**  
8 × 8 pixel

 **Photosensitive area**  
0.16 × 0.16 mm

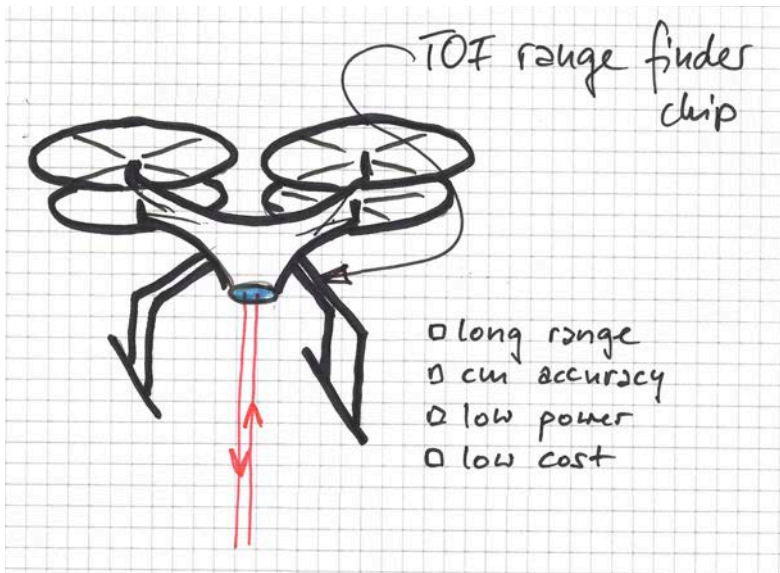
<b>Operating principle</b>	cwTOF
<b>Packaging</b>	CSP24
<b>Frame Rate</b>	up to 8000 fps
<b>Output</b>	up to 18 bit DCS
<b>Data interface</b>	SPI up to 16MHz
<b>Control interface</b>	SPI
<b>Power consumption</b>	155 mW

## Features

The epc611 chip is a general purpose, monolithic, fully integrated photoelectric CMOS device for optical distance measurements and object detection. Its working principle is based on 3D TOF measurement.

The system-on-chip (SOC) contains:

- An on-chip controller managing data acquisition and data communication
- An SPI interface for the command and data communication
- A full data acquisition path including the modulation driver for LEDs or laser diodes, the photoreceiver with an  $8 \times 8$  pixel TOF CCD array, the signal conditioning, the A/D converter and the basic signal processing.
- A supply voltage power management unit

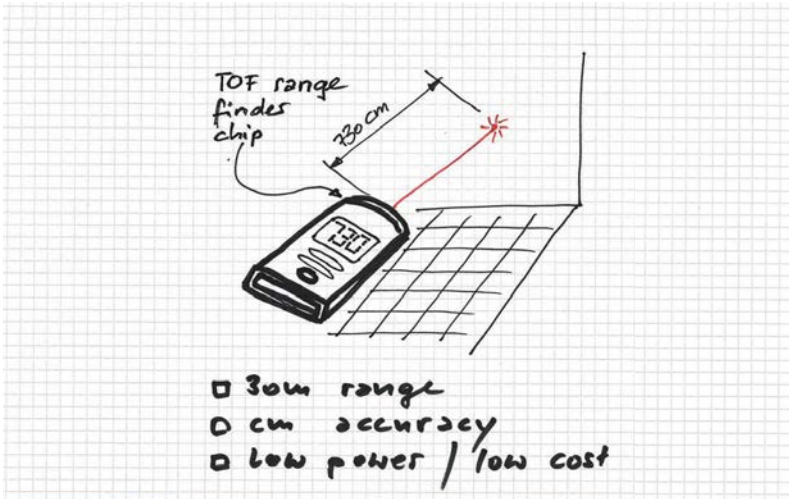


**Application example** Drone altimeter

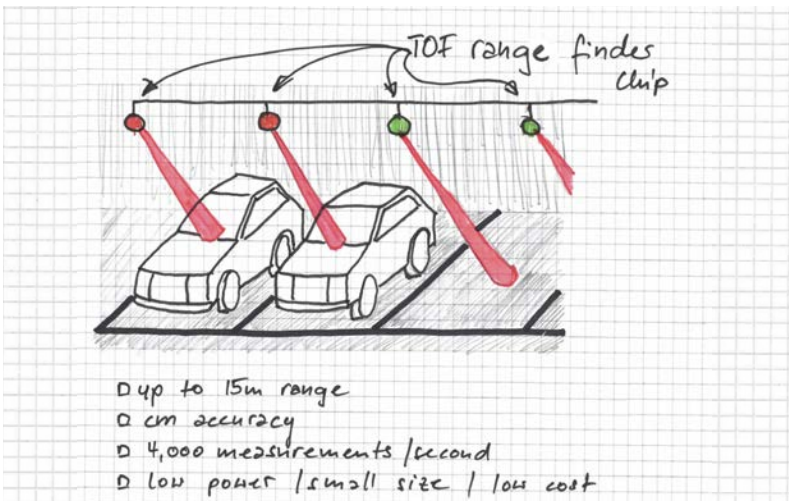
## STANDARD CHIPS



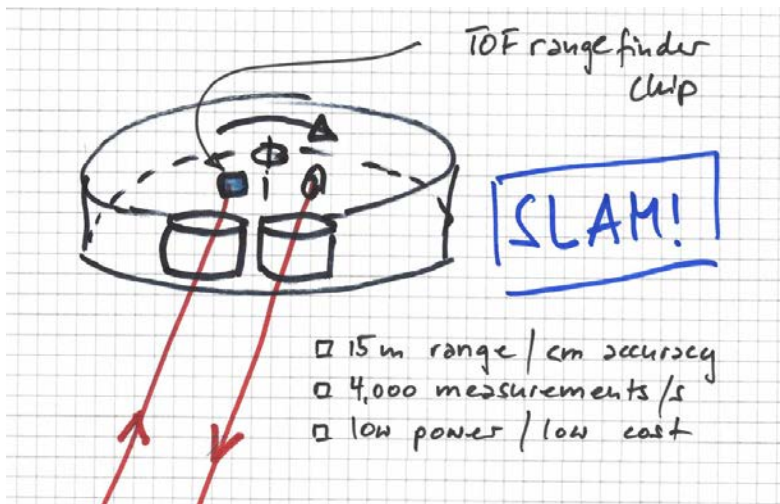
epc611



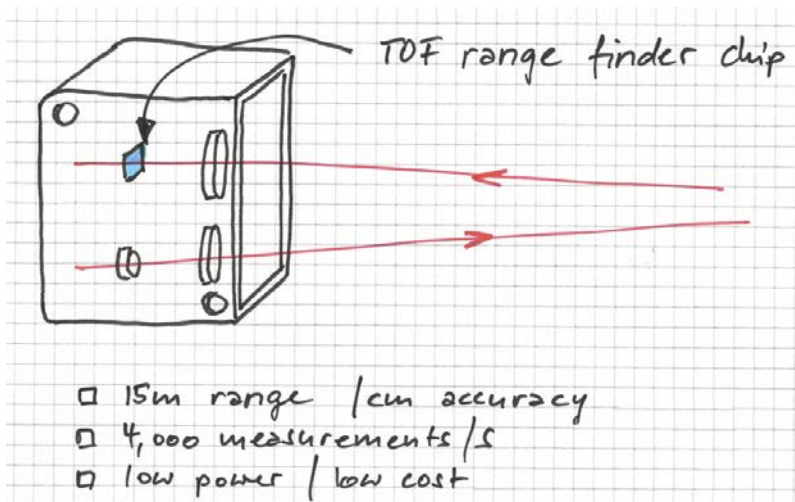
Application example Disto range finder



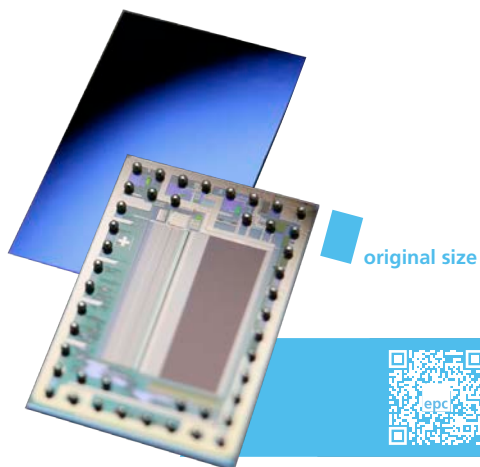
Application example Parking sensor



Application example SLAM scanner



Application example Industrial range finder



STANDARD CHIPS



epc635

 **Size**  
6.3 × 4.2 × 0.25 mm

 **Pixel Pitch**  
20 × 20 μm

 **Pixel Field**  
160 × 60 pixel

 **Photosensitive area**  
3.20 × 1.20 mm

<b>Operating principle</b>	cwTOF
<b>Packaging</b>	CSP44
<b>Frame Rate</b>	up to 512 fps
<b>Output</b>	12 bit DCS
<b>Data interface</b>	TCMI up to 80 MHz
<b>Control interface</b>	I2C
<b>Power consumption</b>	300 mW

