General Description

The DME 502 is a standalone multi-shot fast gated dual channel camera engine with a resolution of 320x240 pixel (QVGA). It is a highly integrated camera system with a wide field of view (FOV). The operating range is up to 10m on white objects. The camera system is a combination of a epc502 sensor board including a lens system, an LED illumination board and a BeagleBone Black host controller board. Even for mobile devices, only a few additional components are needed to integrate this camera, e.g. in a housing.

The host controller operates the epc502 in all available operation modes and reads the pixel values over the TCMI communication. The controller reads the imager data and delivers the results to an external computer via its integrated API. It is also possible to operate the DME 502 as a standalone sensor system. In this case, application software can be downloaded and run on the BeagleBone Black board also by using the full software framework like the operating system and the API kernel.

129 fps full pixel-field dual channel images are delivered by the epc502 camera chip in maximal configuration. By using the advanced operation modes, this can be boosted up to more than 1'000 images per second! The high degree of integration lays base for straight-forward system integration with minimal part count. The extremely high sensitivity of the optical front end allows to operate with a low power illumination subsystem which reduces the power consumption of the overall system significantly.

The camera comes with a fully documented SDK based on open-source SW and HW.

Features

- 320 x 240 pixel (QVGA)
- Single (Count 1 image only) or dual channel mode (Count 1 image and Count 2 image)
- Single shot or multi shot
- Free programmable acquisition timing per shot
- Minimum delay time and minimum count window of 12.5ns
- Multi-shot repetition rate down to 62.5ns
- Wide field of view H94° x V69°
- Low power consumption
- Robust and stable
- High speed USB or ETHERNET interface
- Linux server with API kernel

Applications

- Fluorescence life time imaging (FLIM)
- Nanosecond resolution imaging
- Time-resolved imaging
  e.g. fluorescence, phosphorescence, luminescence
- Time domain based 3D TOF imaging (LIDAR)
- Laser gated imaging (LGI), burst illuminated imaging (BIL)

Figure 1: DME 502

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 502 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 corresponds to the datasheet DME 502 to avoid damage of the DME 502 or cause danger for humans.

Cable-tripping: Place the DME 502 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.

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 502 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 502 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 502 and its software may only be be used in accordance of the datasheet DME 502

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

Limited warranty - Loss of warranty
The DME 502 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 epc502 : www.espros.com → Downloads → Datasheets → Chips.

Download the actual Datasheet DME 502: www.espros.com → Downloads → Datasheets → Camera_and_Modules

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

Table of Contents

2. The DME 502 camera module

2.1. System overview

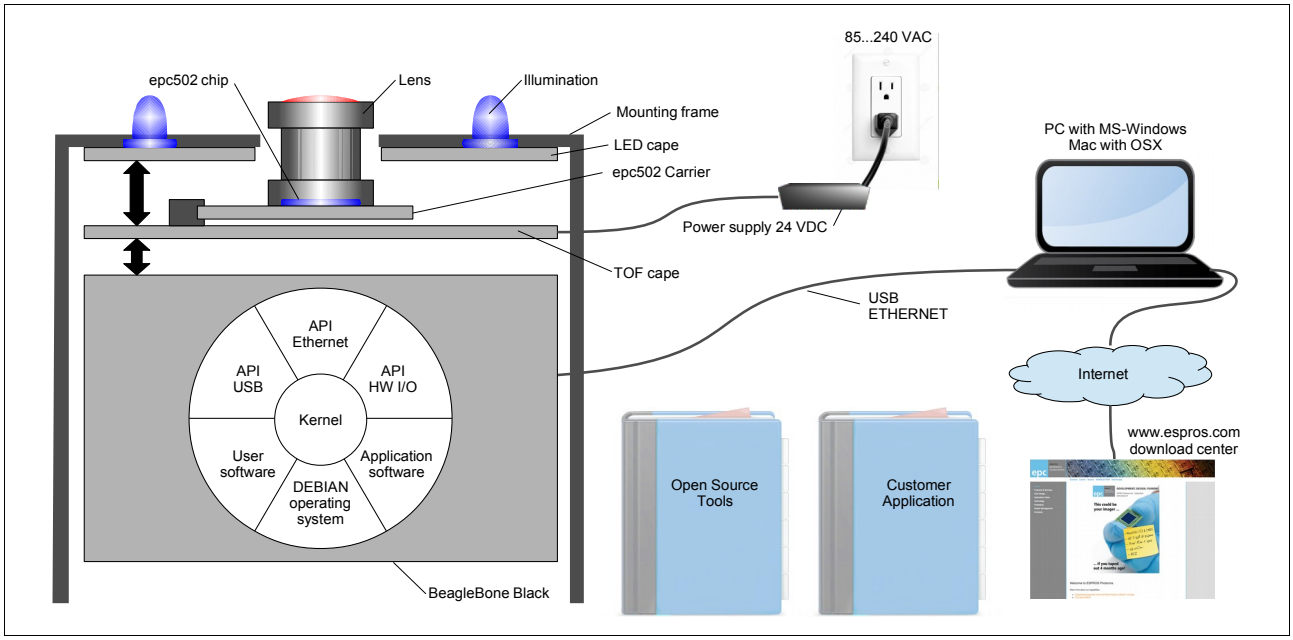

Figure 2: System overview

The DME 502 is a general purpose camera module based on the epc502 chip:

- The camera is based on a BeagleBone Black (BBB) Linux computer board.
- The TOF cape board communicates with the BBB and carries the epc502 Card Edge Connector Carrier board with the epc502 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 kernel manages the camera. Data for further processing is available on APIs (application programming interface) for USB, Ethernet interfaces or hardware I/O. It opens the world for using open source tools or creating own customer applications.

2.2. Scope of Delivery

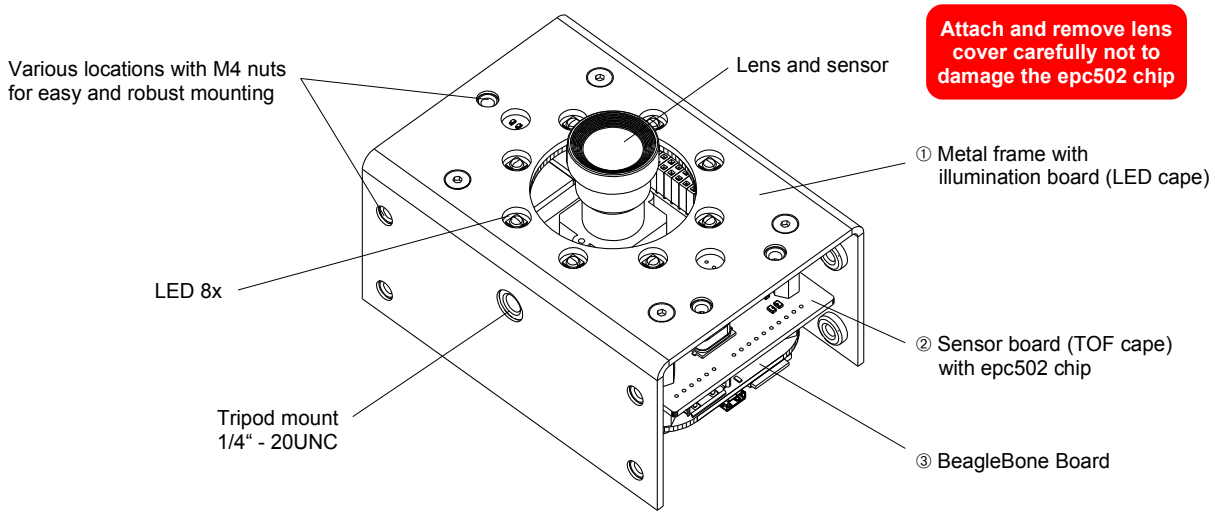

Figure 3: DME 502 overview

2.2.1. Bill of Material

No.	Designation	Remarks
①	Metal frame with camera/tripod mount 1/4” - 20UNC	Use only the 1/4” - 20UNC or the M4 tread inserts for mounting the camera
	LED cape: Illumination board	on Metal frame
②	TOF cape: Sensor board	on LED cape
	epc502-CSP68 chip (P/N P100 348) assembled on card edge connector carrier (P/N P100 350)	on TOF cape
	Optical bandpass filter e.g. infrared filter 860nm	included in lens holder (P/N P100 410)
	Lens holder, M12-Mount with 860nm filter (P/N P100 410)	on epc502 card edge connector carrier board. Filter specifications: see Datasheet epc-bp-860.
	Lens for DME 502 (P/N P100 295): - FOV: H94°, V69° - Lens with non-linear distortion - optimized for NIR - EFL 4.1mm (center) - F2.0 - 1/2" - M12 mount	on lens holder, including lens cover other lens types upon request
③	BeagleBone Black board	Host controller

2.2.2. Documentation

Designation	Remarks
Datasheet DME 502	available at www.espros.com / Downloads
Datasheet epc502	available at www.espros.com / Downloads
Application and configuration software	use the epc502 Evaluation Kit for accessing licensed corresponding tools and software development kit (SDK).

