General Description

This document presents an overview about the functionality, operating modes, the most important steps, screens and functions of the the epc660 Evaluation Kit.

Features

- Fast intro in the epc660 3D-TOF chip
- Many of the epc660 chip operation modes can be evaluated
- Consists of a DME 660 camera engine, power supply and tripod
- Wide FOV of H108° x V77°
- Long operating range up to 10m on white targets in the full field of view
- Camera calibration feature
- Log section to capture single images and movie sequences for further processing
- Many graphic display modes featuring 3D-TOF in color and point cloud presentation, amplitude, grayscale, and DCS
- The book «3D-TOF – A guideline to 3D-TOF sensors that work»

Applications

- Evaluation and development support

Figure 1: Evaluation Kit epc660

1. Precaution and Safety

Eye safety: Do not look directly into the camera under operation. Depending on the mode of operation, the camera device emits highly concentrated non-visible infrared light. It can be hazardous to the human eye. The use of these devices has to follow the safety precautions given in IEC 60825-1 and IEC62471.

The DME 660 camera module is a bare electronic device without a housing around. Therefore, handle it with the necessary ESD precaution.

Over-voltage: Use only power supplies which correspond to the datasheet DME 660 to avoid damage of the DME 660 or cause danger for humans.

Cable-tripping: Place the DME 660 with a tripod on a flat solid ground or fix it correctly on a solid support. Place cables carefully. Falling devices can be damaged or harm persons.

This camera comes with its own calibrated firmware. For proper operation of the camera, upload the correct firmware with the evaluation kit to the camera according the instructions given in the quick guide. Do this when you are changing the camera module.

This camera comes with high quality lens. Do not touch, twist or turn it. Otherwise loss of performance occurs.

EMC compatibility: The DME 660 is designed on module level. It is not an EMC certified device. It is users responsibility to operate it in compliance with the EMC regulations.

The DME 660 is designed on module level. It is NOT a CE, UL, CSA certified device. It is the users responsibility to operate it in compliance with the relevant regulations.

The DME 660 and its software may only be be used in accordance of the datasheet DME 660

This device may not be used in safety applications, explosive atmospheres or in radioactive environment.

Limited warranty - Loss of warranty
The DME 660 should only be installed and used by authorized people. All instructions in this datasheet and in the related documents shall be followed and fully complied with. In addition, the installer and user is required to comply with all local laws and regulations. Should any of these instructions not be carefully followed, seriously injury may occur. The installer and user is fully responsible for the safe use and operation of the system. It is the sole responsibility of the installer and the user to ensure that this product is used according to all applicable codes and standards in order to ensure safe operation of the whole application. Any alteration to the devices by the buyer, installer or user may result in unsafe operating conditions. ESPROS Photonics AG is not responsible for any liability or warranty claim which results from such manipulation or disregarding of given operating instructions.

UPDATES

ESPROS Photonics is constantly striving to provide comprehensive and correct product information. Therefore, please check our website regularly for updated versions of datasheets and documentations: www.espros.com

Download the actual Datasheet epc660: www.espros.com → Downloads → Datasheets → Chips

Download the actual Datasheet DME 660: www.espros.com → Downloads → Datasheets → Camera_and_Modules

Download the actual Manual epc660_Evalkit: www.espros.com → Downloads → Datasheets → Evaluation_Kits

Download the current GUI software (client) and the current BeagleBoneBlack software (server).
Questions: Send an email with your request to your local sales office or to info@espros.com.

Update the DME 660 (BeagleBone board): Go to the folder “ESPROS_TOF-imager_Evaluation_Kit_Software_vX.X.X”. Read the Readme-file and follow the instructions accordingly.

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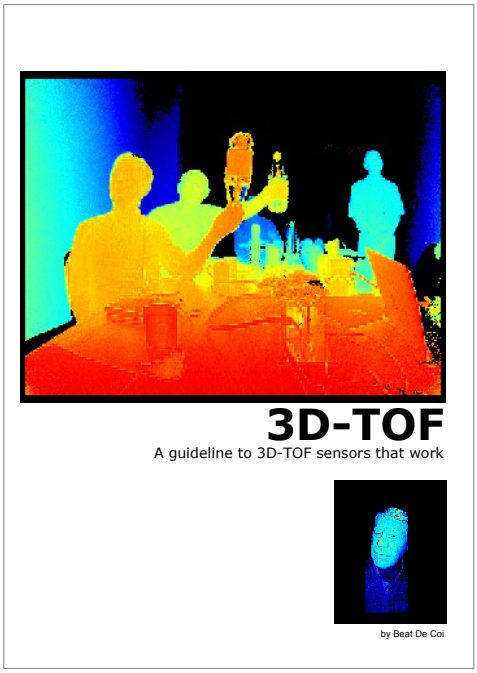


Figure 2: The comprehensive TOF book, enclosed in this evaluation kit

2. epc660 Evaluation Kit

2.1. Scope of delivery

Figure 3: epc660 Evaluation Kit overview

No	Pieces	Designation	Remarks
①	1	Toolbox	
②	1	DME 660-108°/10m	P/N P100 518; with quick release fastener of the tripod
③	1	Power Supply 24V/2.5A	
④	1	Power cord 2 pole EU version and US adapter	Power plug EU Europlug (CEE7/16, 2 pole) Power plug US Type A (NEMA 1-15, 2 pole)
⑤	1	Cable - USB 2.0, A plug - mini-B plug	Length 2m
⑥	1	Plastic bag with Industrial Supply Connector and the toolbox key	The connector can also be inserted in the DME 660
⑦	1	Camera Tripod	
⑧	1	Toolbox belt	
⑨	1	epc660 Quick Start Guide	also available at www.espros.com --> Down-loads
	1	DME Cover Plate Set, includes 2 knurled head screw	P/N P100 512, see Figure 17 and Figure 44
	1	Book "3D TOF - A guideline to 3D-TOF sensors that work"	P/N 100 542. Refer to Chapter 6. Only available with the evaluation kit or as TOF Developer Conference attendee
		Datasheet DME 660	available at www.espros.com → Downloads
		Datasheet epc660	available at www.espros.com → Downloads
		Application and configuration software, SDK: Use the “ESPROS_TOF-Imager_Evaluation_Kit _Software” for accessing the licensed corresponding tools and software development kit (SDK).	available at www.espros.com → Downloads

Table 1: Bill of material of the delivery

2.2. Ordering information

Part Number	Part Name	Remarks
P100 280	epc660 Evaluation Kit EU & US	Power plug EU Europlug (CEE7/16, 2 pole) & US adapter
P100 512	DME Cover Plate Set	1 set is included in the kit