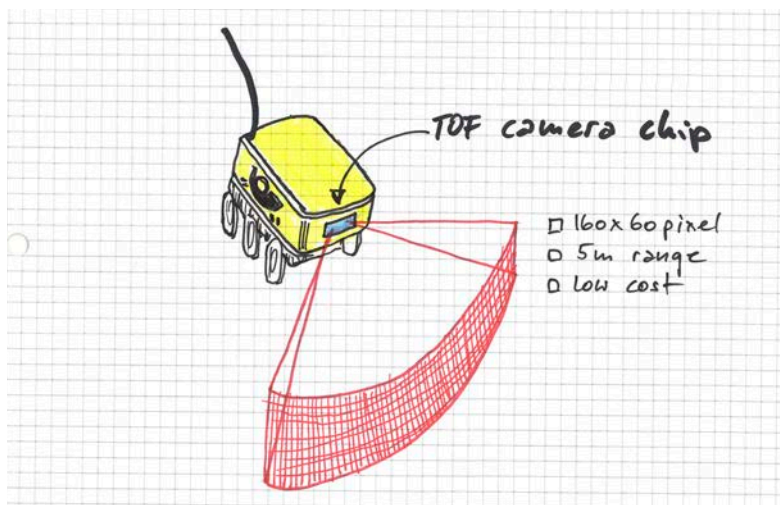
### Features

The epc635 is a fully integrated 3D-TOF imager with a resolution of  $160 \times 60$  pixels (Half-QQVGA). As a system on chip, the epc635 contains next to the CCD pixel-field the complete control logic to operate the device. The output of the chip is 12 bit DCS data per pixel for distance calculation, which are accessible through a high-speed digital 8-bit parallel video interface. Only few additional components are needed to generate a complete 3D camera.

Depending on illumination power and optical design, a resolution in the millimeter range for distances up to dozens of meters is feasible.

Up to 512 full frame TOF images are delivered in rolling mode. The extremely high sensitivity of the chip allows for a reduced illumination power and reduced overall power consumption compared to other TOF imagers.

epc635 is based on the same technology and instruction set as the existing epc660 QQVGA TOF imager from ESPROS. An evaluation kit for the epc635 is available with hard- and software examples and a comprehensive manual to speed up system integration.

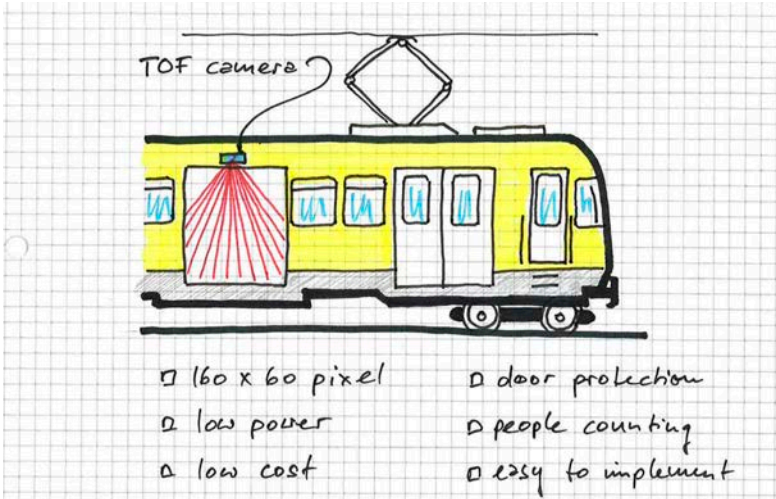


**Application example** Mobile robot AGV

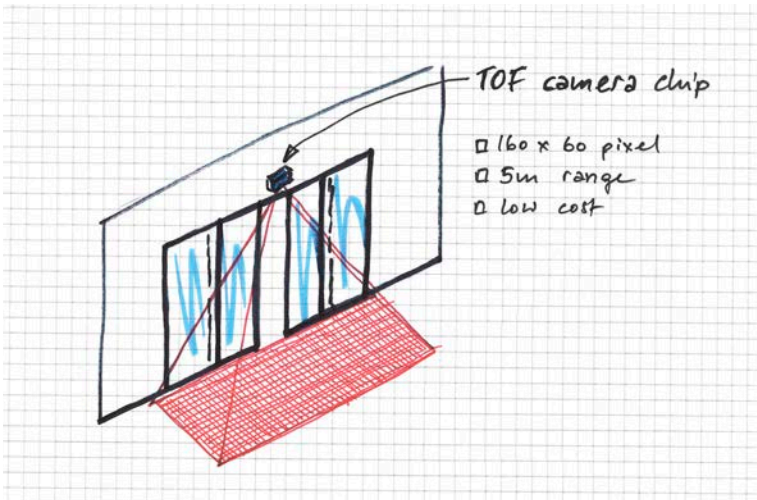
## STANDARD CHIPS



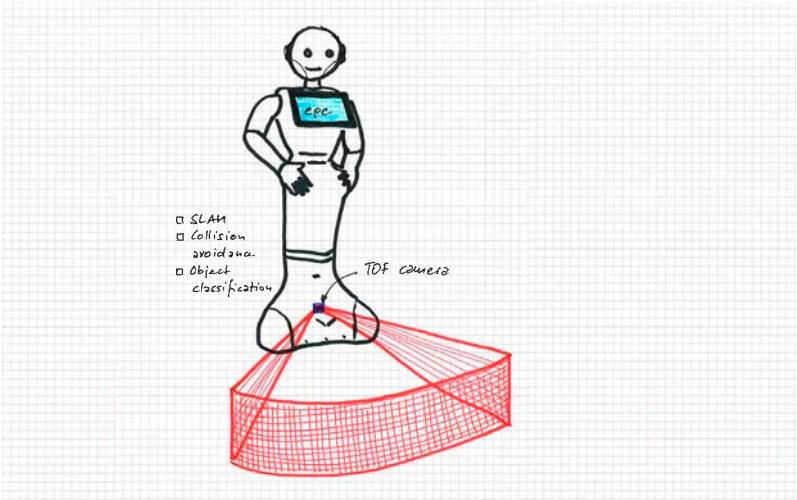
epc635



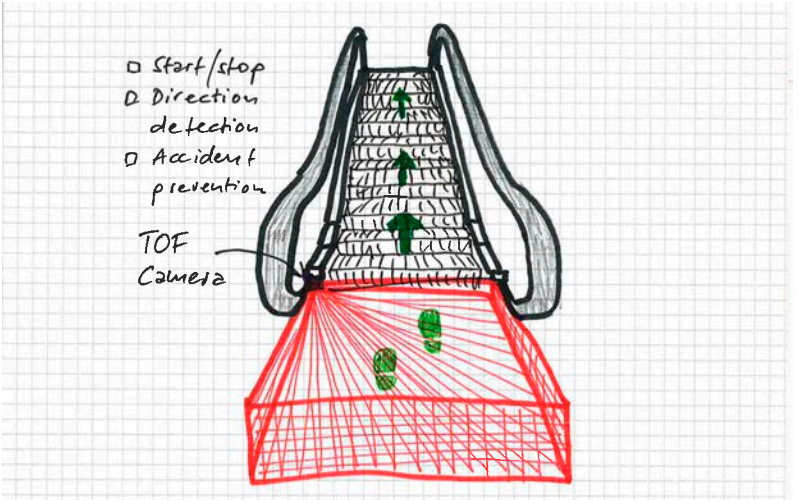
**Application example** Door protection/people counting



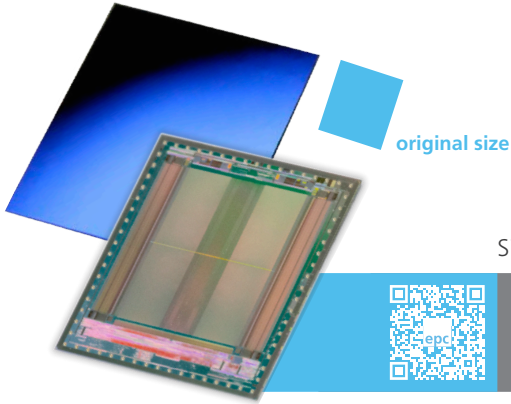
**Application example** Door opening & protection



Application example Humanoid robot




Application example Escalator start/stop sensing




## STANDARD CHIPS

epc660

 **Size**  
9.7 × 8.7 × 0.25 mm

 **Pixel Pitch**  
20 × 20 μm

 **Pixel Field**  
320 × 240 pixel

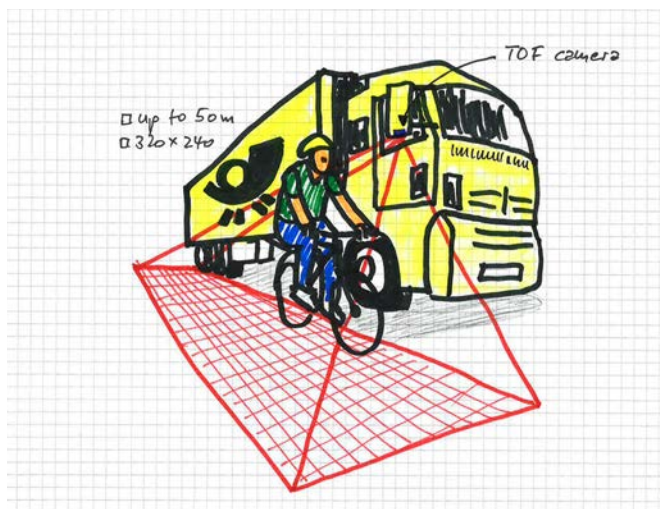
 **Photosensitive area**  
6.40 × 4.80 mm