Table 1: Bill of material of the delivery

3. Ordering Information

Part Number	Part Name	Remark	RoHS compliance
P100 368	DME 502-94º/10m	completely assembled, tested and calibrated	Yes

Accessories:

Part Number	Part Name	Remark	RoHS compliance
P100 350	epc502-000 Card Edge Connector Carrier	epc502 on chip carrier without optical filter	Yes
P100 295	Lens FOV 122°, 1/2", M12	Lens for DME 502: - FOV: H94°, V69° - Lens with non-linear distortion - optimized for NIR - EFL 4.1mm (center) - F2.0 - 1/2" - M12 mount	
P100 410	Lens holder, M12-Mount with 860nm filter		
	Optical bandpass filter	included in lens holder	

Table 2: Ordering Information

Support and technical contact: info@espros.com

4. Technical Data

4.1. Recommended operating conditions

(T_A = 25°C, V_{SUPPLY} = 24V, object reflectivity 90%, unless otherwise stated)

Parameter	Description		Min.	Typ.	Max.	Units	Comments
V_{SUPPLY}	Supply voltage		21.6	24	26.4	VDC	
V_{PP}	Ripple on the supply voltage V_{SUPPLY}				0.25	V_{PP}	Peak value must not be-low min. and not above max. supply voltage
I_{SUPPLY}	Supply current	Idle		0.10		A	after power up
		Imaging, actively illuminated		0.25		A	25 fps, t_{INT} = 1 ms
	Image resolution		320 x 240			Pixel	
FOV	Field of view		H94 x V69			°	with lens P/N P100 295
λ_{LED}	Operating wavelength		850			nm	Illumination LEDs
A_{PIXEL}	Photosensitive area			20 x 20		µm	1 pixel
A_{SENSOR}	Photosensitive area			6.4 x 4.8		mm	320 x 240 pixel
CG	Conversion gain			0.01026		LSB/e-	
H_v	Optical sensitivity			57'508		$\frac{LSB}{Lux/sec}$	@ λ = 630nm
S	Grayscale sensitivity (conversion rate)			61.5		$\frac{nW/cm^2}{LSB}$	@ λ = 850nm, Integration time = 103 µsec.
$t_{INTB\_MGA, MGB}$	Basic integration time for MGA, MGB (Shutter time)		12.5ns		819.2µs		Total integration time = basic integration time x number of cycle repeti-tions
t_{FLASHB}	Basic flash time		12.5ns		819.2µs		Total illumination time = basic flash time x number of cycle repetitions
	Delay times START-FLASH, START-MGA, MGA–MGB, MGB–END.		12.5ns		819.2µs		Refer to Figure 5
	Cycle time		62.5ns				
t_{REP}	Number of cycle repetitions		1		65'535		
d	Operating range		0.00		10.0	m	Measured with an object that has a size at least the size of the pixel (d_{PIX-EL}). It is depending on the integration time t_{INT} and the object reflectivity.
Out	Grayscale data			12		Bit	
A	Amplitude (Measurement output)		0		2'047	LSB	Dynamic range for grayscale measurement
	Data interface		USB 2.0 full speed or Ethernet				
T_{PWR_UP}	Power up time			20		s	
T_A	Operating temperature range		0		60	°C	Ambient

Table 3: Operating conditions

4.2. Optical Power Data

Parameter	Description	Min.	Typ.	Max.	Units	Comments
$E_{e\ PEAK}$	Peak illumination irradiance			372	W/m^2	in 200mm distance to the front surface of the DME 502

Table 4: Optical power data

The analysis of the photo-biological hazards show that the DME 502 emits radiation levels below the safety limits described in EN 62471. The calculated exposure level is below the limit for any exposure time at a distance of 200 mm or more. Therefore, the DME 502 can be assumed to be safe to the eye and skin in terms of the standard and would belong to the open group (RG0).

Refer for details to the report 'DME_660_Photobiological_Safety_Analysis.pdf' which is applicable also for the DME 500. It can be downloaded from the ESPROS website.

4.3. Operating modes

Refer to the Datasheet epc502 and the epc502 Evaluation Kit for detailed description of the operating modes epc502.

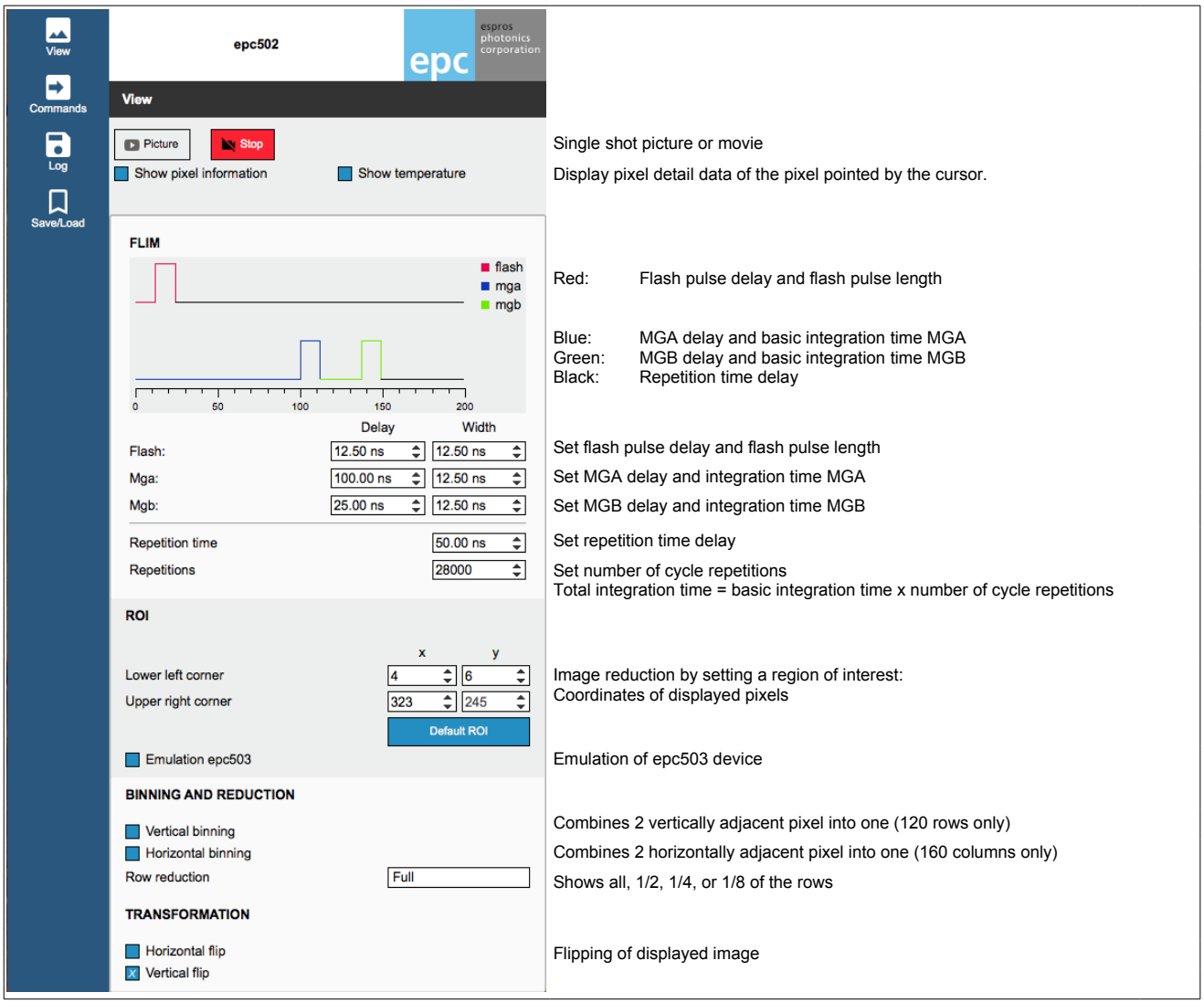

Figure 4: Overview of the operating modes epc502 Evaluation Kit

4.3.1. Measurement Timing

e.g. double shot measurement for FLIM application)

The epcc502 provides a 2 shot measurement with a programmable LED flash pulse (FLIM-flash) and two programmable detection windows (Count 1 and Count2). It allows for example to do FLIM measurements (Fluorescent Life Time Imaging) whereas the decay of the fluorescence is estimated by stimulating a sample with light and measuring by counting windows (shots) the emitted light power. Before readout, this so called FLIM cycle is repeated n times to increasing the signal amplitude.