Table 2: Ordering Information epc660 Evaluation Kit

Figure 4: DME 660 on tripod

Figure 5: epc660 Evaluation KIt

Figure 6: DME 660 tripod mounting

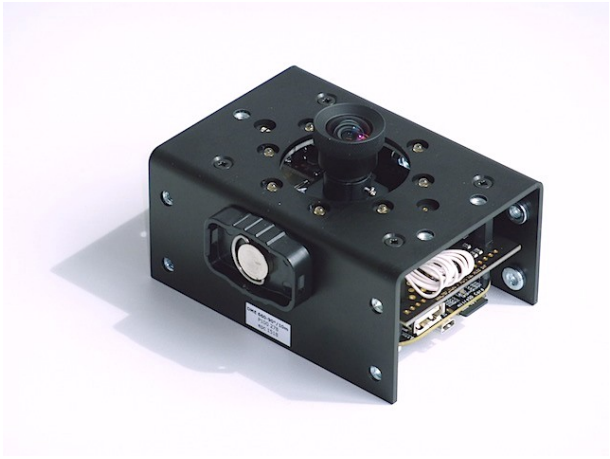


Figure 7: DME 660 with quick release fastener of the tripod

Figure 8: GUI - b&w picture

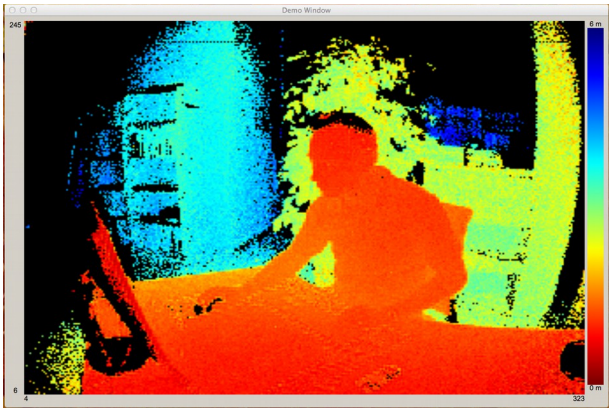


Figure 9: GUI - 3D TOF picture

3. Installation and setup

3.1. Fixation of the DME 660

The DME 660 has various mounting options as shown in Figure 10.

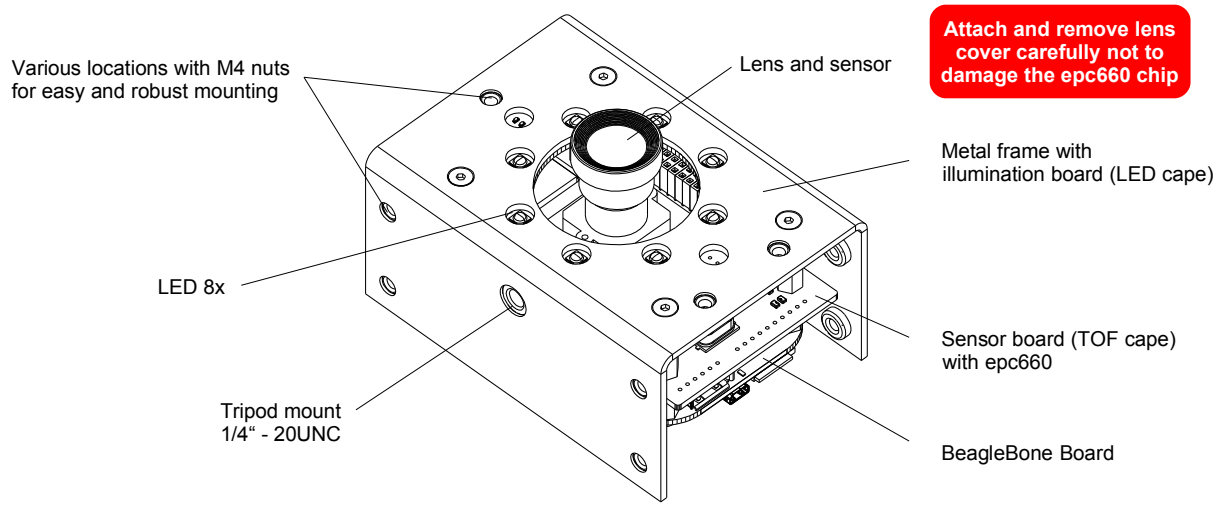


Figure 10: DME 660 overview

3.2. Overview of the DME 660 camera module

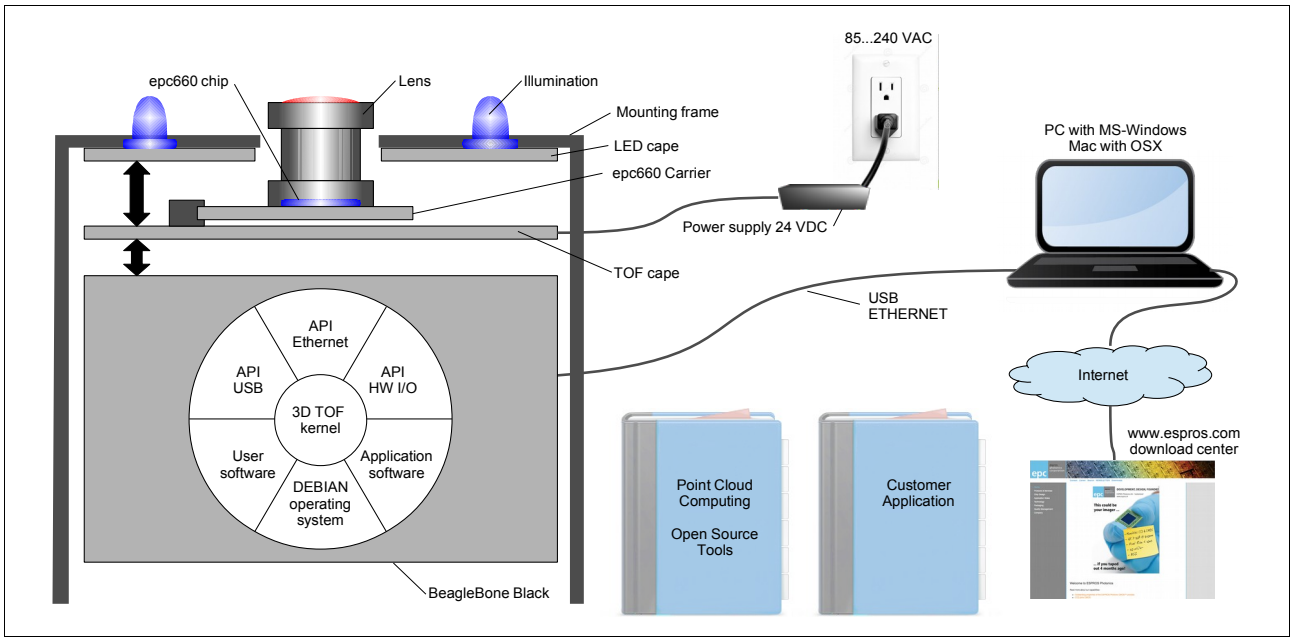


Figure 11: System overview

The epc660 evaluation kit is based on the DME 660 . This is a general purpose camera module based on the epc660 chip:

- The camera is based on a BeagleBone Black (BBB) Linux computer board.
- The TOF cape board communicates with the BBB and carries the epc660 CC Chip Carrier board with the epc660 camera chip and the lens with the lens holder. It carries also the single wire power supply for the hole camera system.
- The camera's active illumination is done by 8 power LEDs on the LED cape which is driven by the TOF cape. The LED cape's metal frame offers two camera mount 1/4” - 20UNC.
- The application software runs on the DEBIAN GNU/Linux operating system. The 3D-TOF kernel manages the camera including correction algorithms. Data for further processing e.g. cloud computing is available on APIs (application programming interface) for USB, Ethernet interfaces or hardware I/O. It opens the world for point cloud computing by using open source tools or by creating own customer applications.