<b>Operating principle</b>	cwTOF
<b>Packaging</b>	CSP68
<b>Frame Rate</b>	up to 158 fps
<b>Output</b>	12 bit DCS
<b>Data interface</b>	TCMI up to 80 MHz
<b>Control interface</b>	I2C
<b>Power consumption</b>	750 mW

**Features**

The epc660 is a fully integrated 3D-TOF imager with a resolution of  $320 \times 240$  pixels (QVGA). It is a highly integrated system-on-chip camera system. Apart from the actual CCD pixel-field, it includes the complete control logic to operate the device. Data communication is done through a high-speed digital 12-bit parallel video interface. Even for mobile devices, only a few additional components are needed to integrate 3D camera capability. Depending on the system design, a resolution in the millimeter range for measurements up to 100 meters is feasible. 39 full frame TOF images are delivered in

maximal configuration. By using the advanced operation modes, this can be boosted up to more than 1000 TOF images per second! The high degree of integration lays base for straight-forward camera system design with minimal part count. The extremely high sensitivity of the optical front end allows for a reduced illumination subsystem and reduces the power consumption of the overall system significantly. An evaluation kit with hard- and software examples and a comprehensive manual helps the system designer to speed up system integration.

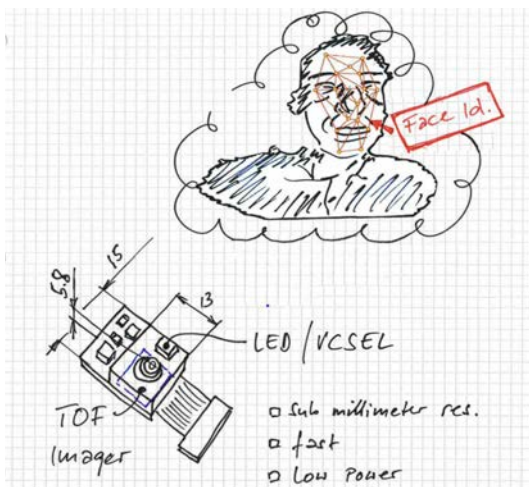


**Application example** Blind spot detection

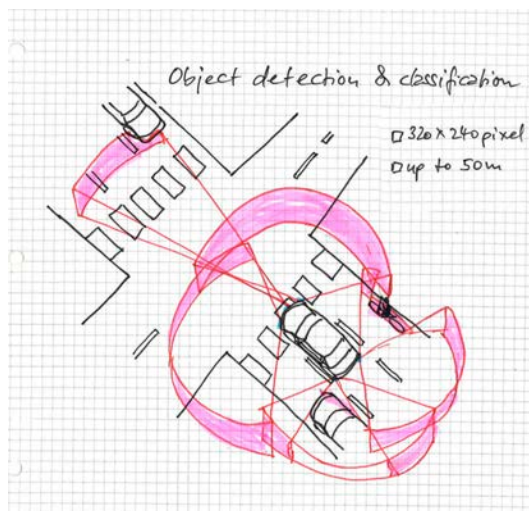
## STANDARD CHIPS



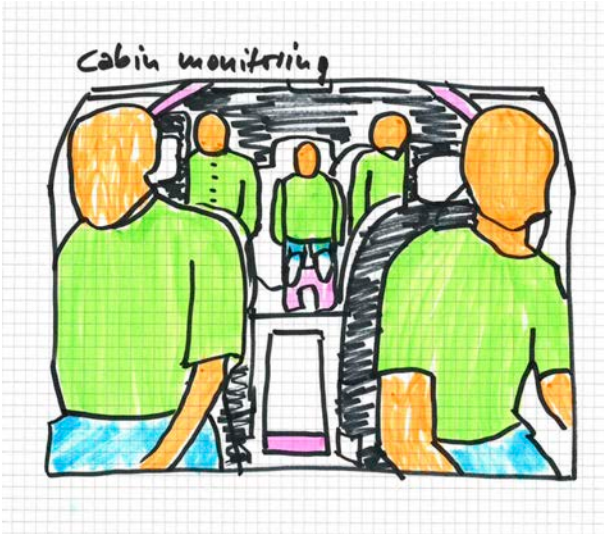
epc660



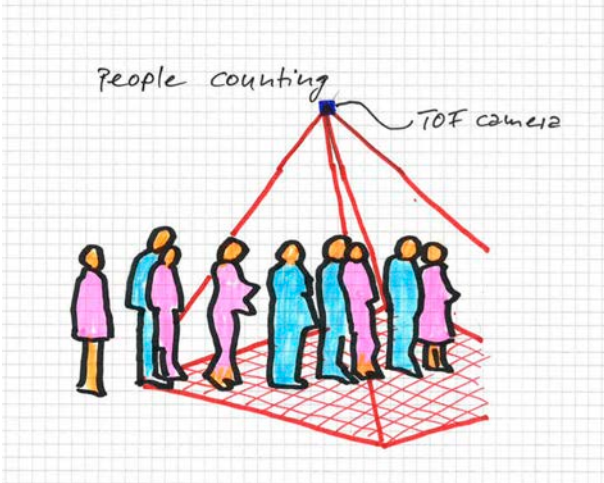
**Application example** Face ID



**Application example** Driver assistance



Application example Cabin monitoring



Application example People counting



**Size**  
8.0 × 1.3 × 0.23 mm

**Pixel Pitch**  
7.5 μm

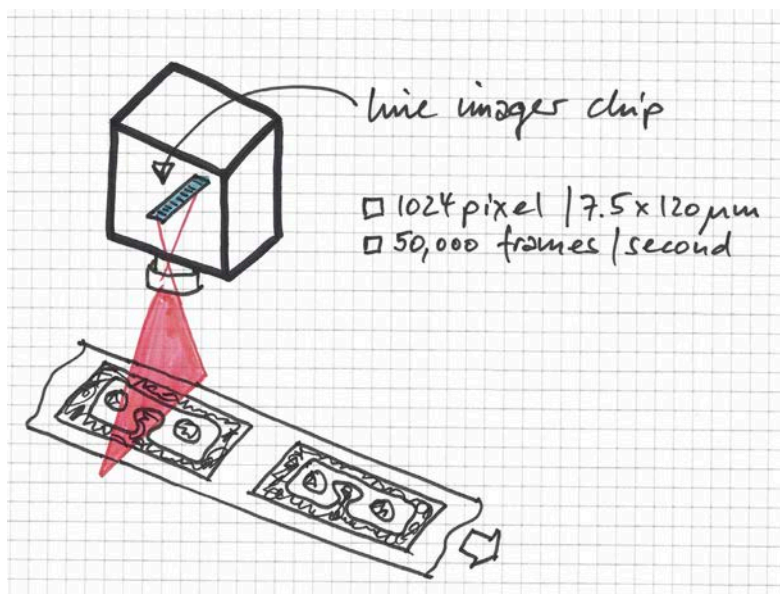
**Pixel Field**  
1024 × 1 pixel

**Photosensitive area**  
0.75 × 120 μm

<b>Operating principle</b>	Line imager
<b>Packaging</b>	CSP32
<b>Frame Rate</b>	500 kfps burst 50 kfps continuous
<b>Output</b>	analog
<b>Data interface</b>	differential and single ended
<b>Control interface</b>	I2C
<b>Power consumption</b>	Single supply voltage

**Features**

The epc901 IC is a high-performance CCD line sensor capable of storing a total of 4 frames in the frame store elements for ultra high-speed image acquisition. The acquisition of the image is controlled by the external control signal SHUTTER. The transmission of the frame over the video amplifier is controlled by the external controller.