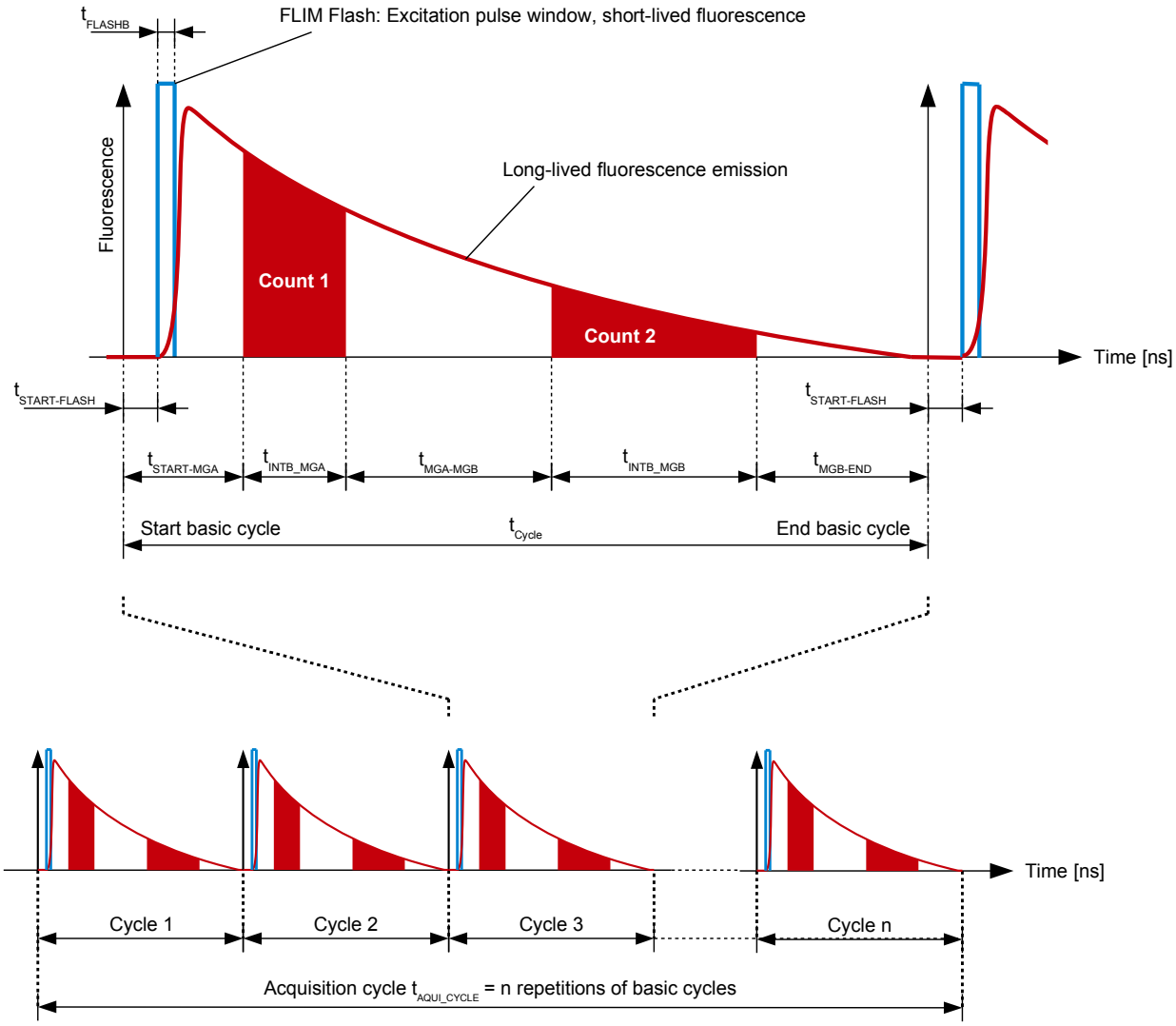

Figure 5: Double shot measurement with stimulation

Figure 6 shows the overall measurement timing diagram. After each acquisition, the two images containing the pixel data has to be read out from the epc502 imager.

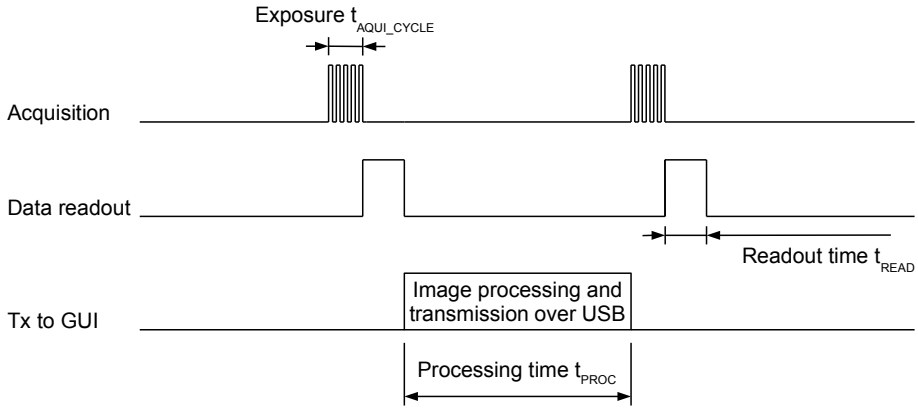

Figure 6: DME 502 measurement timing (standard API)

4.4. Absolute Maximum Ratings

Parameter	Conditions
ESD rating	Not classified. Handle it with the necessary ESD precaution.
Storage temperature range (T_S)	-40°C to +85°C
Relative humidity	15 ... 95%, non-condensing

Table 5: Absolute maximum ratings

5. Interfaces

5.1. Connectors

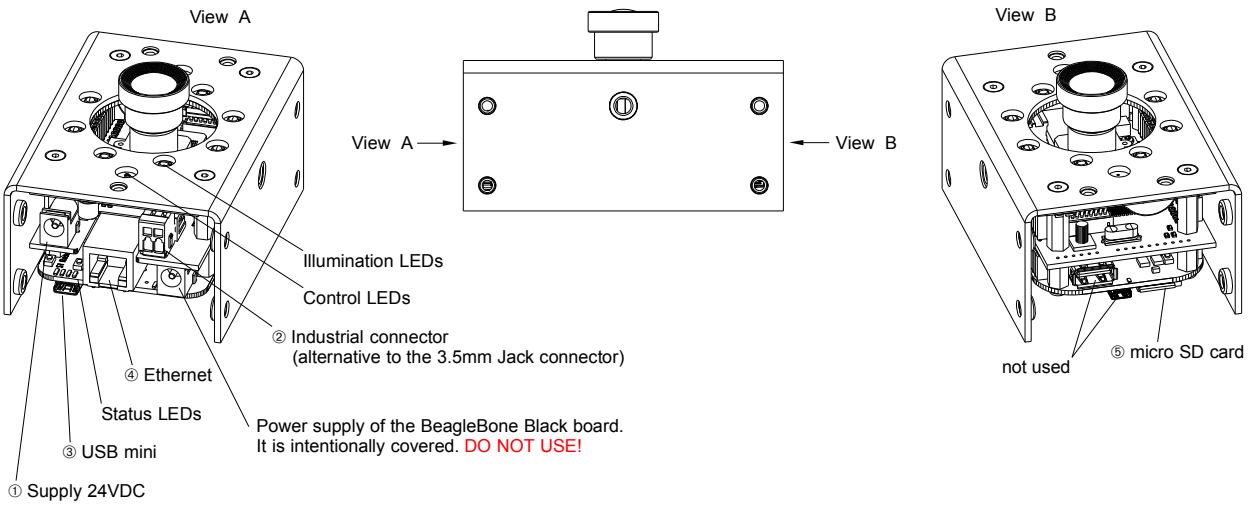

Figure 7: Connectors, status and control LEDs

No.	Connector	Plug	Remarks
①	Supply 24VDC / 2.5A	Power jack 5.0/2.1mm	for supply from power adapter 24VDC / 2.5A
②	Industrial supply	Power jack WAGO 3.5mm	for supply by industrial connection 24VDC / 2.5A
③	USB micro	Micro USB-B	**NEVER CONNECT THE USB CABLE AS LONG POWER IS NOT TURNED ON COMPUTER AND/OR THE CAMERA CAN BE DAMAGED!**
④	ETHERNET	RJ45	
⑤	Micro SD card		

Table 6: Connector list

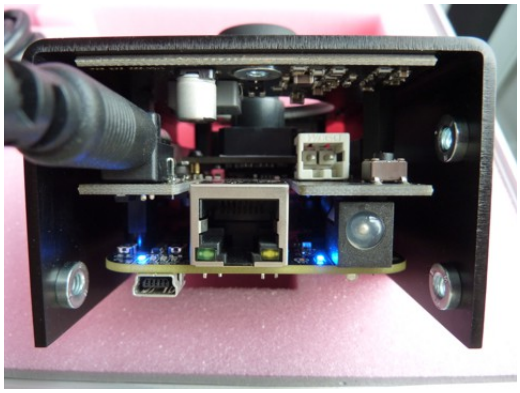

Figure 8: View to the connector side
(USB and ETHERNET not connected)

5.2. Indicators and reset button

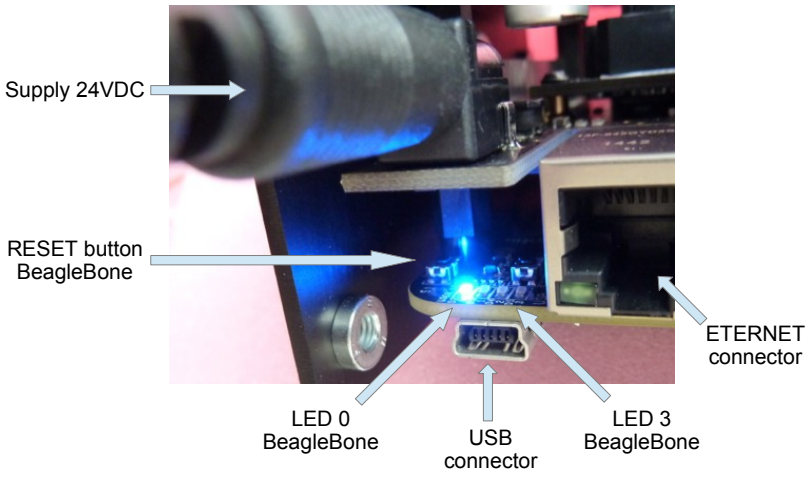

Figure 9: Status LEDs and RESET button

5.2.1. Status LEDs

Status	LED 0	LED 1	LED 2	LED 3	Remarks
Start-up DME 502 or BeagleBone: The blue status LEDs start flashing	☒	☒	☒	☒	After power up or RESET. Startup procedure of the board operating system. For details refer to the BeagleBone manual
After around 20s: Boot epc502 chip					
Trying to boot the epc502 chip	☒	☒	☒	■	Wait until LED 0 only (most left) is flashing only. LEDs 1 to 3 shall be off.
READY for handling requests	☒	☐	☐	☐	Server successfully started on DME 502. Start communicating with the BeagleBone Black server by using either Ethernet or USB.
Regular operation:					
BUSY: Handles request of single command or video	☒	☐	☐	■	
READY again	☒	☐	☐	☐	
Error message:					
Caught signal (Error), application closed	☒	■	■	■	Error detected by API. Reset the BeagleBone.

Table 7: Blue status LEDs on BeagleBone, refer to Figure 9

Notes:
☐ LED off
☒ LED flashing
■ LED on

5.2.2. Monitoring LEDs

Red control LEDs on LED Cape, visible from the frontside; refer to Figure 7:

- D12: On if the LED cape is powered e.g. imaging mode. **Safety advise: Be careful, IR LEDs are active during exposure.**
  Off during modes having not an active illumination e.g. image mode without active illumination.
- D13: On during integration period (exposure) independent of selected mode.

5.2.3. Reset button on BeagleBone

Resets the DME 502 . Instead of the this button, the terminal command, as described in the "Readme" of the GUI source, can be used.

5.2.4. Reset button on TOF cape

Do not use. Resets the epc502 chip only. Lost of the synchronization with the BeagleBone board.