3.3. Software, software development kit (SDK) and application tools

ESPROS Photonics supports the user's development and application by having available various support tools e.g. software development kit (SDK), updates and emulation program downloads for the epc660 chip, application interfaces (API), etc. All they are available by downloading the ESPROS_TOF-Imager_Evaluation_Kit_Software"_vx.x.x. Updates of camera firmware are also included in the package.

After the download, read first the README and CHANGELOG files to get latest operation and application information.

3.4. Exchange of epc660 CC Chip Carrier

Make sure, all assembly procedures are executed on an ESD-compatible workstation.

- Power off the DME 660 and remove cables
- Remove the BeagleBone board
- Remove the TOF cape
- Remove the locking screws from the epc660 CC Chip Carrier
- ⚠ Softly remove the epc660 CC Chip Carrier. The epc660 chip can be destroyed when excessive force is applied.
- Remove lens holder
- Attach the lens holder to the new epc660 CC Chip Carrier
- ⚠ Softly insert the new epc660 CC Chip Carrier
- Insert the locking screws for the epc660 CC Chip Carrier
- Install the TOF cape
- Install the BeagleBone board
- ⚠ First power on the DME 660
- Connect the USB cable
- Download and install on the DME 660 the latest server software according the Readme.txt
- Start the epc660 Evaluation Kit GUI and run a black & white video (start)
- Unlock the fixation of the lens.
- Adjust lens focus
- Lock the fixation of the lens
- Calibrate the DME 660 with this new chip carrier

4. Operation software

The Evaluation Kit epc660 uses software which can be downloaded from the ESPROS Homepage at www.espros.com, click to the link “Downloads” as shown below:

Figure 12: ESPROS homepage with the Download link

You will get a folder structure. Go to the subfolder 03_Evaluation Kits/Evaluationkit_epc660 and download the corresponding file for Windows or Mac of the ESPROS_TOF-Imager_Evaluation_Kit_Software”_vx.x.x. Unpack the file. You will get a folder structure like shown in Figure 13.

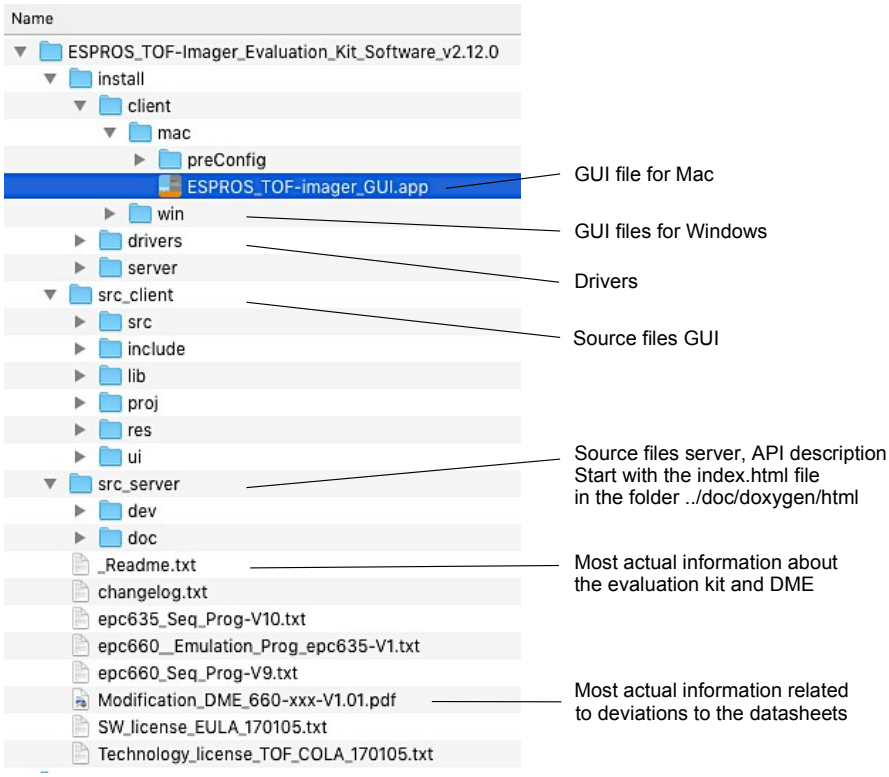


Figure 13: Folder structure after installation

5. GUI Functionality

5.1. Start the GUI software

Note:
First after installation of a new software release, read the files README and CHANGELOG of the download package to get latest evaluation kit information.

After start of the “ESPROS_TOF-imager_GUI” application file, the connect dialog will be displayed.

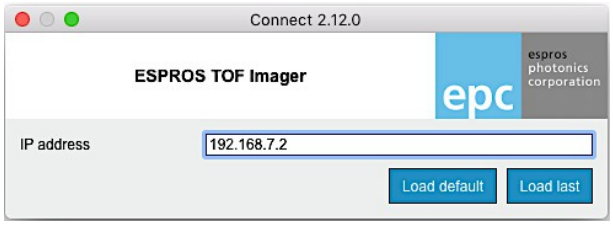


Figure 14: Connect dialog after start up

Followed the selection “Load default”, the dialog of preconfigured, basic operation modes appear.

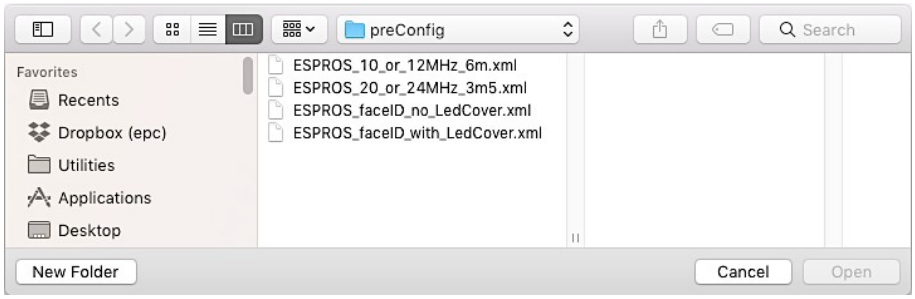


Figure 15: Pre-configurations

Select one of the pre-configurations to start the GUI:

- ESPROS_10_or_12MHz_6m: Basic setup for 6m operating range.
- ESPROS_20_or_24MHz_3m5 Basic setup for 3.5m operating range.
- ESPROS_faceID_no_LedCover Basic setup for doing Face ID without LED cover.
- ESPROS_faceID_with_LedCover Basic setup for doing Face ID: This configuration needs a the special LED cover.

Figure 16: Face ID operation

Figure 17: DME with LED cover for face ID

5.2. Overview

The GUI consists of two windows: The control window Figure 18 and the display window Figure 19. The control window is used to set parameters, choose the way of displaying the camera images and to log data. It consists of two section: Left is the dock with the Apps and right is the control section.