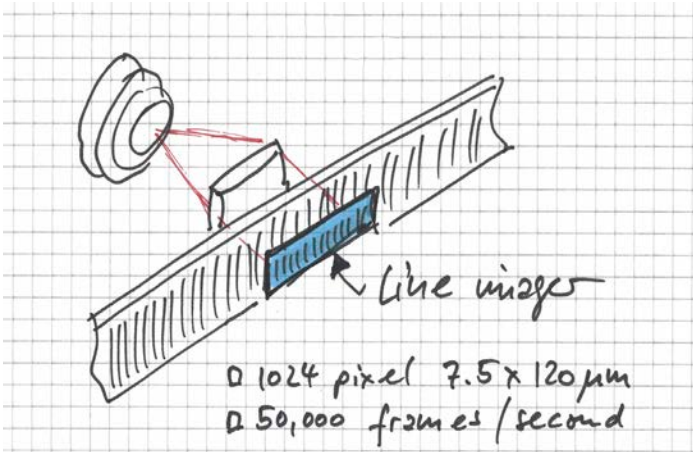


**Application example** Surface scanner for bank bill counterfeit check

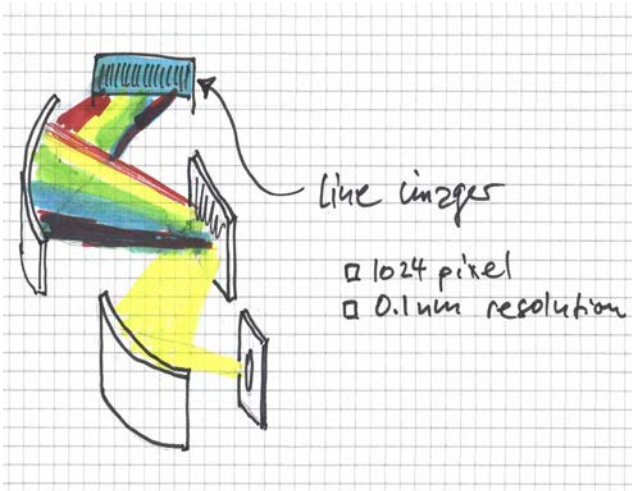
## STANDARD CHIPS



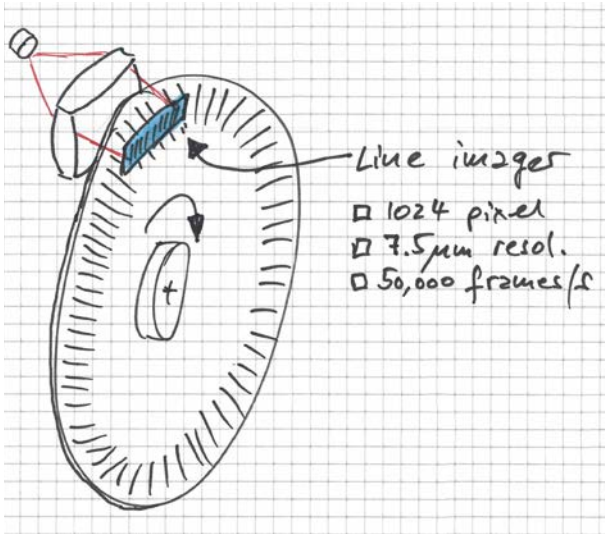
epc901



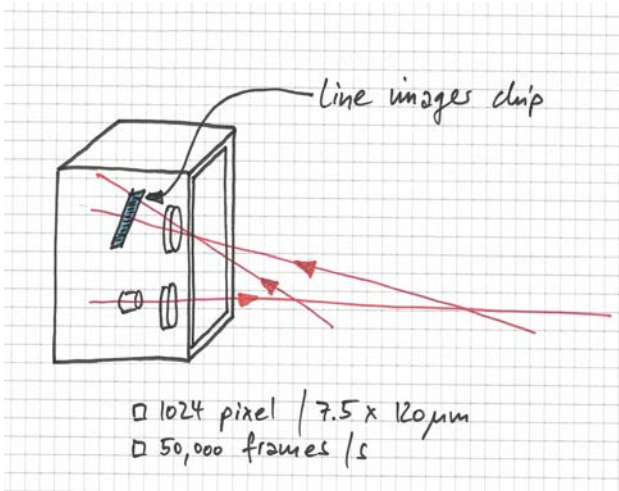
**Application example** Linear encoder



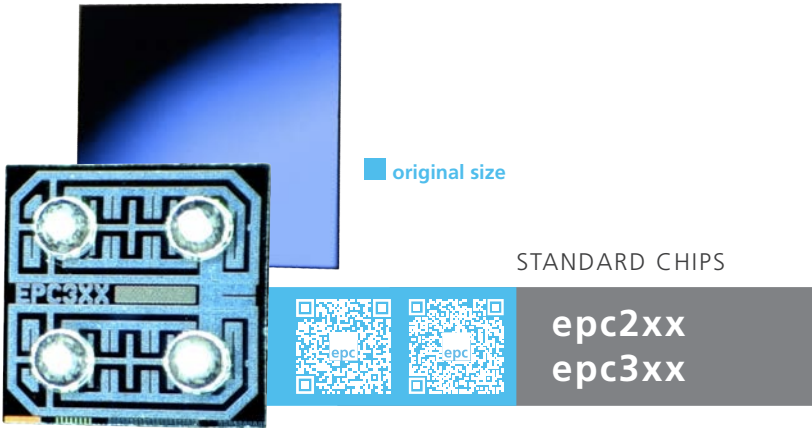
**Application example** Spectrometer



Application example Rotary encoder



Application example Industrial triangulation sensor



**Size**  
1.75 × 1.75 mm  
multiples of 0.5 × 1 mm

**Pixel Pitch**  
0.5 × 1 mm

**Pixel Field**  
1 × 1 pixel  
up to several hundred

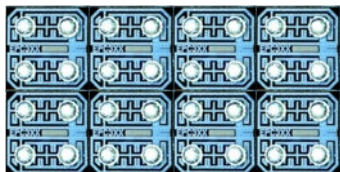
**Photosensitive area**  
1.65 × 1.62 mm  
multiples of 0.4 × 0.9

<b>Operating principle</b>	Photodiode Photodiode arrays
<b>Packaging</b>	CSP5 multiples of CSP4
<b>Frame Rate</b>	n/a
<b>Output</b>	Analog photo-current
<b>Data interface</b>	n/a
<b>Control interface</b>	n/a
<b>Power consumption</b>	Reverse voltage up to 20V

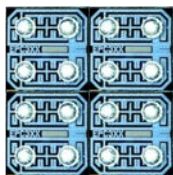
### Features

The epc200 is a high-sensitive, high-speed, low-cost photodiode for light-barriers, light-curtains and the like applications. It is designed to be used in a reverse-bias mode with a bias voltage between 1.5 and 20Volts. The diodes feature a very high quantum efficiency of 90 % in the near IR range and a response time down to less than 100 ns. The advanced Chip Scale Package (CSP) makes this device ideal for miniaturized systems where a minimal space requirement is key. This device allows the design of short to long range light barriers from a few millimeters up to tens of meters.

The epc3xx family products are high-sensitive photodiode arrays for light-barrier, light-curtain and the like applications with following configurations: 2 × 1, 4 × 1, 4 × 2, 8 × 2 elements. They are designed to be used in a reverse-bias mode with a bias voltage between 1.5 and 20 Volts. The individual diodes feature a very high quantum efficiency of 90 % in the near IR range and a response time down to less than 100 ns. The advanced Chip Scale Package (CSP) makes them ideal for miniaturized systems where a minimal space requirement is key.