6. Mechanical Properties

6.1. Part list

No.	Part name	Qty.
1	BeagleBone Black Rev. C	1
2	Illumination board: LED cape	1
3	Distance sleeve M3/18mm, hole/hole, PA	4
4	Distance sleeve M3/12mm, bolt/hole, PA	4
5	Screw - cylinder head, cross recess, M3x6	4
6	Metal frame	1
7	Nut self-clinching	2
8	Sunk screw, M3x8	4
9	Lens FOV 122°, 1/2", M12 (P/N P100 295)	1
10	Connection Cable	1
11	Lens holder, M12-Mount with 860nm filter	1
12	Sensor board: TOF Cape	1
13	Screw - cross recessed, M1.6x3	2
14	Mounting pillar	2
15	Screw - cross recessed, M2x5	2
16	Female header Dip, 2.54, 180°	1
17	epc502 Card Edge Connector Carrier	1
18	5.0/2.1mm DC Power Jack 24VDC / 2.5A	1
19	Industrial supply female plug	1
20	Industrial supply male connector	1
21	Micro SDHC card 16GB, programmed	1

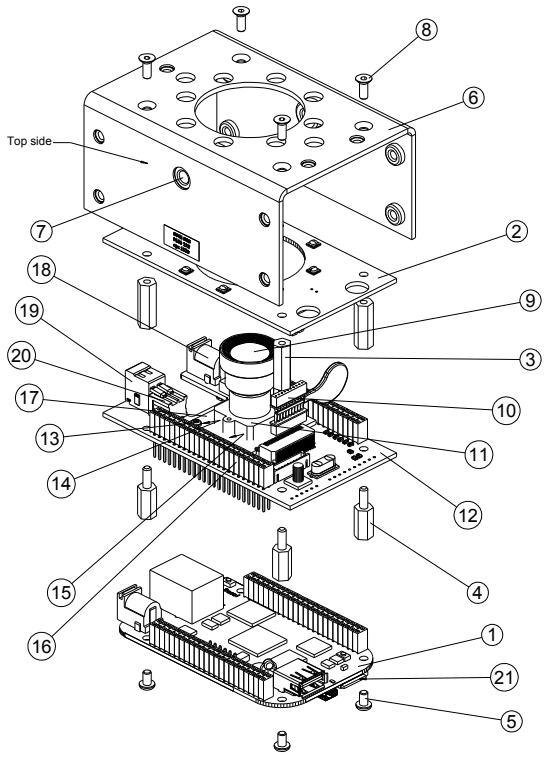

Figure 10: Part list and exploded view

6.2. Mechanical / Optical Properties

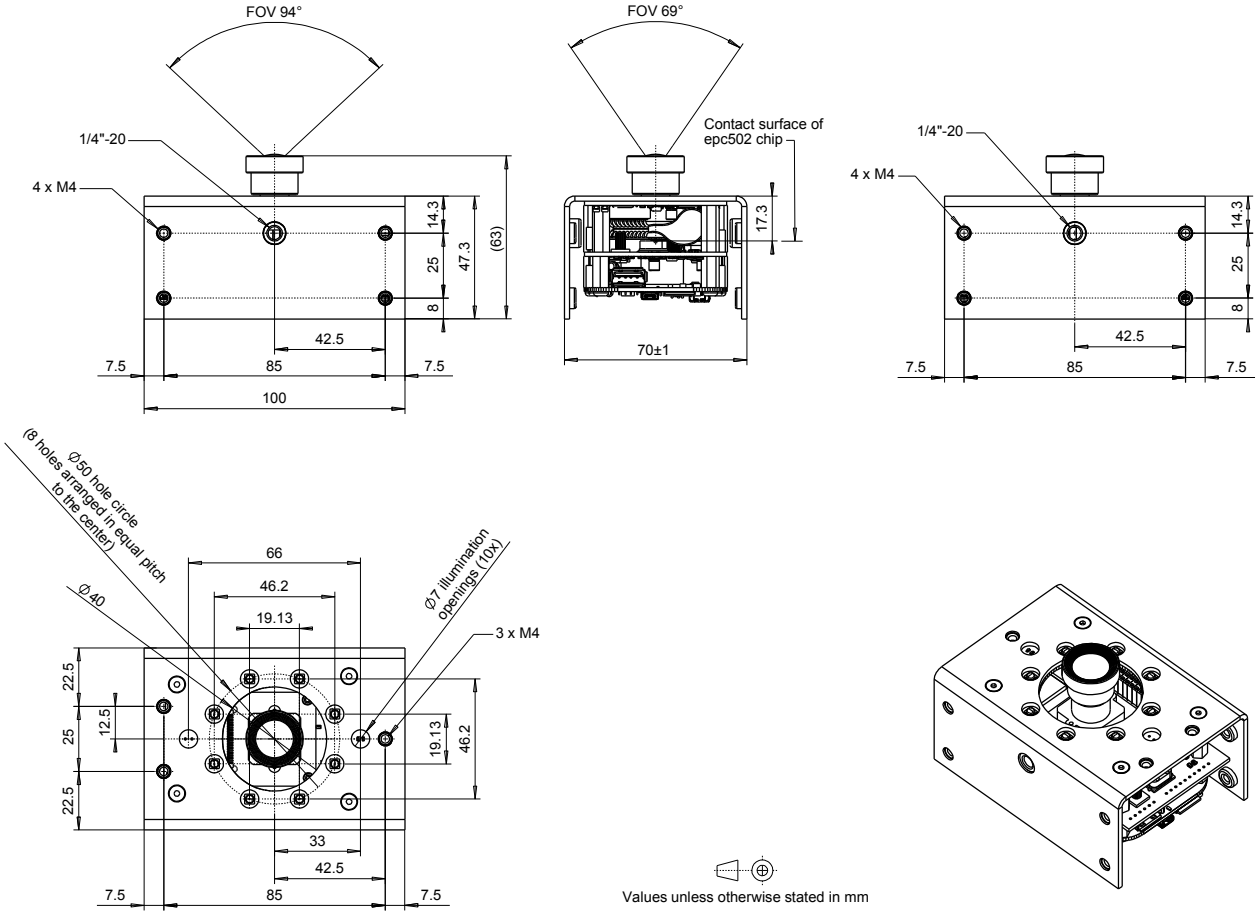

Figure 11: Reference dimensions of the optical axis and illumination

7. Electrical Circuits

Note: The DME 502 uses the DME 660 hardware in combination with an epc502 chip instead of an epc660 chip.