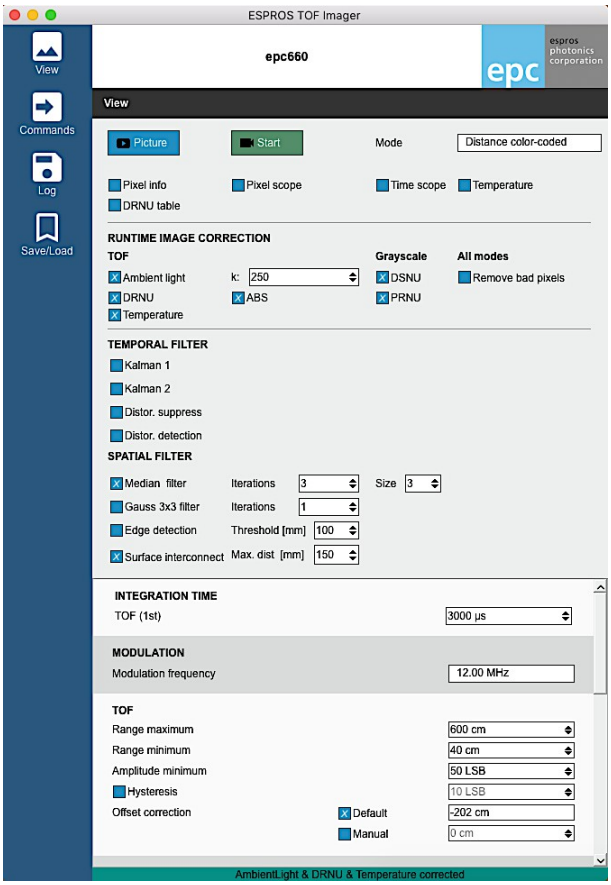


Figure 18: Control window

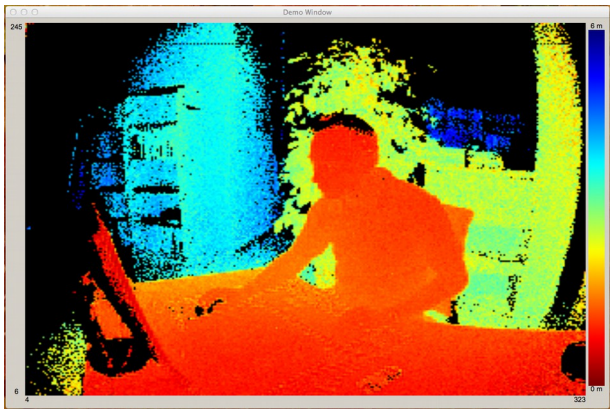
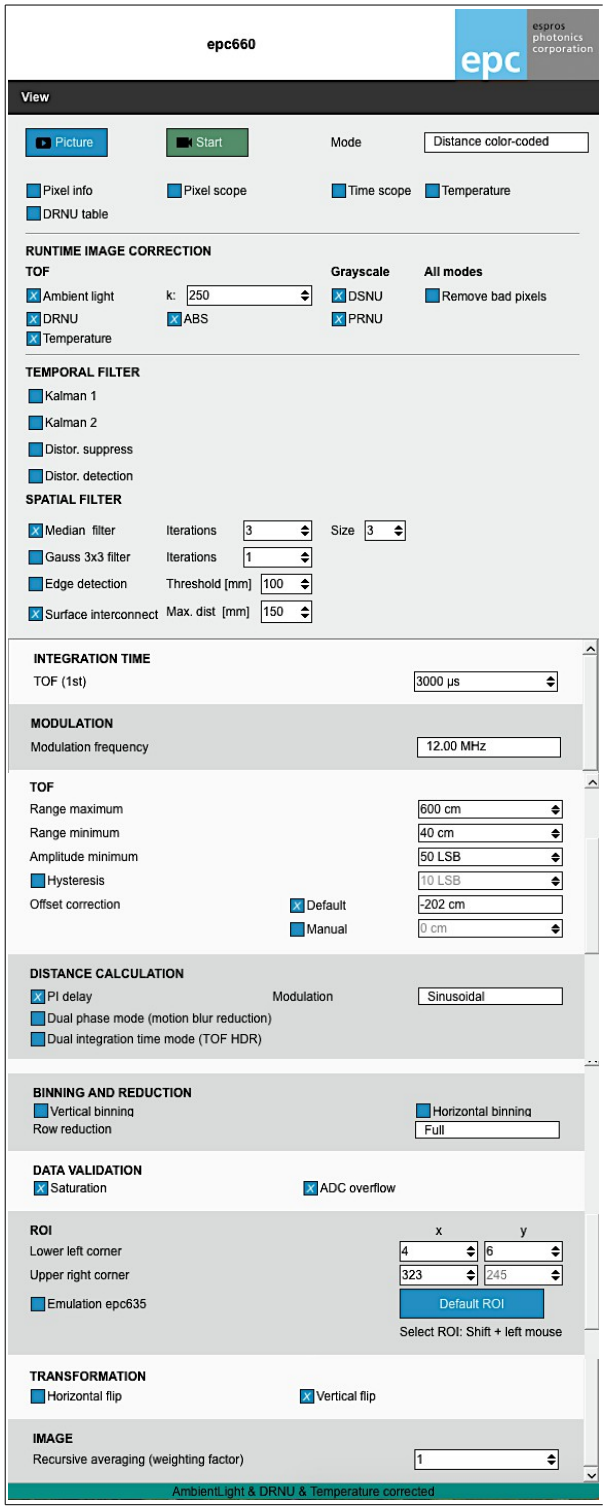


Figure 19: Display window

Most of the functions are self-explaining and are not described here.

5.3. Operating mode and display setting



	Notes
Displays connected chip type	
Single shot picture or movie Display mode (grayscale, 3D-TOF, amplitude, DCS, etc.)	
Selection for additional information windows e.g Pixel Info: Displays pixel detail data of the pixel pointed by the cursor.	
Image and fix pattern noise correction based on calibration. Refer for details to application note AN10 available on www.espros.com, section DOWNLOADS. ABS: Enables enhanced ambient-light suppression	1/2
Smoothing of run-time distance data by temporal filters (Kalman filters). Refer for details to application note AN12 available on www.espros.com, section DOWNLOADS.	
Smoothing of run-time distance data by spatial filters. Reduces pixel resolution by increasing picture quality. E.g. the median filter replaces pixel by pixel the value by the median of the selected sliding filter window (size)	
Remove erroneous distance data for in-pixel distance transitions e.g. edges	
Translation from points into surface in the point cloud function	
Integration (or exposure) time for grayscale imaging: 1st Integration time for 3D-TOF imaging 2nd integration time for 3D-TOF high dynamic range imaging (MGX mode)	
Select unambiguity distance and distance resolution by setting illumination modulation frequency	1/2
3D image data representation setup	
Data clipping: upper end of color coding	
Data clipping: Lower end of color coding	
Set data values with too low signal to maximum distance value	
Smooths measurement: Set a hysteresis window for distance value changes	
Overall shifting of measured distance values	
Distance calculation concept	
enabled: Result is based on DCS0 ... DCS3, see Figure 23	1/2
DCS0/DCS1 resp. DCS2/DCS3 sampling at same int. time, refer to Table 3	
DCS0/DCS1 resp. DCS2/DCS3 sampling with different integration times	
Combines 2 vertically adjacent pixel into one (120 rows only)	
Combines 2 horizontally adjacent pixel into one (160 columns only)	
Shows all, 1/2, 1/4, or 1/8 of the rows	
Mark-up of saturated pixels in the picture	
Mark-up of overexposed pixels in the picture	
Coordinates of displayed pixels	
Displays the epc635 pixel-field 160x60 pixel	
Flipping of displayed image	
Smooths measurement: Averaging of distance values over time	
Green underlay: Camera is calibrated for the selected parameters	1/2

Figure 20: Operating mode and display setting

Notes:

1. DME 660 supports with calibrations default modulation frequency settings for 12MHz, 24MHz (full range, around 31.5cm/calibration step) and 24MHz face ID (up to 1m, round 2cm/calibration step).