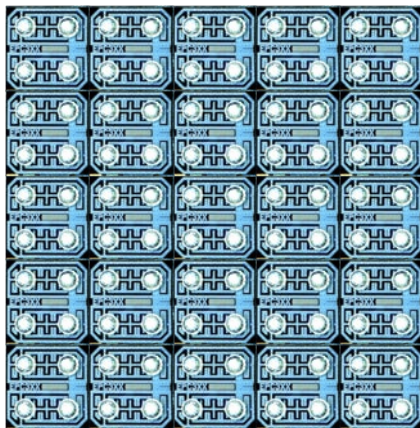
epc330



epc320

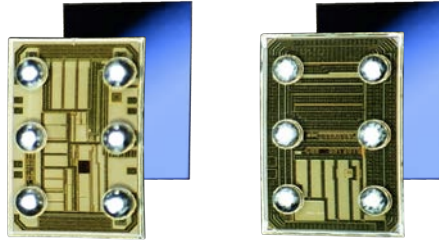


epc310

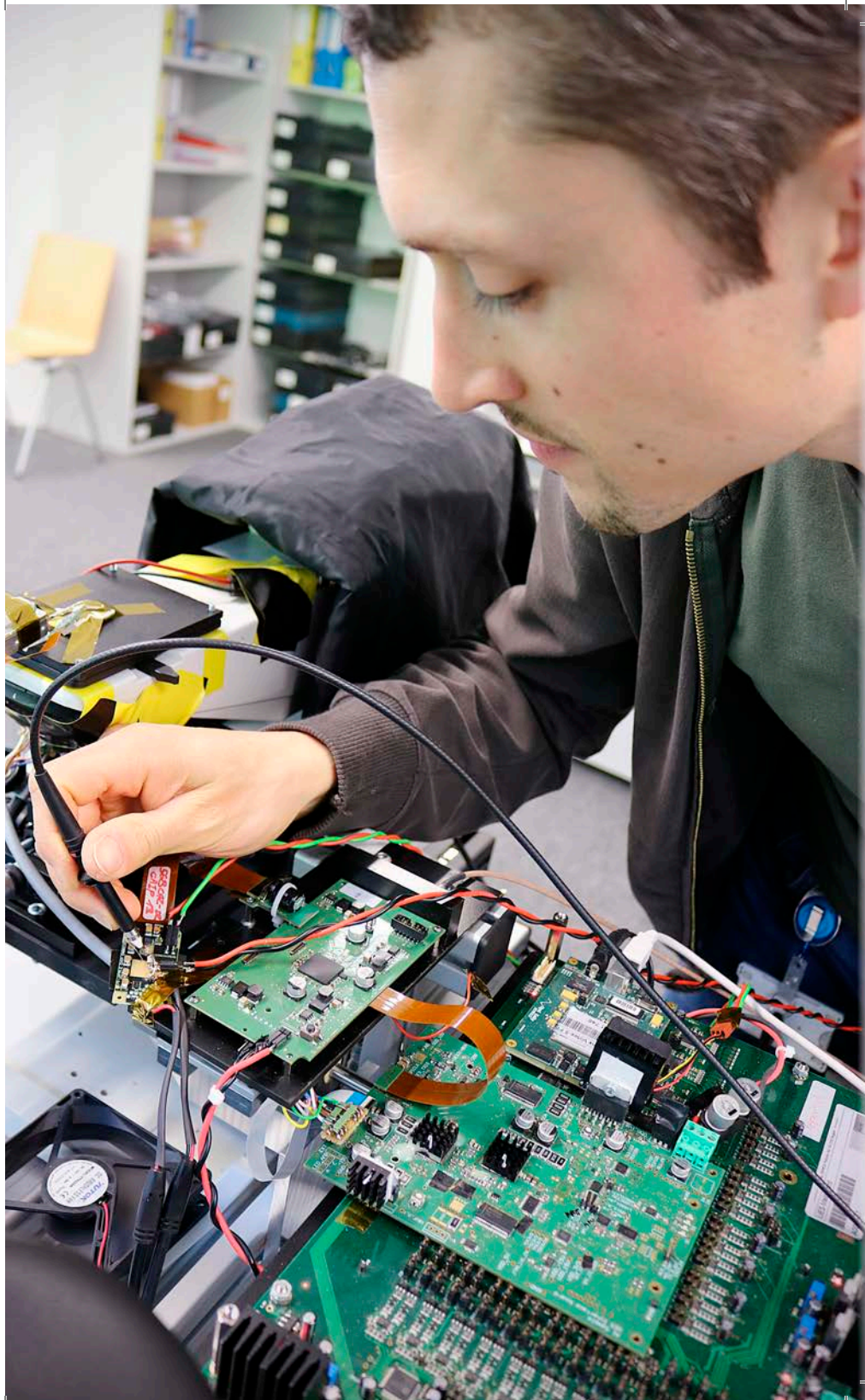


your customized array

# general purpose chips



Product	epc13x	epc70x
<b>Application</b>	Photodiode amplifier	High side switch Low side switch
<b>Supply voltage</b>	5V	9.6...30V
<b>Supply current</b>	2 mA	1 mA
<b>Input</b>	Photodiode	Logic level signal
<b>Output</b>	digital or analog	Open drain or open source 30V/50 mA
<b>Sensitivity</b>	80 nA photodiode current	Input + 5V TTL
<b>Special features</b>	Ambient-light suppression	Short circuit proof
<b>Package</b>	CSP6 1.4 × 1.0 × 0.35 mm	CSP6 1.4 × 1.0 × 0.35 mm





➤ **Supply voltage**  
5V

➤ **Supply current**  
2 mA

★ **Special features**  
Ambient-light  
suppression

🎯 **Sensitivity**  
80 nA photodiode current

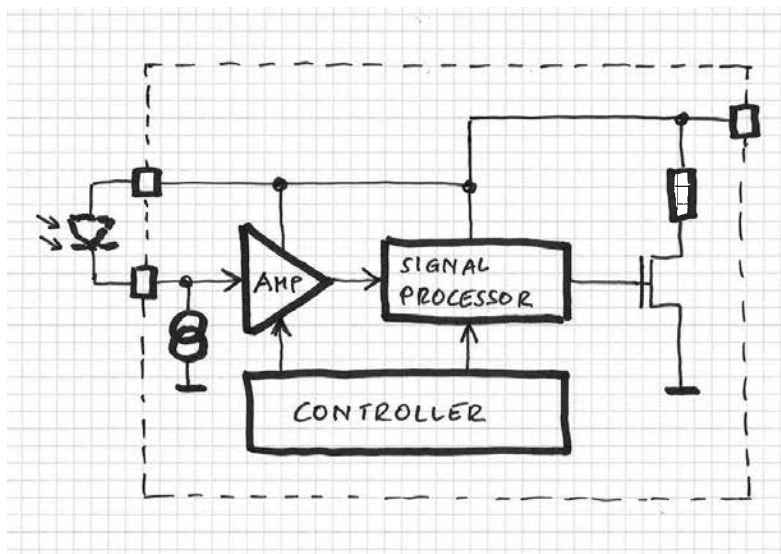
<b>Operating principle</b>	Photodiode amplifier
<b>Packaging</b>	CSP6 1.4 × 1.0 × 0.2 mm
<b>Input</b>	Photodiode
<b>Output</b>	digital or analog

**Features**

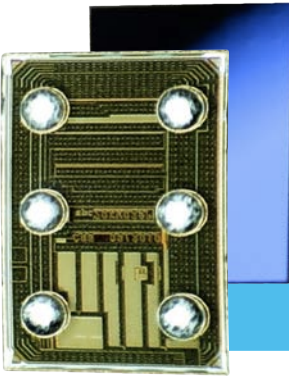
The epc130 to epc139 family products are monolithic, integrated highly sensitive photodiode amplifiers for light-barrier, light-curtain and similar applications. They amplify current pulses from reverse-biased PIN photodiodes (e.g. epc200, epc3xx) and discriminates the amplified input light-pulse before driving the open-drain output stage. The devices are controlled by an internal digital controller which needs no external clock signal.

They can be connected in anti-polar mode to the power supply lines for decreasing the wiring effort in matrix operated light-curtain products. The devices are optimized to utilize the minimum count of external components.

The devices allow the design of short to long range light-barriers from a few millimeters up to tens of meters. epc130/epc131 are the same devices but with an analog output.



epc13x block diagram



## GENERAL PURPOSE CHIPS



epc70x

➤ **Supply voltage**  
9.6 ... 30V

➤ **Supply current**  
1 mA

★ **Special features**  
Short circuit proof

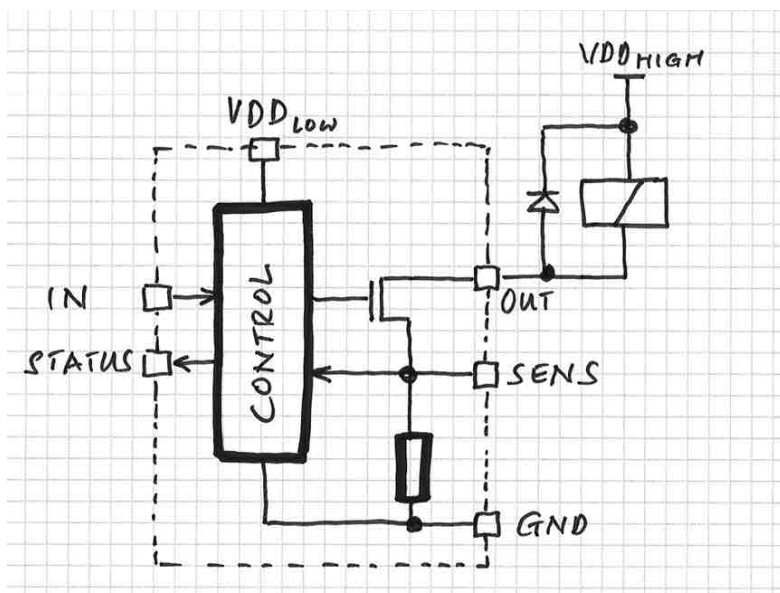
⊗ **Sensitivity**  
Input + SV TTL

<b>Operating principle</b>	High side switch Low side switch
<b>Packaging</b>	CSP6 1.4×1.0×0.2mm
<b>Input</b>	Logic level signal
<b>Output</b>	Open drain or open source 30V/50mA

**Features**

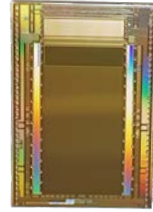
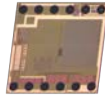
The epc70x family products are general purpose CMOS power switches for 24V interfaces. The devices are capable to drive a load of 50 mA at 30VDC. If higher driving current is necessary or the output voltage shall be higher than 30VDC, the chips can be used to drive an external power transistor. In this mode of operation, also the external transistor is fully protected against over-current by the driver chip. If the current through the external load exceeds a specified threshold during a period longer

than a predefined time, the output is turned off to protect the output switch. The switch is turned on again after a predefined off-time, thus enables the load again in a self-healing mechanism. The over-current information is indicated on the STATUS pin. The epc70x family is easy to use and reduces to a minimum the need for external components, thereby saving pcb space and money.