7.1. epc502 on Card Edge Connector Carrier

7.1.1. Schematics

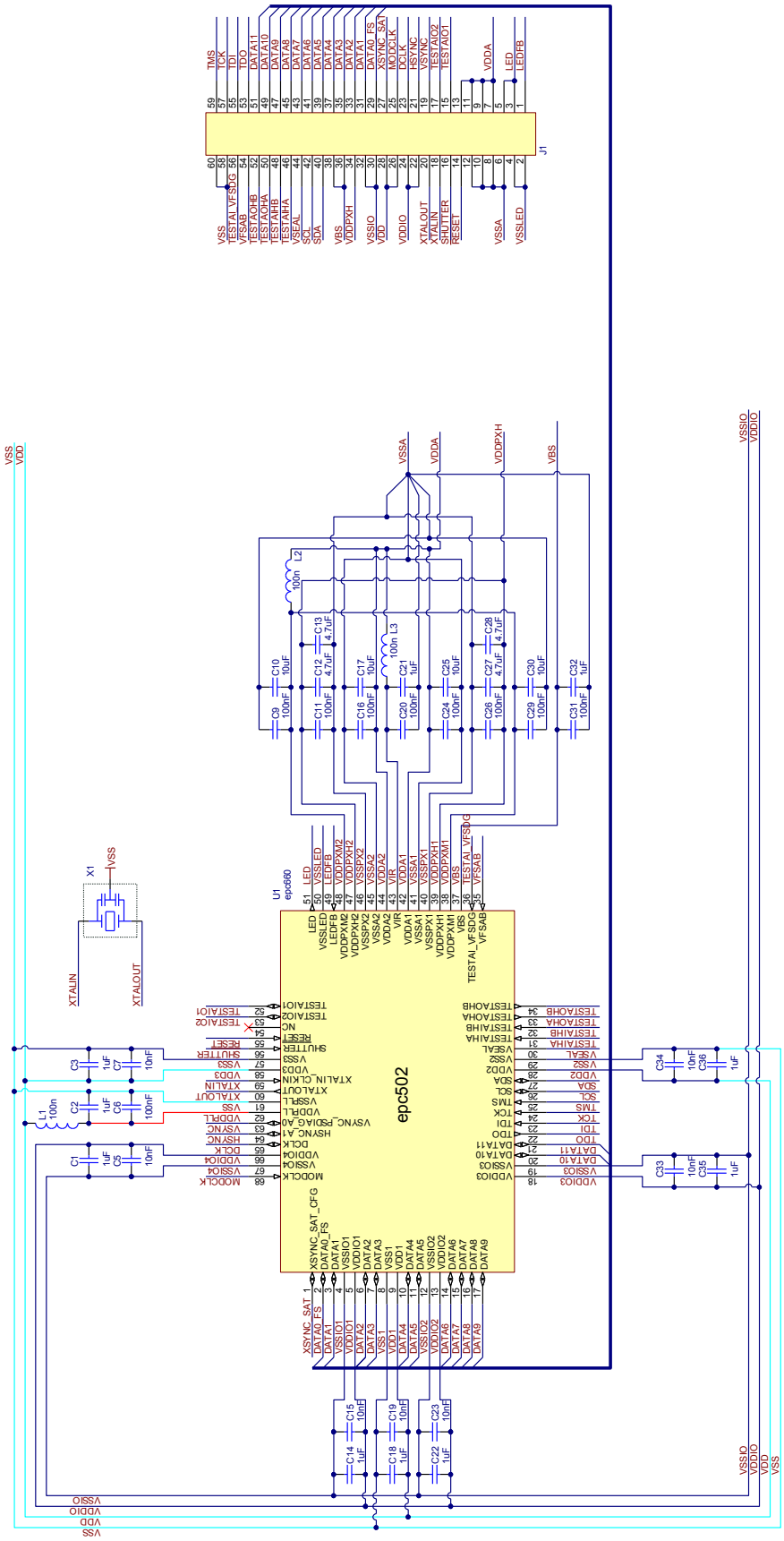

Figure 12: Schematic

7.2. PCB Layout

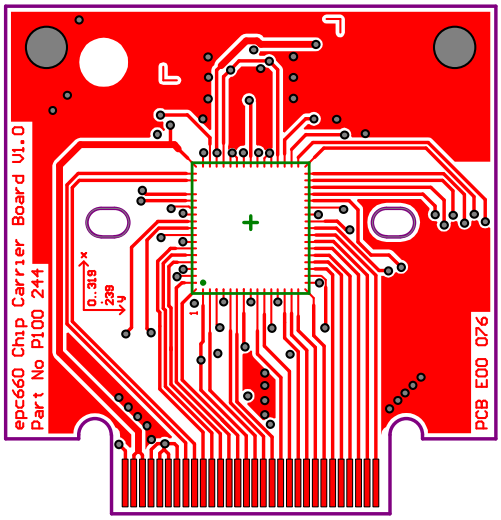

Figure 13: PCB layout top

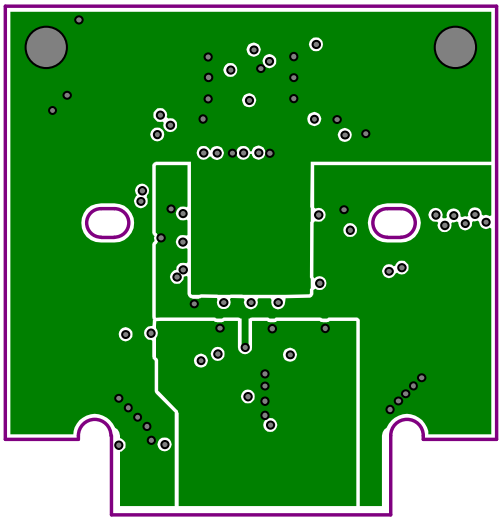

Figure 14: PCB layout top-middle

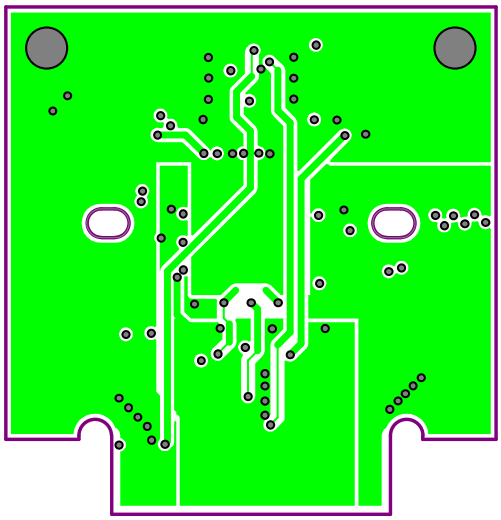

Figure 15: PCB layout bottom-middle

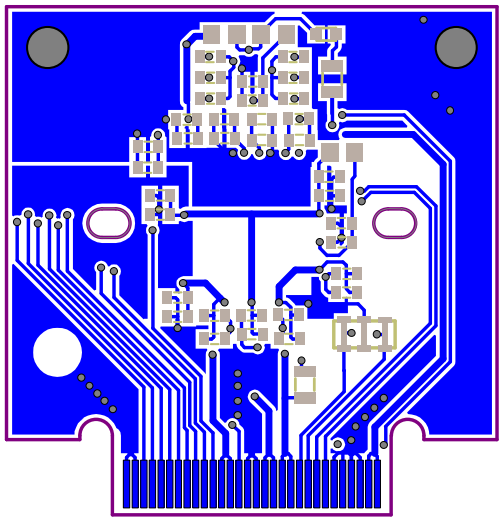

Figure 16: PCB layout bottom

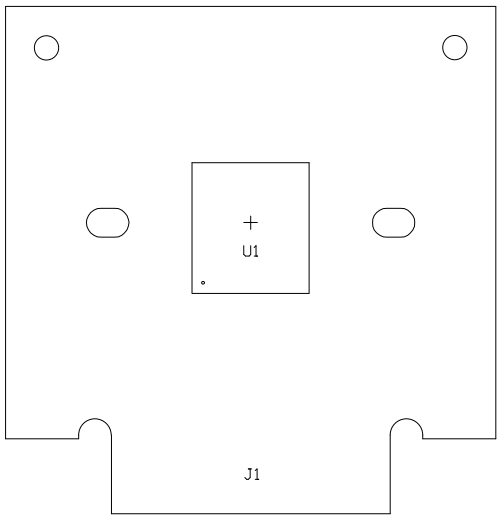

Figure 17: PCB assembly top

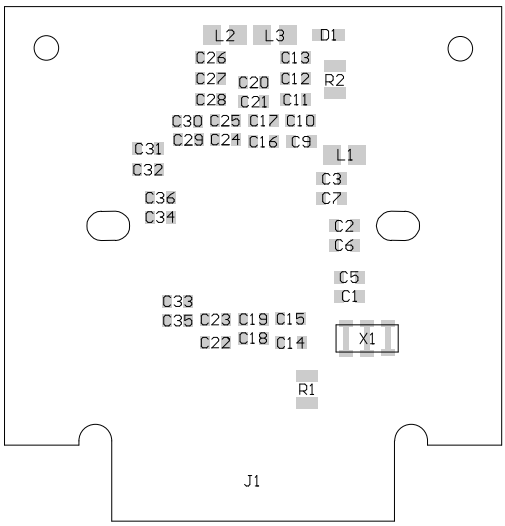

Figure 18: PCB assembly bottom

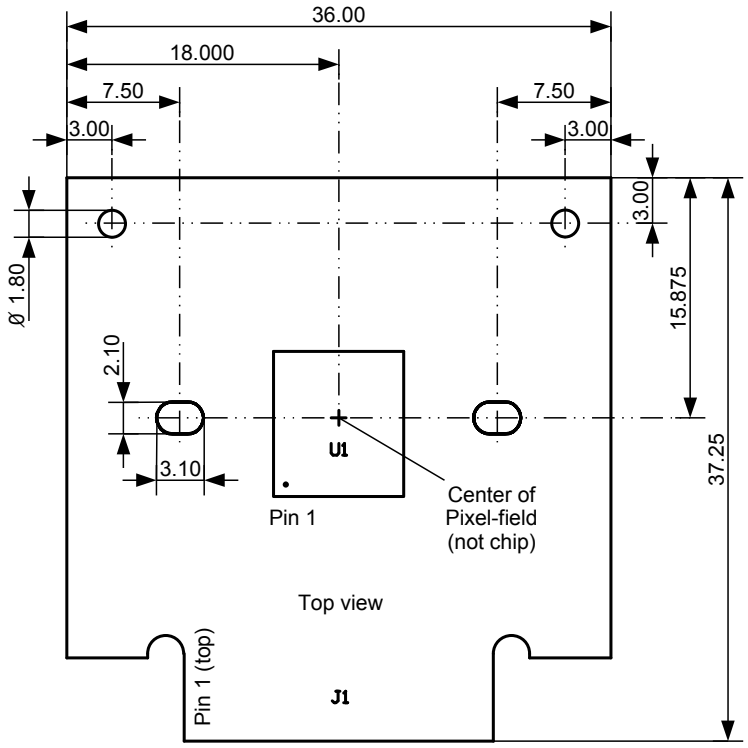

Figure 19: Mechanical dimensions PCB

7.3. Pin Table