Figure 21: Modulation frequency selection

2. Calibrated parameter. Note: DME's without 24 MHz face ID calibration will use instead the regular 24MHz calibration.

5.4. Distance calculation concepts

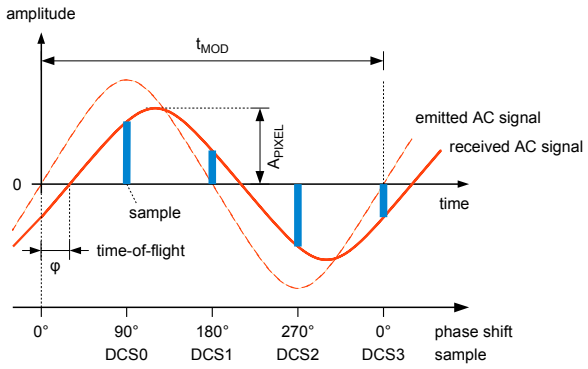


Figure 22: Sampling of the received waveform

There are two check-boxes to choose the way of distance calculation: PI delay and Dual MGX (refer to Figure 20). These functions allow to reduce motion blur and/or accelerate the distance measurement sequence.

	PI Delay	Dual MGX
Enabled	Distance measurement is made by the acquisition of 4 DCS (Differential Correlation Samples). This setting provides the most accurate distance measurement option. Pixel non-linearities are suppressed by differential measurement. Because the distance acquisition is made sequentially by four images, motion blur artifacts occur. This is the default operation mode.	In this mode, in a first acquisition, DCS0 is sampled on the upper row, whereas the DCS1 is sampled into the adjacent lower row. In the second acquisition, DCS2is sampled on the upper row, whereas the DCS3 is sampled into the adjacent lower row. With these two acquisitions, all 4 DCS are sampled and the distance calculation can take place. Please note that this mode reduces the vertical resolution by 2 (120 rows).
Disabled	Distance measurement is made by the acquisition of 2 DCS. This setting provides a doubled frame rate than with 4 DCS. Also motion blur is reduced. However, pixel non-linearities become visible and therefore, more calibration an compensation is needed.	Full vertical resolution is maintained. This is the default operation mode.

Table 3: PI Delay and Dual MGX mode (motion blur reduction)

Thus, if PI Delay is disabled and Duals MGX is enabled, distance acquisition is made by just on integration. This is the fastest mode which has virtually no motion blur artifact. Figure 23 shows the concepts in a graphical manner.

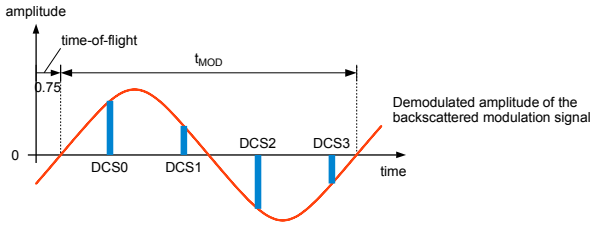
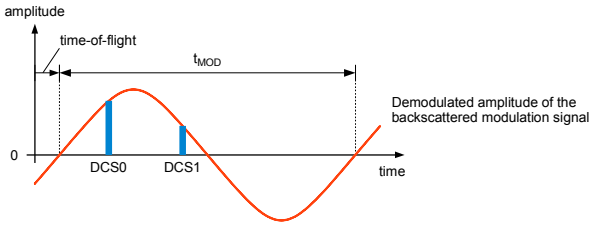
PI delay = ON	PI delay = OFF
	
Sampling of the received waveform with DCS0 ...DCS3: π-delay matching (PI delay matching)	Sampling of the received waveform only with DCS0 &DCS1, no PI delay matching
Best image quality (reduced data acquisition offsets) gives full resolution and full sensitivity	Reduced motion blur Doubled 3D TOF frame rate
3D TOF frame rate = 1/4 of DCSx frame rate	Half vertical resolution (half number of rows)

Figure 23: Sampling of the received waveform with or without PI-delay matching

More detailed information regarding the various operating modes can be found in the epc660 datasheet.