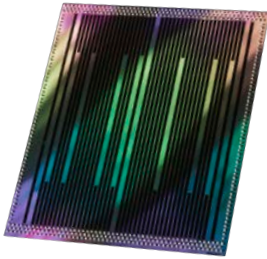


epc70x block diagram

# asic and foundry



Product	epc905	epc907
Operating principle	Imager with 2 frame stores	pTOF
Pixel field	88 × 73 pixel	256 × 144 pixel
Pixel pitch	20 × 20 μm	45 × 45 μm
Photosensitive area	1.8 × 1.52 mm	11.52 × 6.48 mm
Packaging	CSP12	CSP150
Size	2.7 × 2.7 × 0.25 mm	18.7 × 12.4 mm
Frame rate	Up to 100 fps	Up to 320 fps
Output data	8 bit	6 bit logarithmic
Data interface	SPI up to 8.4 MHz	4 × LVDS 500 Mbit/s
Control interface	SPI	LVDS SPI up to 16.8 MHz
Power consumption	20 mW	2.7 W

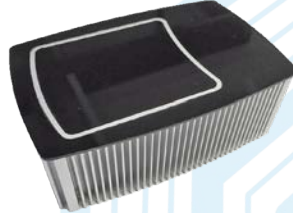


epc908	epc909	this could be your project
High-speed imager	Gated imaging	<p>We love challenges and it is a pleasure for us to design your customized chip for your application. There are many applications where our technology makes the difference and gives you an unique selling point and a competitive advantage.</p> <p>Applications could be:</p> <ul style="list-style-type: none"> <li>• Night-vision</li> <li>• Ambient-light independent imaging</li> <li>• NIR imaging</li> <li>• High-speed imaging</li> <li>• TDI imaging</li> <li>• Gated imaging</li> <li>• Differential imaging</li> </ul>
924 × 768 pixel	640 × 360 pixel	
30 × 30 μm	15 × 15 μm	
27.72 × 23.04 mm	9.6 × 5.4 mm	
CSP412	CSP92	
32 mm × 25.9 mm	11.7 × 10.5 mm	
Capture: up to 20 Mfps Readout: 1180 fps	625 fps	
analog	12 bit	
20 × analog video, differential	4 × LVDS 500 Mbit/s	
I2C up to 1 Mbit/s	SPI up to 16 MHz	
n/a	n/a	

# modules



Product	TOF>frame 611	TOF>range 611
<b>Range</b>	0.1 ... 2 m	0.05 ... 15 m
<b>Resolution</b>	8 × 8 pixel	1 pixel, range finder
<b>Ambient-light</b>	100 kLux	100 kLux
<b>Field of View</b>	12° hor/ver	0.18° hor/ver
<b>Accuracy</b>	± 4 cm	< 2 m: ± 4 cm > 2 m: ± 2 %
<b>Frame rate</b>	Up to 80 fps	Up to 500 fps
<b>Temperature Range</b>	-20 ... +85°C	-20 ... +85°C
<b>Interface</b>	UART 1 MBit/s	UART 1 MBit/s
<b>Data output</b>	Resolution 0.1 mm 4 Bytes per pixel ROS driver	Resolution 0.1 mm 4 Bytes per pixel ROS driver
<b>Dimensions</b>	39.6 × 16.3 × 8 mm	39.6 × 17 × 56 mm




TOFcam 635	TOFcam 660	your customized module
Wide FOV: 0.1 ... 7.5 m Narrow FOV: 1.0 ... 15 m	4 m@18 % reflectivity (wide FOV) 12 m@18 % reflectivity (narrow FOV)	<p>ESPROS designs and manufactures world class TOF camera modules such as our standard modules and reference designs.</p> <p>The world's most stringent and quality oriented companies have engaged the skills and experience of ESPROS engineers, and you can too.</p> <p>ESPROS offers full design, and design review services, ensuring the most cost effective, efficient, and fastest time to market for your 3D TOF camera module.</p>
160x60 pixel	320x240 pixel (QVGA)	
100kLux	100kLux	
Wide FOV: 50° x 19° Narrow FOV: 5° x 5°	108° x 77° (wide FOV) 60° x 45° (narrow FOV)	
0.1 ... 1 m: ±2 cm 1 ... 15 m: ±2 %	0.1 ... 2 m: ±4 cm 2 m... max. distance: ±2 %	
Up to 50 fps	Up to 40 fps	
-20 ... +60°C	-20 ... +60°C	
UART 10MBit/s	Gigabit-Ethernet RJ45/HDI connector	
14 bit distance data in mm 2 bit confidence data 12 bit grayscale data ROS driver	Distance data in mm Confidence data Grayscale data ROS driver	
80.5x24x28 mm	136x88x46 mm	

## MODULES



## TOF &gt;frame 611

 **Dimensions**  
39.6 × 16.3 × 8 mm

 **Resolution**  
8 × 8 pixel

 **Field of view**  
12° hor/ver

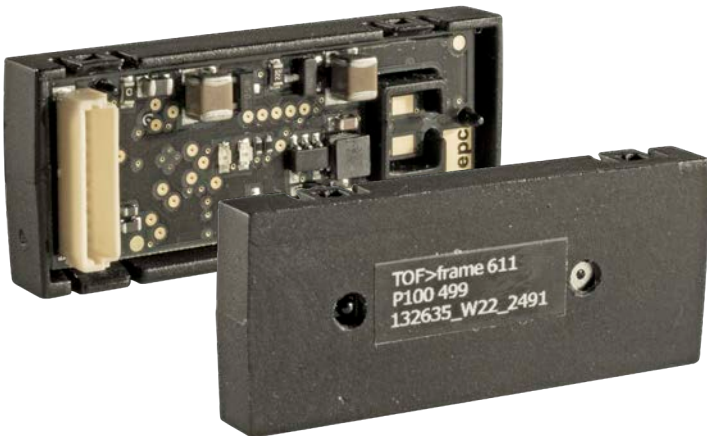
 **Range**  
0.1 ... 2 m

<b>Ambient-light</b>	100kLux
<b>Accuracy</b>	±4 cm
<b>Frame rate</b>	Up to 80fps
<b>Temperature Range</b>	-20 ... +85°C
<b>Interface</b>	UART 1 MBit/s
<b>Supply voltage</b>	5V
<b>Data output</b>	Resolution 0.1 mm 4 Bytes per pixel ROS driver

**Features**

The TOF>frame 611 is a miniaturized and cost optimized 3D TOF camera. It is based on the ESPROS proprietary time-of-flight technology using the epc611 TOF chip and a small LED to illuminate the scenery. The camera controls the illumination and the imager chip to obtain distance and confidence images. Due to the high performance of the imager chip with its unique ambient-light suppression, the camera can be used in outdoor applications at full sunlight. This allows a wide variety of new

applications, e.g. for mobile robotics. This very small module is easy to use because it delivers fully calibrated and compensated 3D images. All the complex engineering and time consuming design tasks regarding optics, illumination and signal processing are already solved.



## MODULES



## TOF &gt;range 611



**Dimensions**  
39.6 × 17 × 56 mm



**Resolution**  
1 pixel, range finder



**Field of view**  
0.18° hor/ver



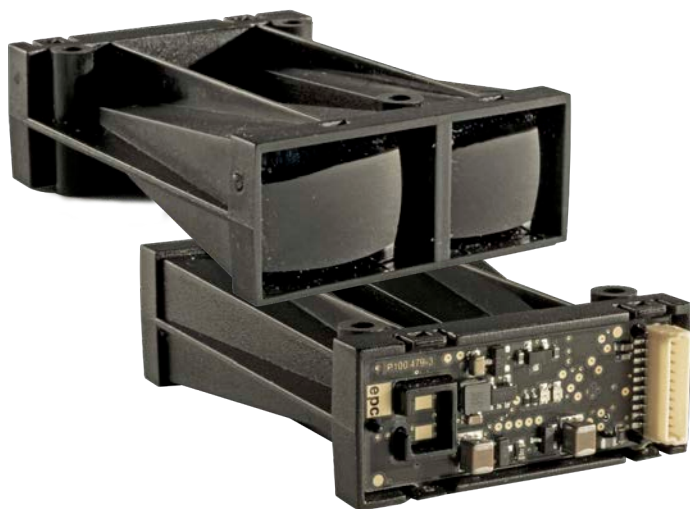
**Range**  
0.05 ... 15 m

<b>Ambient-light</b>	100kLux
<b>Accuracy</b>	<2m: ±4 cm >2m: ±2 %
<b>Frame rate</b>	Up to 500fps
<b>Temperature Range</b>	-20 ... +85°C
<b>Interface</b>	UART 1 MBit/s
<b>Supply voltage</b>	5V
<b>Data output</b>	Resolution 0.1 mm 32 Bit ROS driver

**Features**

The TOF>range 611 is a miniaturized and cost optimized range-finder. It is based on the ESPROS proprietary time-of-flight technology using the epc611 TOF chip and a small LED to illuminate the scenery. The range-finder controls the illumination and the imager chip to obtain distance and confidence information. Due to the high performance of the imager chip with its unique ambient-light suppression, the range-finder can be used in outdoor applications at full

sunlight. This allows a wide variety of new applications, e.g. for mobile robotics. This very small module is easy to use because it delivers fully calibrated and compensated distance values. All the complex engineering and time consuming design tasks regarding optics, illumination and signal processing are already solved.