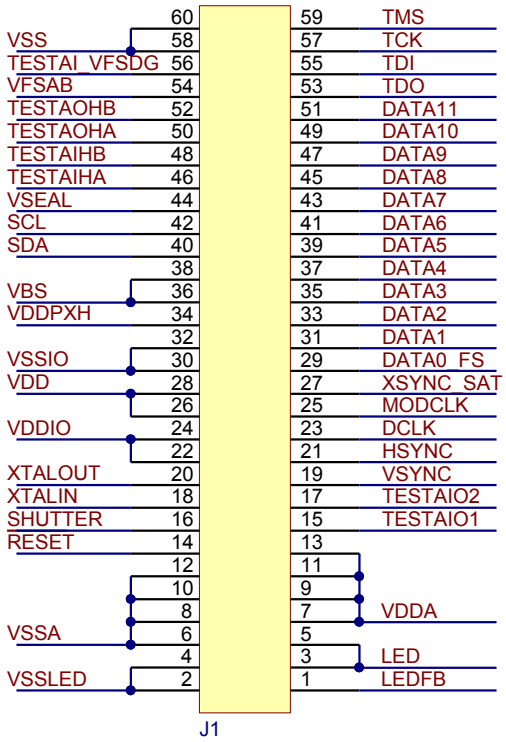

Figure 20: Pin table

8. TOF Cape

8.1. Schematics

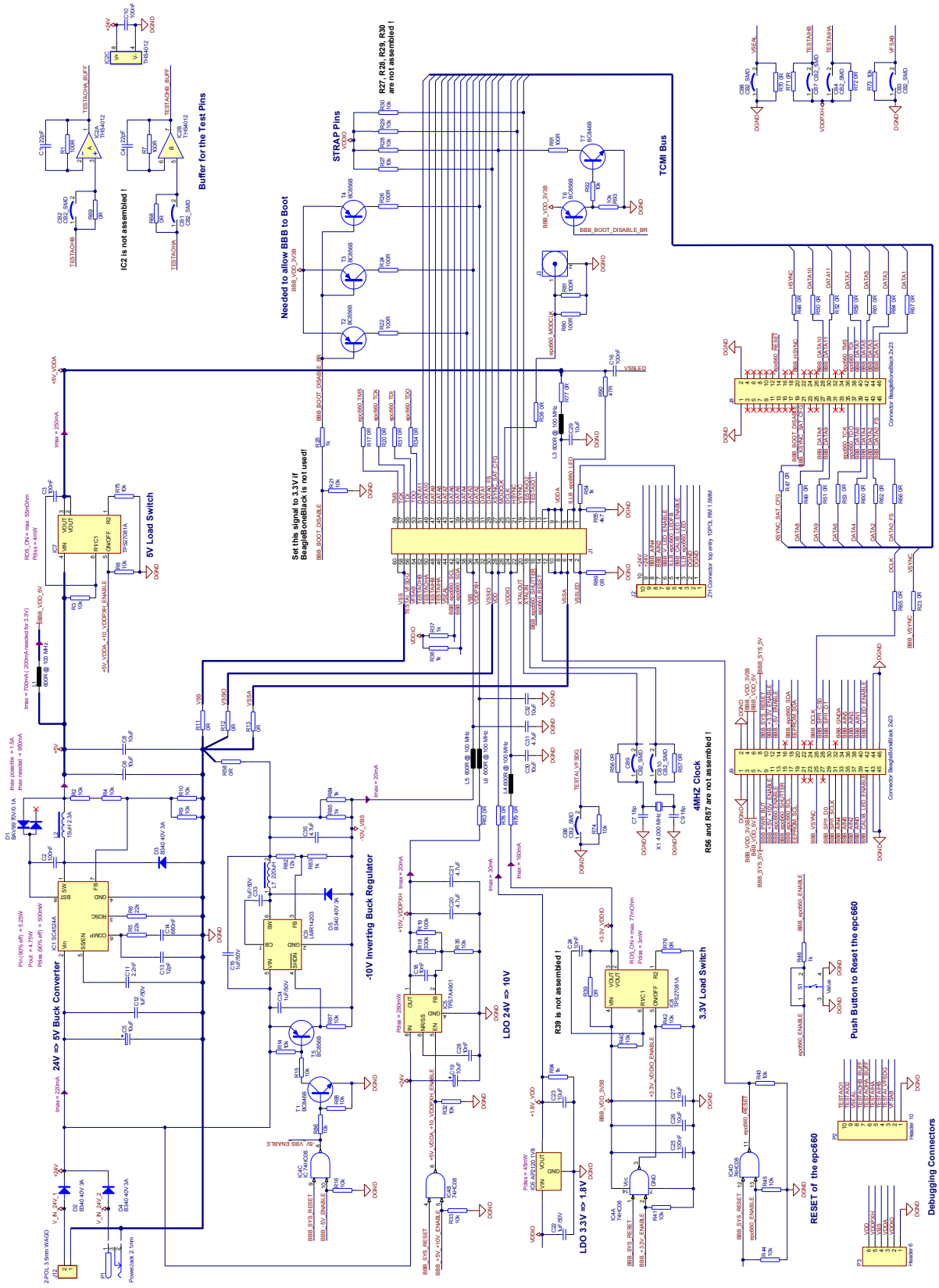

Figure 21: Schematic

8.2. PCB Assembly

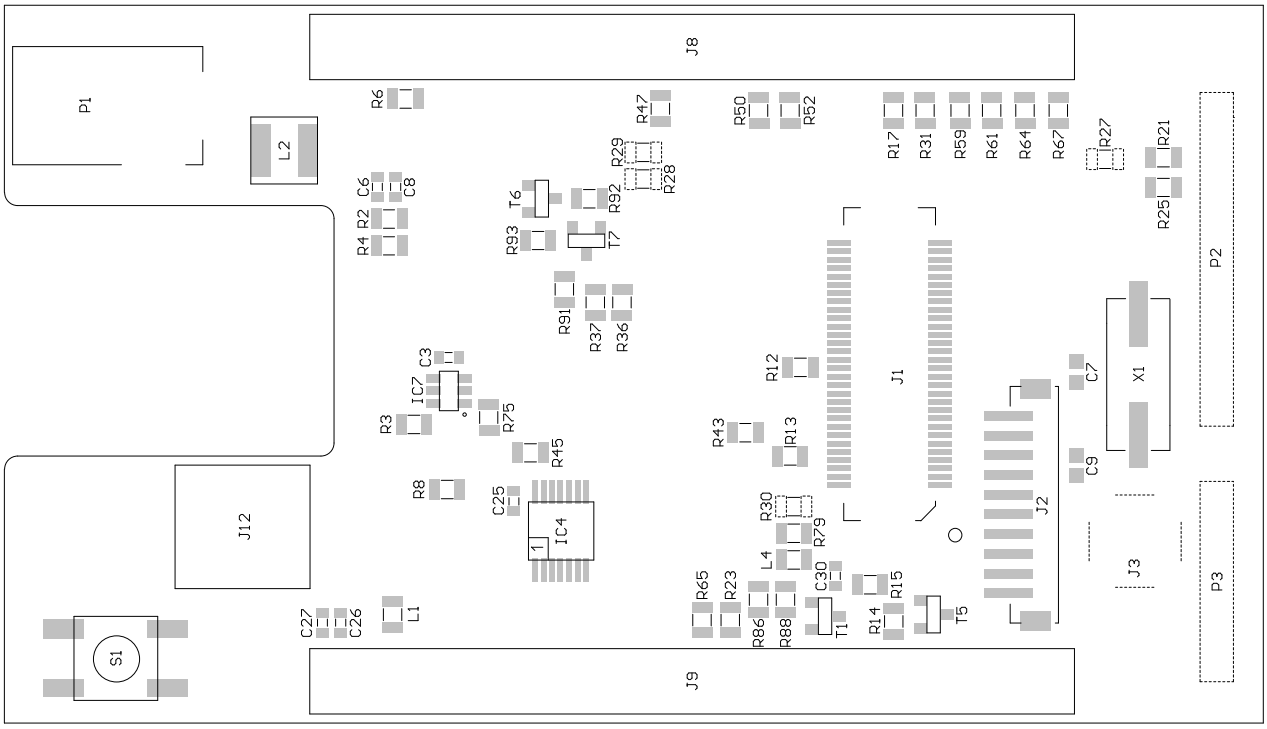

Figure 22: PCB assembly top

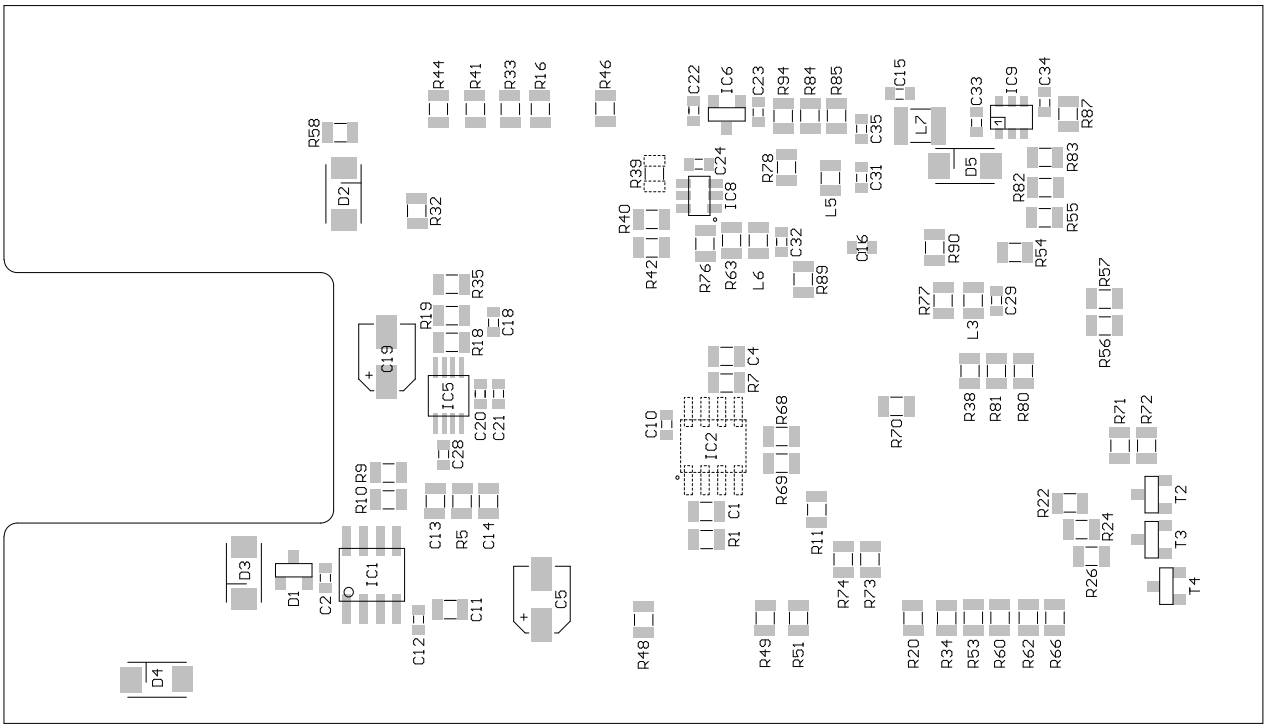

Figure 23: PCB assembly bottom

8.3. Pin Table J8 & J9

Figure 24: Pin table J8 & J9

9. LED Cape

9.1. Schematics

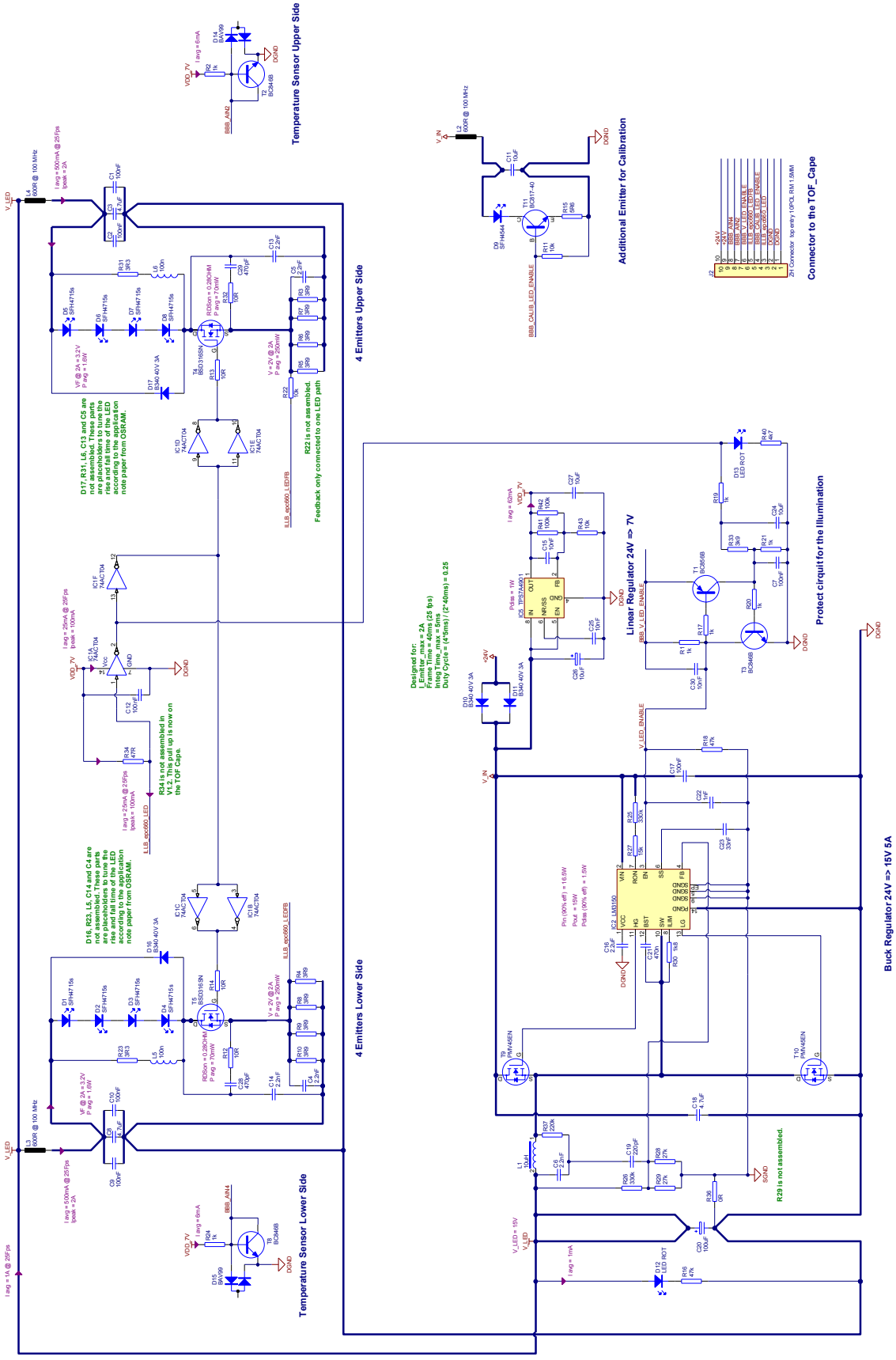

Figure 25: Schematics

9.2. PCB Assembly

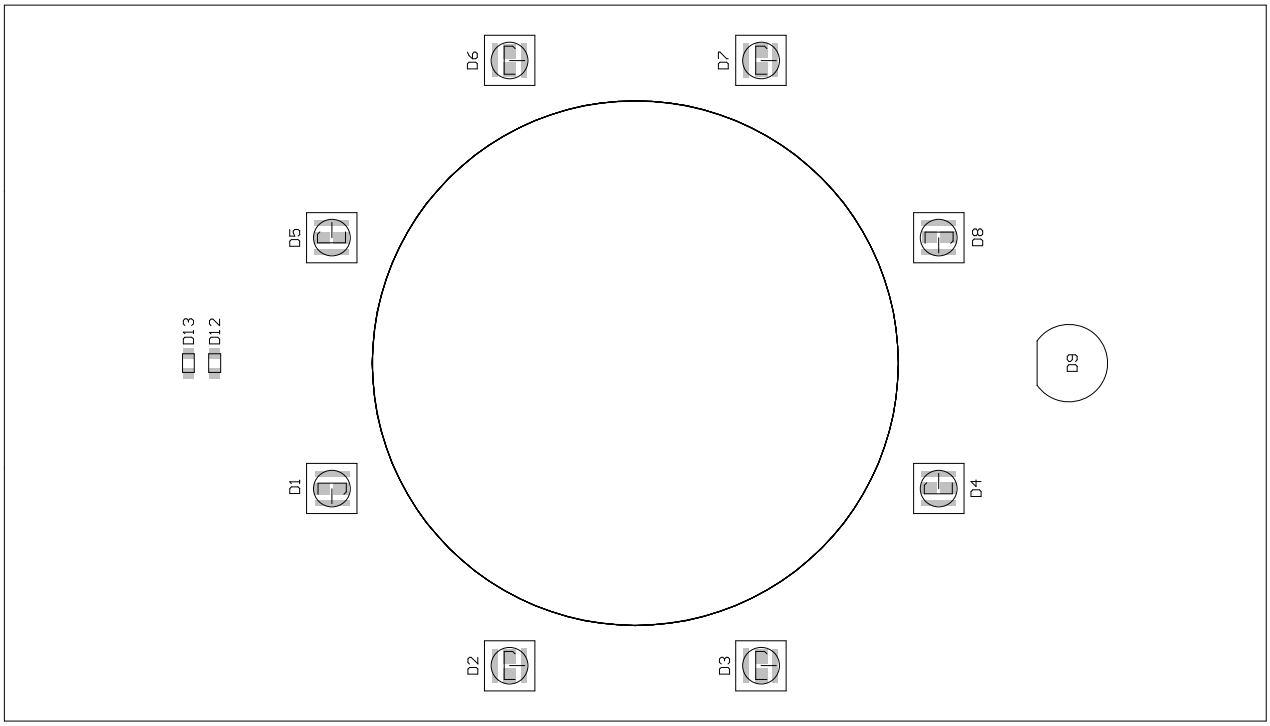

Figure 26: PCB assembly top

D1..D8: Illumination LEDs
D12, D13: Monitoring LEDs (red), refer to chapter 5.2.2, Monitoring LEDs

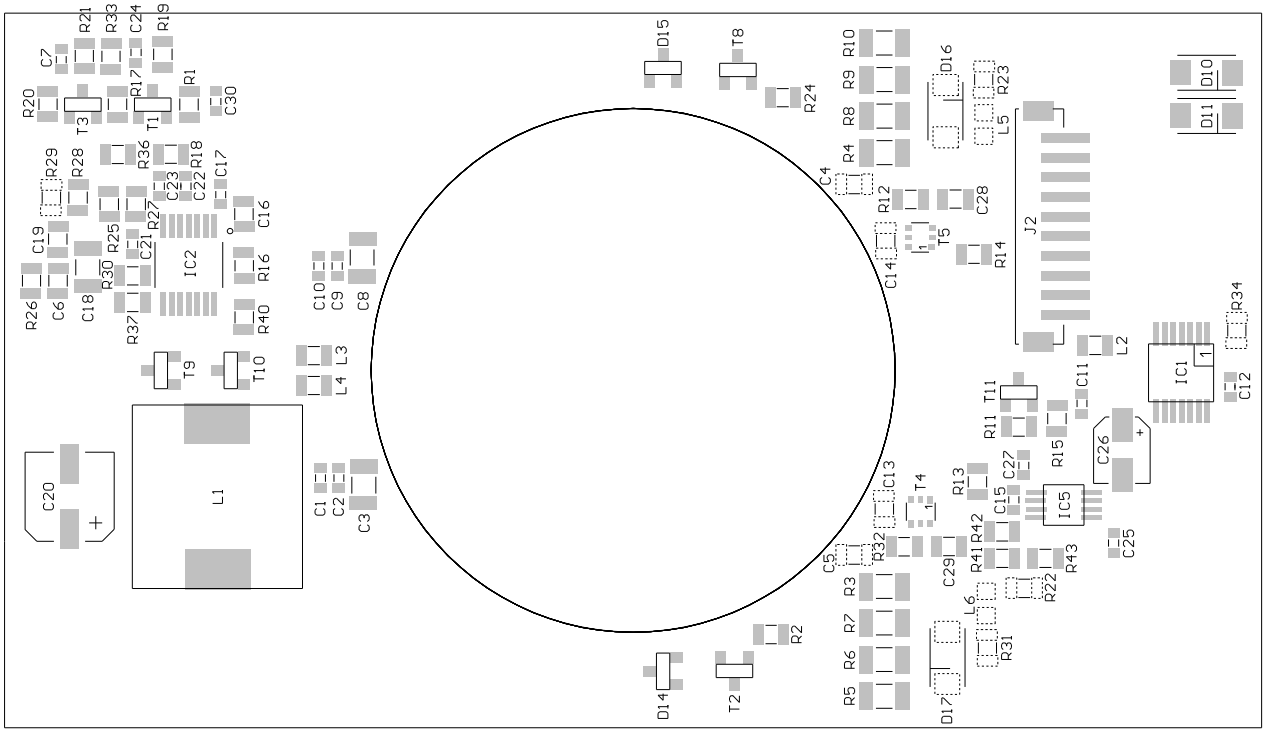

Figure 27: PCB assembly bottom

10. BeagleBone Black Board

10.1. System Overview

- Processor: AM335x 1GHz ARM® Cortex-A8
- 512MB DDR3 RAM, 4GB 8-bit eMMC on-board flash storage
- 3D graphics accelerator, NEON floating-point accelerator, 2x PRU 32-bit micro controllers
- USB client for power & communications, USB host, Ethernet
- Software Compatibility: Debian, Android, Ubuntu, much more
- Open-source tools for different applications available

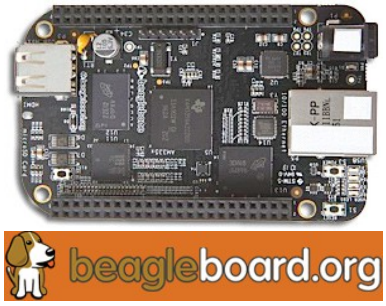

Figure 28: The BeagleBone Black board

10.2. Modification on BeagleBone board

The BeagleBone board is modified the following way for working properly in combination with the DME TOF cape.