5.5. Miscellaneous functions

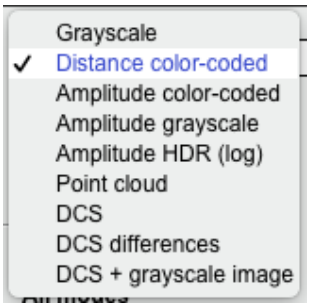


Figure 24: Mode selection overview

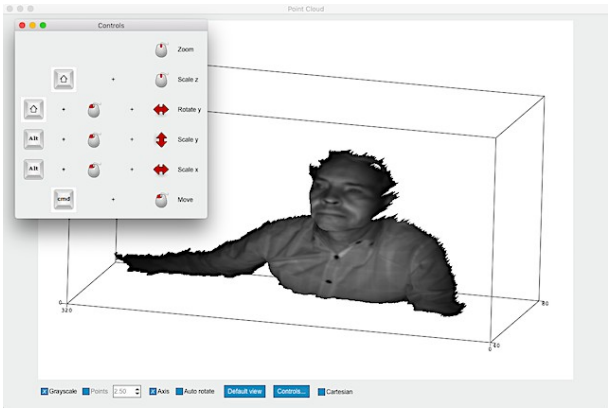


Figure 25: The controls dialog to adjust the point cloud view

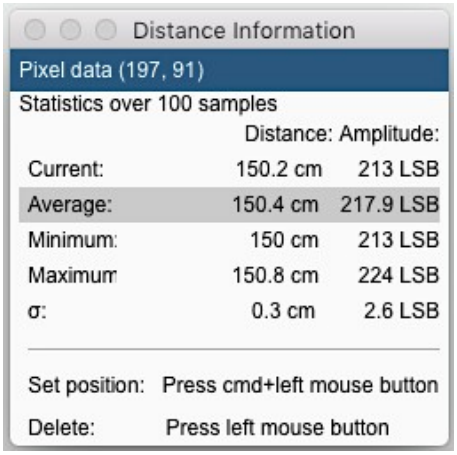


Figure 26: Pixel info

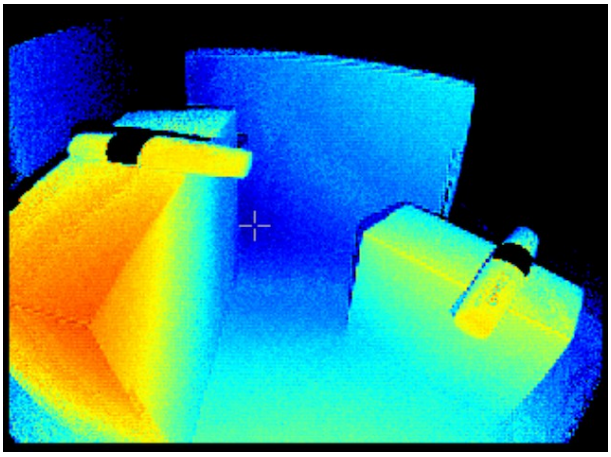


Figure 27: Grey mark-up cross of the pixel info selection

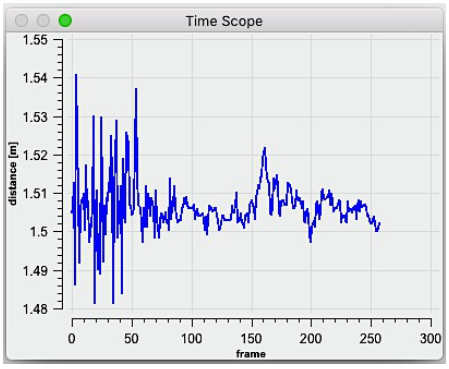


Figure 28: Time sequence data of the pixel info at mark-up

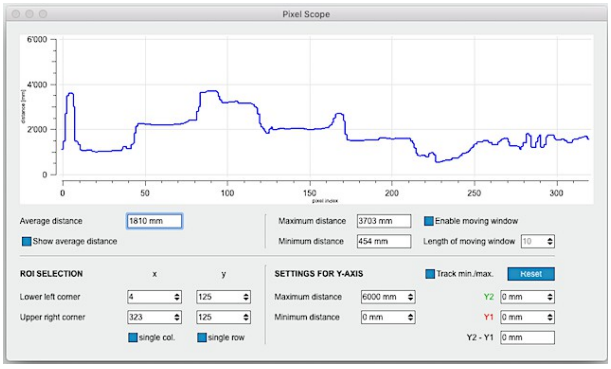


Figure 29: Pixel scope

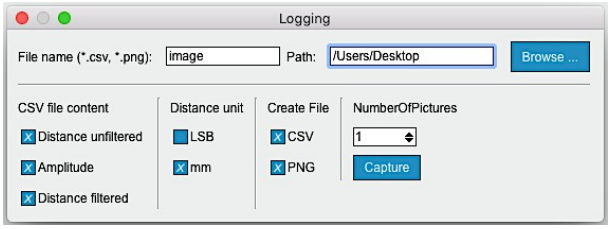


Figure 30: Logging options

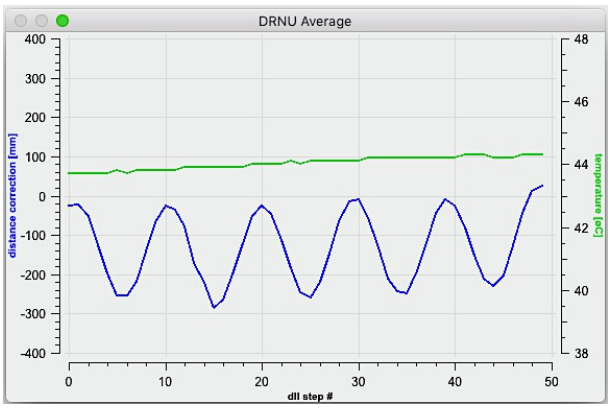


Figure 31: DRNU table for distance corrections

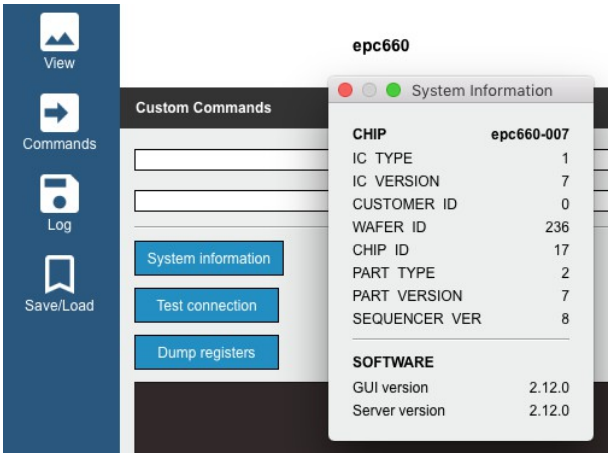