## MODULES



## TOFcam 635

**Dimensions**

80.5 × 24 × 28 mm

**Resolution**

160 × 60 pixel

**Field of view**

Wide FOV: 50° × 19°

Narrow FOV: 5° × 5°

**Range**

Wide FOV: 0.1 ... 7.5 m

Narrow FOV: 1.0 ... 15 m

<b>Ambient-light</b>	100kLux
<b>Accuracy</b>	0.1 ... 1 m: ±2 cm 1 ... 5 m: ±2 %
<b>Frame rate</b>	Up to 50 fps
<b>Temperature Range</b>	-20 ... +60 °C
<b>Interface</b>	UART 10MBit/s
<b>Power consumption</b>	5V, 1W depending on operation mode
<b>Data output</b>	14 bit distance data in mm 2 bit confidence data 12 bit grayscale data ROS driver

**Features**

The TOFcam 635 is a new design of a miniaturized and cost optimized 3D camera. It is based on the ESPROS proprietary time-of-flight technology using the epc635 TOF chip. The camera controls the illumination and the imager chip to obtain distance and grayscale images. The depth images are compensated against ambient-light, temperature and reflectivity of the scene. Thanks to the high performance of the imager chip with the unique ambient-light

suppression, the camera can be used in many cases under full sunlight condition. The output of the TOFcam 635 is depth and gray-scale images – allowing a variety of new applications, e.g. for mobile robotics. This module brings you right in front with the latest technology of 3D depth sensing. All the complex engineering and time consuming design tasks regarding optics, illumination and signal processing are already solved.



## MODULES



## TOFcam 660

**Dimensions**  
136 × 88 × 46 mm

**Field of view**  
108° × 77° (Wide FOV)  
60° × 45° (Narrow FOV)

**Resolution**  
320 × 240 pixel (QVGA)

**Range**  
4 m @ 18 % reflectivity (Wide FOV)  
12 m @ 18 % reflectivity (Narrow FOV)

<b>Ambient-light</b>	100kLux
<b>Accuracy</b>	0.1 ... 2m: ±4cm 2 m ... max. distance: ±2 %
<b>Frame rate</b>	Up to 40 fps
<b>Temperature Range</b>	-20 ... +60 °C
<b>Interface</b>	Gigabit-Ethernet RJ45/HDI connector
<b>Power consumption</b>	5W depending on operation mode
<b>Data output</b>	Distance data in mm Confidence data Grayscale data ROS driver

## Features

The TOFcam 660 is a cost optimized 3D camera. It is based on the ESPROS proprietary time-of-flight technology using the epc660 TOF flagship chip. The camera controls the illumination and the imager chip to obtain distance and grayscale images. The depth images are compensated against ambient-light, temperature and reflectivity of the scene. Thanks to the high performance of the imager chip with the unique ambient-light suppression, the camera can be used in many cases under full sunlight

condition. The TOFcam 660 outputs depth and grayscale images – allowing a variety of new applications, e.g. for mobile robotics. This module brings you right in front with the latest technology of 3D depth sensing. All the complex engineering and time consuming design tasks regarding optics, illumination and signal processing are already solved.





# we're ready to serve

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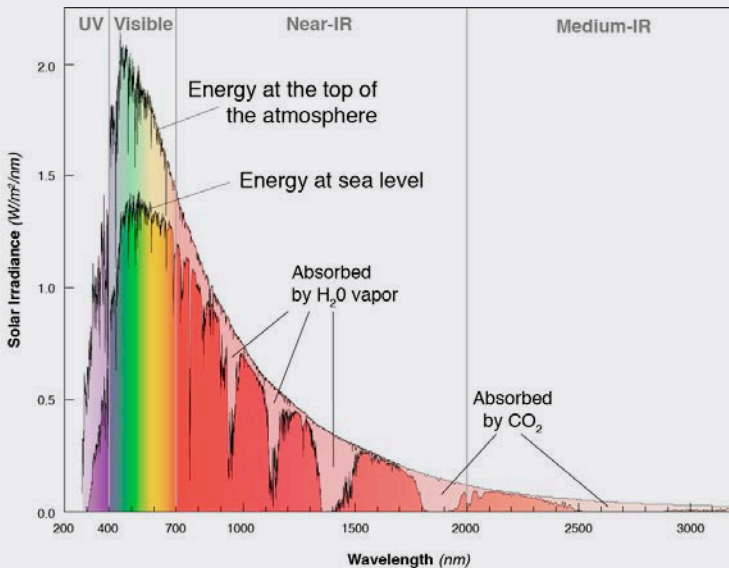


# The sun is a light source competing with the TOF illumination

## Sunlight Spectrum

The sun emits light in a very wide spectrum. It is good for growing plants (UV), make thing visible for us (VIS), allow us to feel (SWIR) and help the planet not freeze (LWIR). However, it competes with our sensor's illumination. Or better, the opposite: The illumination of our sensors compete with the incredible amount of photons generated by

the sun. Dealing successfully with this competition needs well designed TOF imager systems with appropriate bandpass filters and powerful ambient-light suppression technologies. ESPROS TOF imagers all have built in an ambient-light suppression circuit which subtracts ambient-light in real time from the distance signal.



Source:ESA

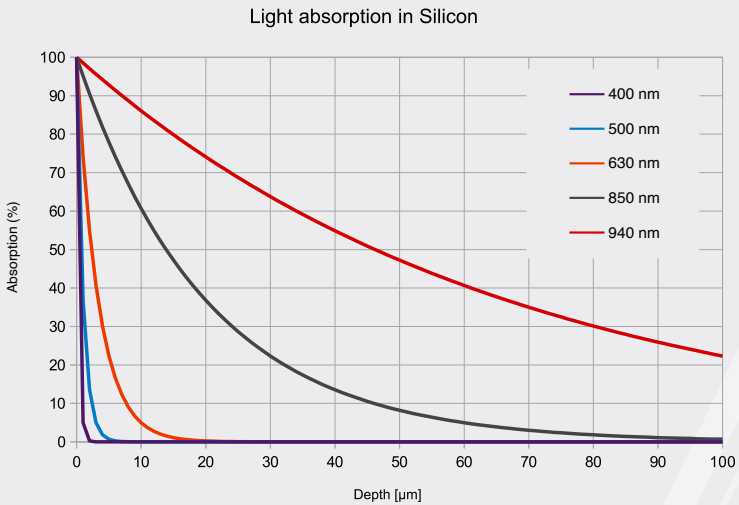
### Quantum efficiency

The Beer's law defines the light absorption in matter which is typically dependent on the wavelength. The absorption takes place exponentially with thickness of the sensor material:

$$E(x) = E_0 e^{-\alpha x}$$

- $E_0$ : Irradiance in  $W/m^2$
- $\alpha$ : Absorption coefficient in  $cm^{-1}$

The curves below show the amount of light absorbed in silicon related to the thickness of the silicon absorption layer. ESPROS imagers have an absorption layer of  $50\mu m$  which absorbs more than 90 % of the light @ 850 nm. That is an incredible 90 % quantum efficiency (QE).

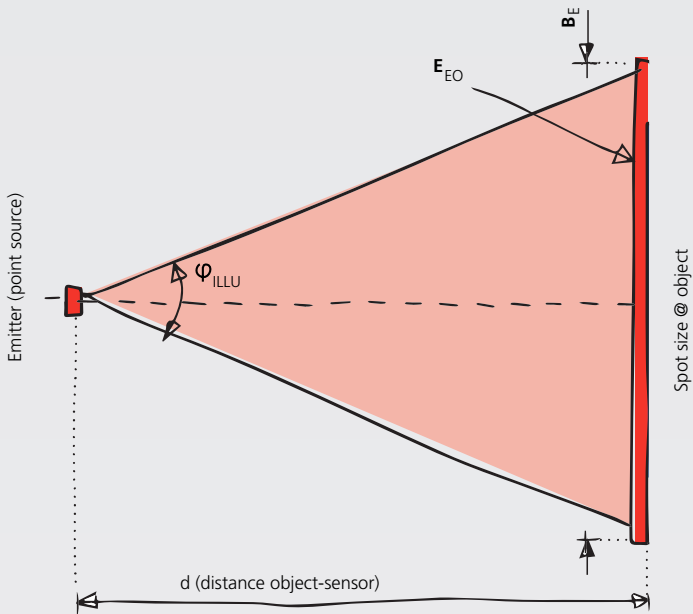


# TOF sensors rely on the amount of reflected light



Get our optical power calculation tool AN02

[www.espros.com/downloads/09\\_Application\\_notes](http://www.espros.com/downloads/09_Application_notes)