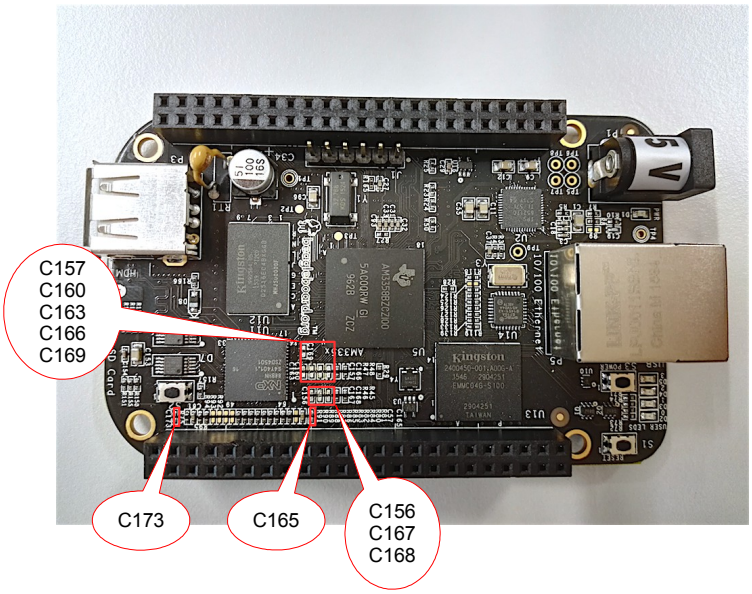

Figure 29: Marked capacitors are removed/disassembled from the Beagle Bone board top side

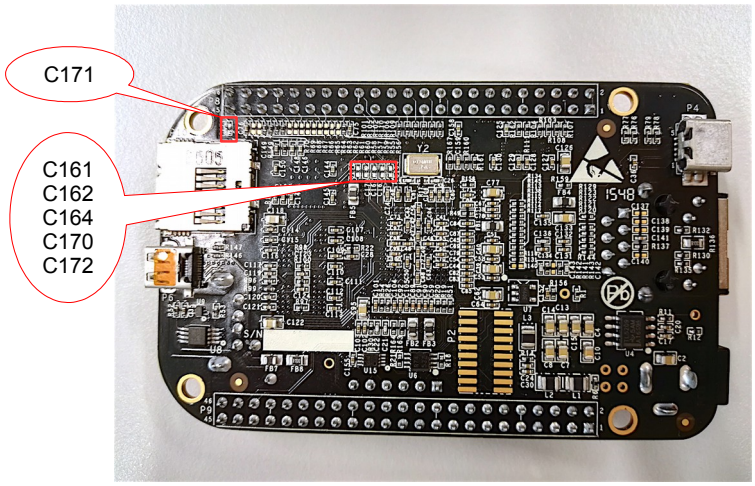

Figure 30: Marked capacitors are removed/disassembled from the Beagle Bone board bottom side

10.3. Documentation

Technical description of the BeagleBone Black board can be downloaded from www.beagleboard.org.

- BeagleBone Hardware Specs and Material, BeagleBone Black wiki
- BeagleBone Black System Reference Manual, BeagleBoard.org, 2014
- BeagleBone Black, Document No. 450-5500-001 (Schematics), BeagleBoard.org, 2014

11. Installation and Setup

11.1. Mechanical fixation

The DME 502 has various mounting options provided by the metal frame:

- On each long side
  - one tripod mount 1/4” - 20UNC, refer to Figure 3
  - four nut M4
- On top side: three nut M4

Use the options only to attach the DME 502 to a housing, a tripod or something else. Never use the threaded pillars or attache something directly to one of the PCB. You may damage the PCB.

11.2. Setup of the DME 502

The DME 502 can be operated by using the GUI software provided with the epc502 Evaluation Kit. The setup is described in the QUICK START GUIDE.

11.3. Software 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 epc502 chip, application interfaces (API), etc. They are available by contac-t-ing ESPROS by email at info@espros.com. The same way, the user can update the DME 502 (BeagleBone board) by using this service.

11.4. Exchange of epc 502 Card Edge Connector Carrier

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

- Power off the DME 502 and remove cables
- Remove the BeagleBone board
- Remove the TOF cape
- Remove the locking screws from the epc502 Card Edge Connector Carrier
- ⚠ Softly remove the epc502 Card Edge Connector Carrier. The epc502 chip can be destroyed when excessive force is applied.
- Remove lens holder
- Attach the lens holder to the new epc502 Card Edge Connector Carrier
- ⚠ Softly insert the new epc502 Card Edge Connector Carrier
- Insert the locking screws for the epc502 Card Edge Connector Carrier
- Install the TOF cape
- Install the BeagleBone board
- ⚠ First power on the DME 502
- Connect the USB cable
- Download and install the latest server software according the Readme.txt
- Start the epc502 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 502 with this new chip carrier

12. epc502 Evaluation Kit

There is an evaluation kit available which supports the development of own applications on the DME 502 in terms of the evaluation of the optical performance parameters.

12.1. Scope of Delivery

Figure 31: epc502 Evaluation Kit overview

No	Pieces	Designation	Remarks
①	1	Toolbox	
②	1	DME 502-94°/10m	P100 368; 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 502
⑦	1	Camera Tripod	
⑧	1	Toolbox belt	
⑨	1	epc502 Evalkit Quick Start Guide	also available at www.espros.com/Downloads
		Datasheet DME 502	available at www.espros.com/Downloads
		Datasheet epc502	available at www.espros.com/Downloads
		Application and configuration software, SDK	Use the epc502 Evaluation Kit for accessing licensed corresponding tools and software development kit (SDK).

Table 8: Bill of material of the delivery

12.2. Ordering Information

Part Number	Part Name	Remarks
P100 366	epc502 Evaluation Kit EU & US	Power plug EU Europlug (CEE7/16, 2 pole) & US adapter

Table 9: Ordering information epc502 Evaluation Kit

Figure 32: DME 502 on tripod

Figure 33: epc502 Evaluation Kit

Figure 34: DME 502 tripod mounting

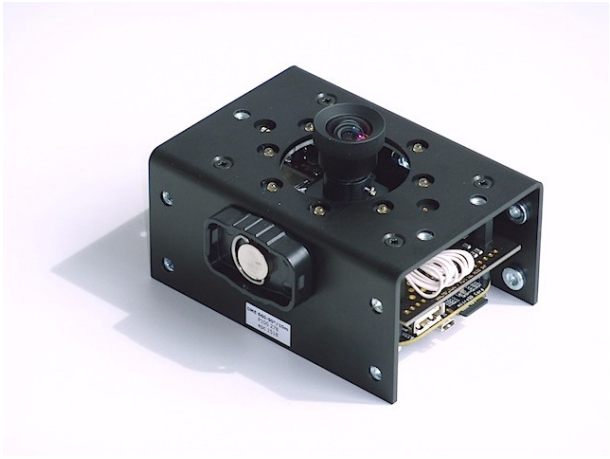

Figure 35: DME 502 with quick release fastener of the tripod

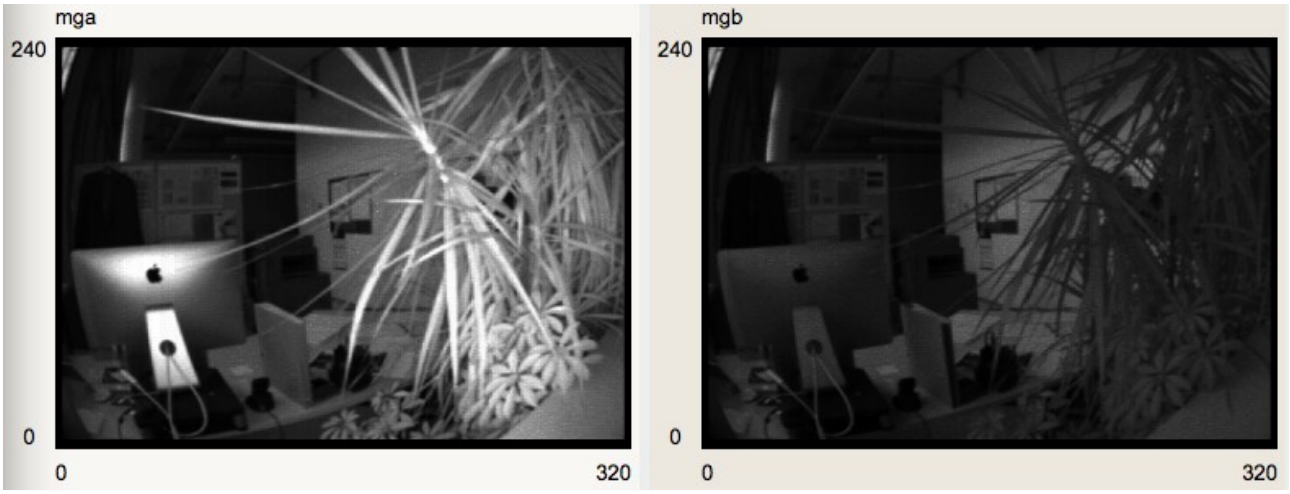

Figure 36: Pictures MGA and MGB

13. Maintenance and disposal

13.1. 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.

13.2. 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.

14. Addendum

14.1. Related documents

- Datasheet epc502 , 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

14.2. Links

www.espros.com

www.beagleboard.org

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

14.3. 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:

- **Putty**: http://www.chiark.greenend.org.uk/~sgtatham/putty/licence.html
  Copyright (C) 1997-2015 Simon Tatham
- **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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