Figure 32: Read system info in the Commands dialog

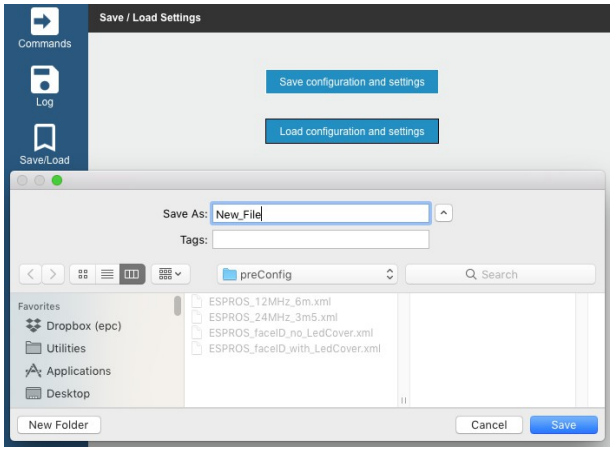


Figure 33: Save and reload system setups in the Save/Load dialog

5.6. Regular greyscale and distance image

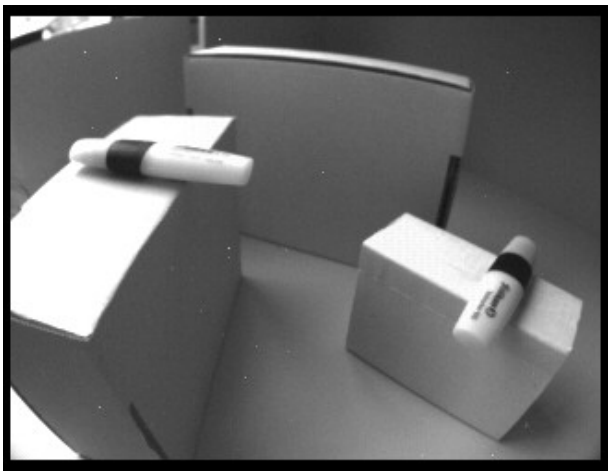


Figure 34: Grayscale picture

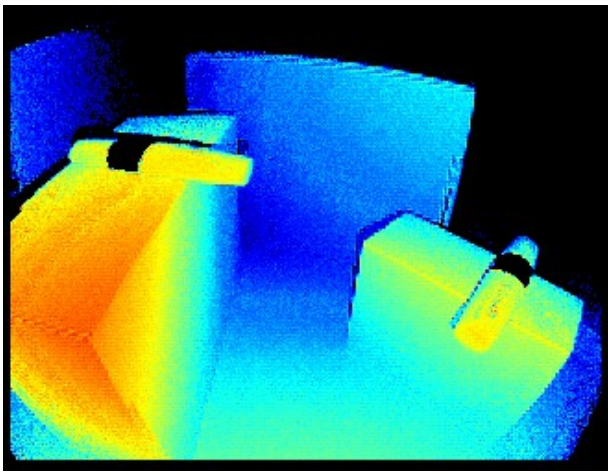


Figure 35: Raw distance picture

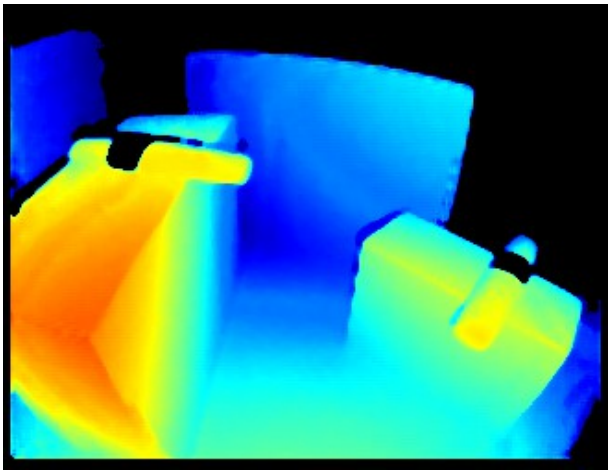


Figure 36: Filtered distance picture

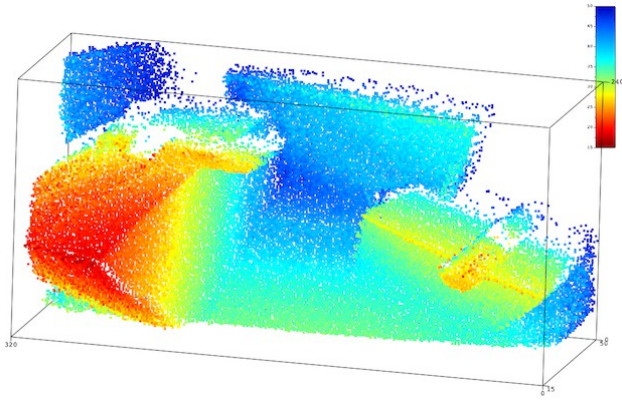


Figure 37: Point cloud

5.7. Self-illuminated grayscale images created by TOF mode

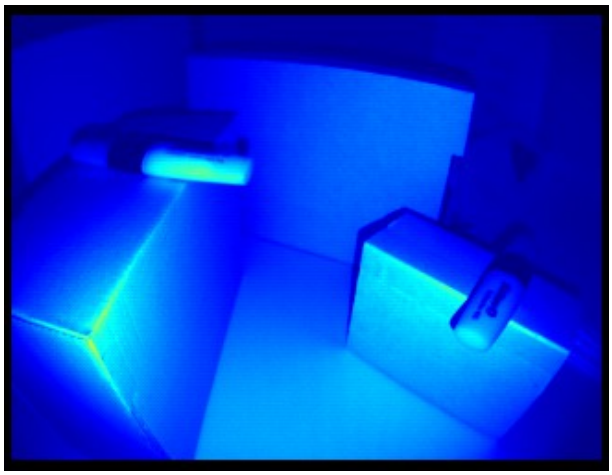


Figure 38: TOF amplitude picture color-coded

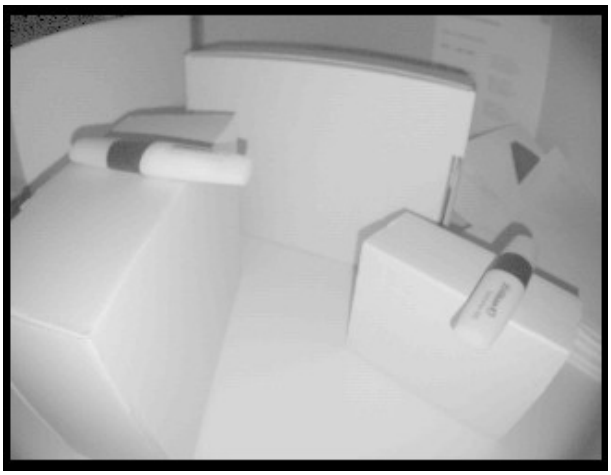


Figure 39: TOF amplitude picture HDR (log)