Spot size on the object

$$B_E = 2 \cdot d \cdot \tan \frac{\varphi_{ILLU}}{2} \quad [m]$$

Calculate the irradiance in the scenery

$$E_{EO} = I_E \cdot \frac{i_{APP}}{i_{NOM}} \cdot 4\pi \cdot \left( \sin \frac{\varphi_{ILLU}}{4} \right)^2 \cdot \frac{4}{B_E^2 \cdot \pi} \quad \left[ \frac{W}{m^2} \right]$$

Radiant intensity

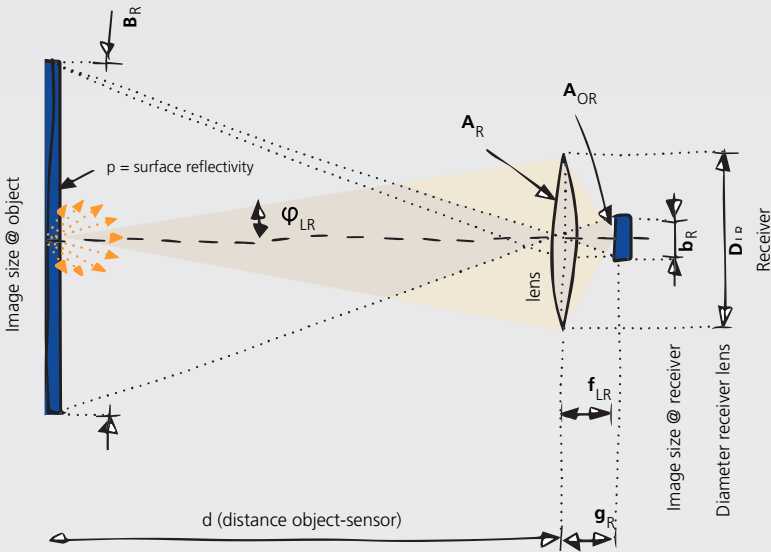
Transform angle / rad

Area

Optical power calculation

Time-of-flight (TOF) is a fundamental principle to measure the distance to an object. An emitter emits light into the scenery (red cone) where it is reflected by objects. The reflected light (blue cone) is detected by the pixels in the imager. By measuring the round-trip time of the light, the

distance can be obtained. However, distance measurement is possible only, if enough light is reflected back to the imager. Thus, the optical power budget calculation is essential to determine, whether an application is feasible or not.



Half-angle of the illumination of the receiver lens

$$\varphi_{LR} = \text{atan} \left( \frac{D_{LR}}{2 \cdot d} \right)$$

The irradiance at the receiver is

$$E_R = E_{EO} \cdot \rho \cdot 2 \cdot \sin^2 \left( \frac{\varphi_{LR}}{2} \right) \cdot \frac{A_{OR}}{A_R} \quad \left[ \frac{W}{m^2} \right]$$

# object light reflection

## Reflectivity in NIR (approximative)

Reflective surface	Reflective index (%)	Reflective surface	Reflective index (%)
Mirror, highly polished, retro-reflectors	140 ... 30000 %	Negroid face, front	10 ... 30 %
Stainless steel, micro-finished	400 %	Green field, lawn, vegetation	6 ... 25 %
Aluminum, polished	140 %	Dark grey, other dark colors	10 ... 20 %
Stainless steel, brushed	120 %	Brick, red	10 ... 20 %
Testcard Kodak white/ white copy paper	90 %	Testcard Kodak gray	18 %
Aluminum, high-gloss	80 ... 90 %	Forest	5 ... 18 %
Snow	80 ... 90 %	Water surface	5 ... 22 %
Cloud	60 ... 90 %	Wood, dark	10 ... 15 %
Roadway, dirty and gravel	30 ... 70 %	Clear glass, PMMA	6 ... 8 %
Transparent brown plastic bottle	60 %	Carbon, black	2 ... 10 %
Stainless steel, dull	50 ... 60 %	Roadway, asphalt new, dry	10 %
Light grey, light green	40 ... 60 %	Soil	7 %
Wood, light	40 ... 60 %	Roadway, asphalt wet	5 %
Caucasian face, front	30 ... 50 %	Automobile tire, black (new)	1.5 %
Concrete, sandstone, gray	15 ... 50 %	Black velvet	0.4 %
Clear plastic bottle	40 %	Black, ESD foam	0.2 %
Middle brown, middle gray	20 ... 30 %		
Green field, lawn, vegetation	6 ... 25 %		
Carpet	2 ... 35 %		

# ambient-light conditions

## Typical ambient-light levels

Outdoor	Illuminance [Lux]
Dark night	<0.001
Starlight	0.001 ... 0.01
Full moon	0.01 ... 0.1
Street illumination, worse	0.1
Street illumination, good	20
Sunset	1 ... 100
Cloudy, heavily	100 ... 2 000
Cloudy	2k ... 10k
Cloudy, lightly	10k ... 25k
Hazy, transparent clouds	25k ... 50k
Sunshine	up to 130k

Office, business area	Illuminance [Lux]
Traffic area, corridor	20 ... 50
Lobby, reception, restroom, staircase	150 ... 200
Conference room, reception room	200 ... 750
Office work	700 ... 1 500

Hospital, doctor's surgery	Illuminance [Lux]
Patient's room, storage space	100 ... 200
Diagnostic room	300 ... 750
Surgery room, emergency room	750 ... 1 500

Education, school area, library	Illuminance [Lux]
Auditorium, indoor in general	100 ... 200
Classroom	300 ... 750
Laboratory	750 ... 1 500

Shop area	Illuminance [Lux]
Shopwindow, packing table	200 ... 1 000
Shopwindow, outside	1 500 ... 3 000

Production area	Illuminance [Lux]
Warehouse, reception room	150 ... 300
Regular production	300 ... 750
Inspection area	750 ... 1 500
Electronic production	1 500 ... 3 000

# TOF camera design is not easy. talk to the experts.

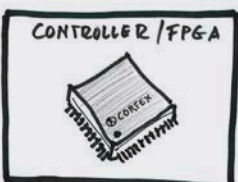
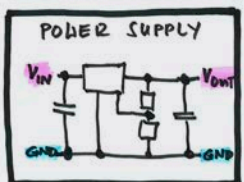
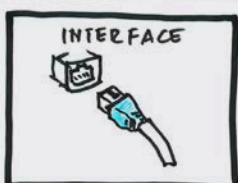
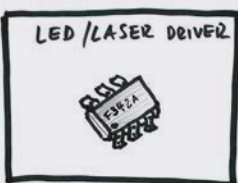
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## Application support

To successfully design TOF cameras, many engineering majors need to be mastered. The final system is only as good as the weakest part: Be it an unstable power supply, an imager lens not suited for TOF applications, illumination which do not match the application requirements, illumination drivers not delivering a stable current for the high frequency modulation, etc.

ESPROS provides design support in every aspect, from electronics and software to optics. Our reference designs are real implementations used in industrial applications. They work under indoor and outdoor conditions. Multi-camera applications are also supported due to a powerful interference detection and suppression algorithm. Ask your ESPROS Pro nearby for support.

TOF ecosystem



VARIOUS

- THERMAL
- EYE SAFETY
- FUNCTIONAL SAFETY
- COST
- HOUSING

# characterizing optoelectronic components is fundamental

## Radiometry units

Understanding the fundamental radiometric dimensions is important to characterize light-sources and photodetectors.

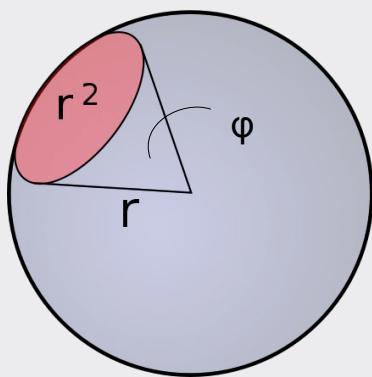
The table below shows the most important of them.

Name	S1 Symbol	Unit	S1 Units
Radiant energy	$Q_e$	Joule	J
Radiant flux	$\Phi_e$	Watt	$W = J/s$
Radiant intensity	$I_{e,r} \Omega$	Watt per steradian	$W/sr$
Spectral intensity	$I_{e,r} \Omega, \nu$	Watt per steradian per meter	$W/sr/m$
Irradiance	$E_e$	Watt per square meter	$W/m^2$
Spectral irradiance	$E_{e,\lambda}$	Watt per square meter per nanometer	$W/m^2/nm$

### Angular calculation

The definition of a steradian is fundamental to characterize and specify light-sources.

Typically, light sources datasheets use Watt per Steradian (W/sr) for the specification of the optical power on the optical axis.



Angle  $\varphi$  of the cone for 1 sr is  $65.54^\circ$

$$\text{sr} = 4\pi \cdot \left(\sin \frac{\varphi}{4}\right)^2$$



$$\text{sr} = 4\pi \cdot \left(\sin \frac{\varphi}{4}\right)^2$$