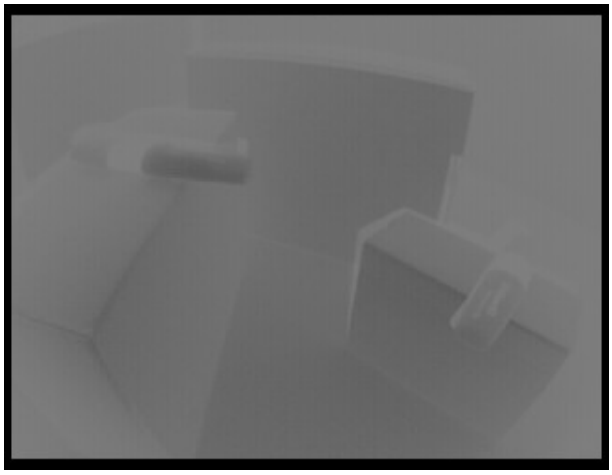


Figure 40: DCS0

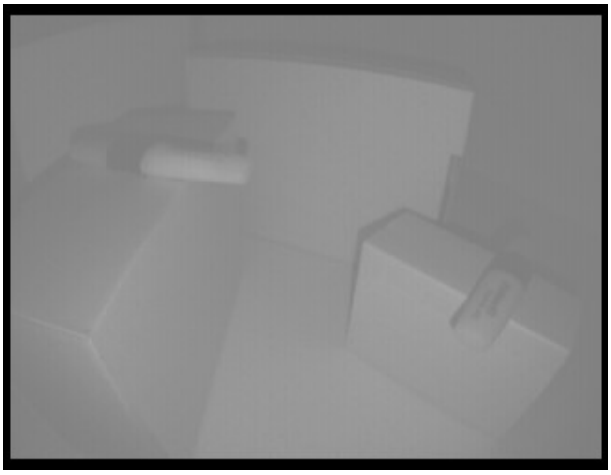


Figure 41: DCS2

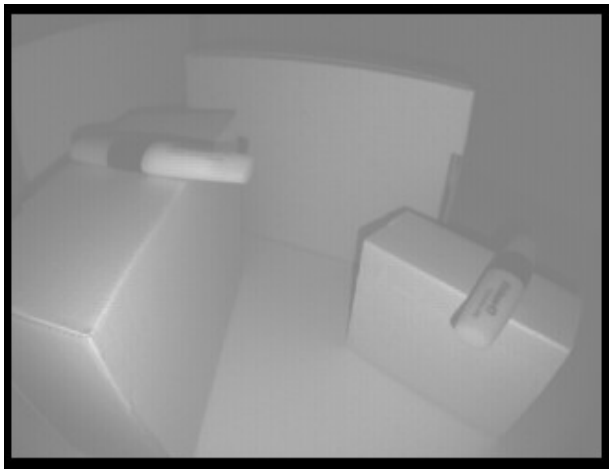


Figure 42: DCS1

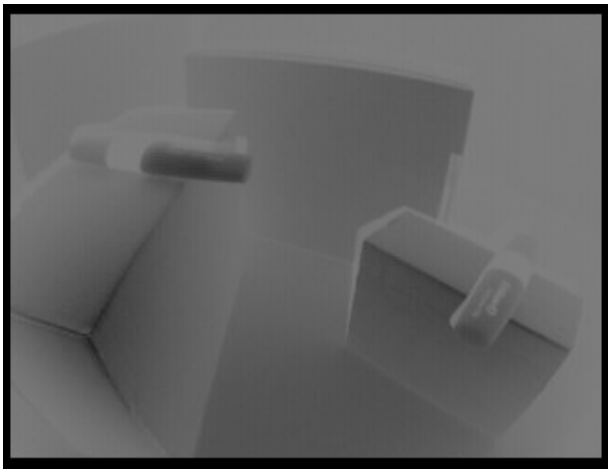


Figure 43: DCS3

5.8. Mechanical dimensions LED cover

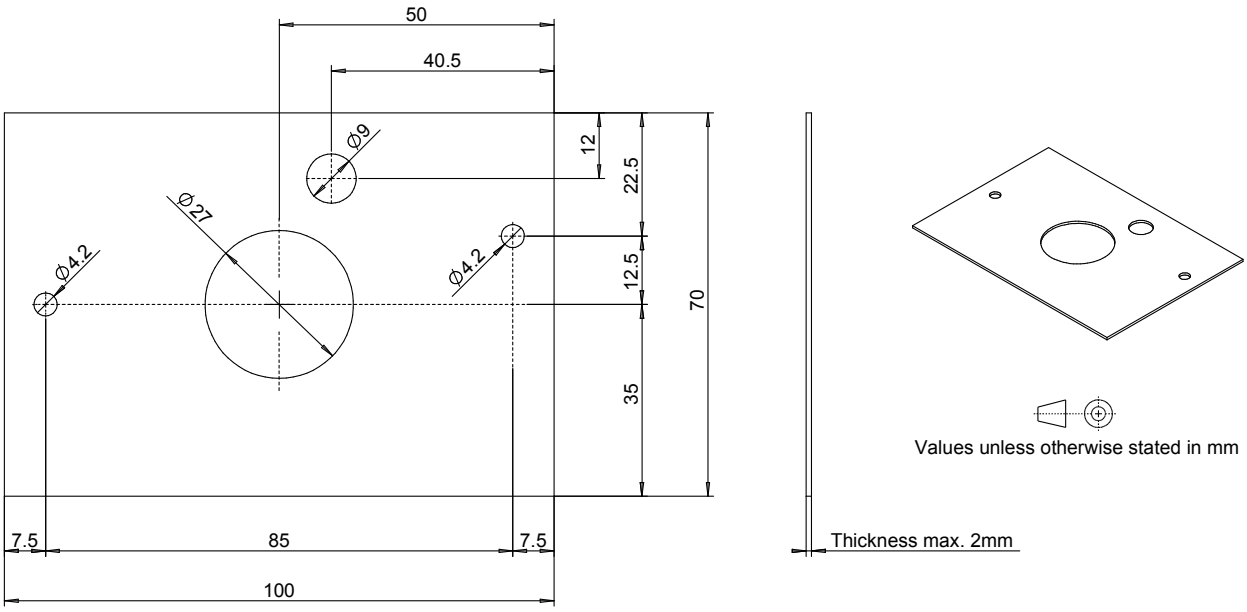


Figure 44: Mechanical dimensions LED cover for face ID and near-field applications. See also Figure 17

5.9. I²C command syntax

The command section / window uses the following syntax for accessing the DME 660 (epc660 chip) by I²C commands:

1. Write to direct address:
Command: w <Direct_address> <Hex value> ---> Response: <01>
Example:
Command: w 92 34 ---> Response: 01

2. Read from direct address:
Command: r <Direct_address> ---> Response: <Hex value>
Example:
Command: r 92 ---> Response: <Hex value>

3. Write to EEPROM (values is active only after power-up or reset)
Command: w 11 <EEPROM_address> <Hex value> ---> Response: <02>
Example:
Command: w 11 92 34 ---> Response: 02

4. Read from EEPROM, data only
Command: w 11 <EEPROM_address> ---> Response: <02>
Command: r 12 ---> Response: <Hex value>
Example:
Command: w 11 92 ---> Response: 01
Command: r 12 ---> Response: <Hex value>

5. Read from EEPROM, EEPROM address and data
Command: w 11 <EEPROM_address> ---> Response: <02>
Command: r11 02 ---> Response: <EEPROM_address> <Hex value>
Example:
Command: w 11 92 ---> Response: 01
Command: r 11 02 ---> Response: 92 <Hex value>

6. 3D TOF - A guideline to 3D-TOF sensors that work

The book «3D-TOF – A guideline to 3D-TOF sensors that work», by Beat De Coi, provides the important ingredients to make TOF systems work first-time-right. In order to support the engineers with comprehensive documentation and tools about theory, background and application information, it is enclosed in this evaluation kit package.

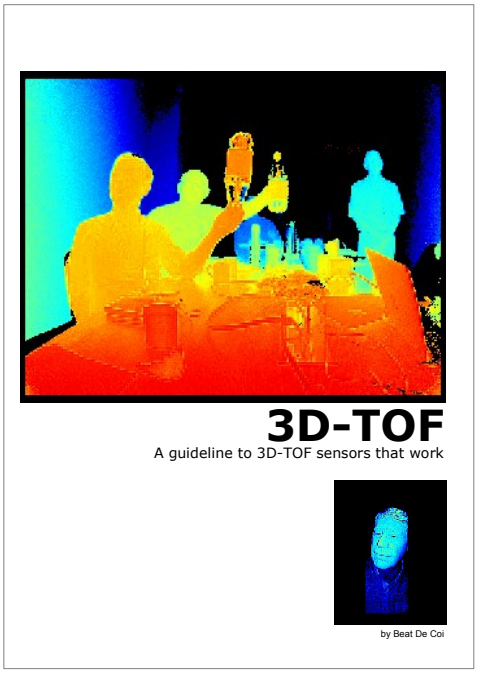


Figure 45: The comprehensive TOF book

On 200 pages, all relevant topics about to understand the background and how to implement a TOF System are presented in a very comprehensive way. In addition, lots of useful system design information are published, like the reflectivity of more than 50 different materials, the spectral power of sunlight (day and night), optical power calculation, eye safety considerations, and so on.

The book is available only with the evaluation kit or as TOF Developer Conference attendee, refer to www.espros.com.

7. Maintenance and disposal

7.1. Maintenance

The components of the device do not need regular maintenance. A functional check is recommended each time the device is taken into operation:

- Check the mounting position and the detection area of the sensor with respect to the operational conditions. Also check that there is no hazardous situation.
- From time to time, clean the lens with a soft towel and with a little soapy water to remove dust or dirt.

7.2. Disposal

Disposal should be done using the most up-to-date recycling technologies for electronic components according to the local regulations and laws. The design and manufacture of the kit's components are done in compliance with the RoHS legal regulations. Traces of dangerous materials may be found in the electronic components, but not in harmful quantities.

8. Addendum

8.1. Related documents

- Datasheet epc660, ESPROS Photonics Corp.
- Application note AN10_Calibration_and_Compensation, ESPROS Photonics corp.
- Application note AN11_DME_660_Photobiological_Safety_Analysis, ESPROS Photonics corp.
- Application note AN12_TOF_data_improvement_toolbox, ESPROS Photonics corp.
- BeagleBone Hardware Specs and Material, BeagleBone Black wiki
- BeagleBone Black System Reference Manual, BeagleBoard.org
- BeagleBone Black, Document No. 450-5500-001 (Schematics), BeagleBoard.org

8.2. Links

www.espros.com

www.beagleboard.org

www.pointcloud.org - Point Cloud Library (PCL)

www.pdal.io - Point Data Abstraction Library (PDAL)

www.opencv.org - OpenCV (OpenSource Computer Vision)

8.3. Licenses

We appreciate the use of the following open source or free software in our tools and respect the large amount of work the owners have done:

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- **Qt-4.8**: http://www.gnu.org/licenses/old-licenses/lgpl-2.1.html
  Copyright (C) 2012 Nokia Corporation
- **Qwt-6.1:** http://qwt.sourceforge.net/qwtlicense.html
  Copyright (C) 1997 Josef Wilgen & Copyright (C) 2002 Uwe Rathmann under **Qwt License, Version 1.0**
- **QwtPlot3D**: http://qwtplot3d.sourceforge.net/web/navigation/license.txt
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