optris infrared thermometers

Operator's Manual

optris® PI LightWeight kit

IR camera with recording box for flight applications

Optris GmbH
Ferdinand-Buisson-Str. 14
D – 13127 Berlin
Germany

Tel.: +49 30 500 197-0
Fax: +49 30 500 197-10

E-mail: info@optris.de
Internet: www.optris.com

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1 General notes

1.1 Intended use

The optris PI LightWeight kit consists of a miniaturized lightweight Linux computer (Recording box) and a weight-optimized PI400 LW, PI450 LW or PI640 LW infrared camera. The system is ideally suited for radiometric infrared recordings from the air, like for maintenance work and quality inspections of solar and wind power systems and for building thermography.

The Recording box includes a Linux operating system that allows on-flight recording of infrared videos to the maximum speed of the camera.

The optris PI 400 LW, 450 LW or 640 LW measures the surface temperature based on the emitted infrared energy of objects **[►Basics of Infrared Thermometry]**. The two-dimensional detector (FPA - focal plane array) allows a measurement of an area which will be shown as thermal image using standardized color palettes. The radiometric processing of the picture data enables the user to do a comfortable detailed analysis with the software PI Connect retrospectively.

The PI is a precise instrument and contains a sensitive infrared detector and a high-quality lens. The alignment of the camera to intensive energy sources (high power laser or reflections of such equipment, e.g.) can have effect on the accuracy of the measurement or can cause an irreparable defect of the infrared detector.

- Avoid static electricity, arc welders, and induction heaters. Keep away from very strong EMF (electromagnetic fields).
- Avoid abrupt changes of the ambient temperature.
- In case of problems or questions which may arise when you use the infrared camera contact our service department.

Read the manual carefully before the initial start-up. The producer reserves the right to change the herein described specifications in case of technical advance of the product.

1.2 Warranty

Each single product passes through a quality process. Nevertheless, if failures occur contact the customer service at once. The warranty period covers 24 months starting on the delivery date. After the warranty is expired the manufacturer guarantees additional 6 months warranty for all repaired or substituted product components. Warranty does not apply to damages, which result from misuse or neglect. The warranty also expires if you open the product. The manufacturer is not liable for consequential damage or in case of a non-intended use of the product.

If a failure occurs during the warranty period the product will be replaced, calibrated or repaired without further charges. The freight costs will be paid by the sender. The manufacturer reserves the right to exchange components of the product instead of repairing it. If the failure results from misuse or neglect the user has to pay for the repair. In that case you may ask for a cost estimate beforehand.

1.3 Scope of delivery

- IR camera PI400 LW or PI450 LW or PI640 LW (LightWeight) with one lens and fixed mounted USB cable (40 cm)
- Recording box (Linux computer)
- Power supply (100-240 VAC / 24 VDC)
- Power cable (with open ends)
- Video cable bridge (HDMI to micro-HDMI, 16 cm)
- USB 2.0 cable bridge (USB to mini-USB, 15 cm)
- Special USB+video cable for GoPro camera (mini-USB to mini-USB, 30 cm)
- Video cable (stereo mini jack-open ends) including external recording pin
- 32 GB high speed USB 3.0 memory stick
- 32 GB micro SDHC memory card
- CD-ROM including PIConnect software, camera calibration files, documentation
- Rugged outdoor case, IP67
- Operators manual

1.4 Maintenance

Never use cleaning compounds which contain solvents (neither for the lens nor for the housing).

Take care that no foreign substances penetrate into the venting slots of the Recording box.

1.4.1 Cleaning

The housing of the Recording box can be cleaned with a soft, humid tissue moistened with water or a water based cleaner.

Blow off loose particles using clean compressed air. The lens surface can be cleaned with a soft, humid tissue moistened with water or a water based glass cleaner.

2 Technical Data

2.1 Recording box

2.1.1 General specifications

Operating temperature:	0…50 °C
Storage temperature:	-20...75 °C
Relative humidity:	10...95 %, non-condensing
Material (housing):	aluminum
Dimensions:	96 mm x 67 mm x 47 mm (L x W x H)
Weight:	172 g (without the four mounting bricks)
Vibration:	IEC 60068-2-6 (sinus shaped), IEC 60068-2-64 (broad band noise)
Shock:	IEC 60068-2-27 (25 g and 50 g)
Operating system	Linux Ubuntu Mate

2.1.2 Electrical specifications

Power supply:	10 to 48 VDC
Power consumption:	12 W
Cooling:	active via integrated temperature controlled fan
Boards:	ODROID-XU4 + interface board
Processor:	Samsung Exynos5422 (Cortex™ A15 2GHz and Cortex™ A7) Octa core
Hard disc:	eMMC 5.0 HS400 16 GB Flash Storage
RAM:	2 GB LPDDR3 RAM
Ports:	2 x USB 3.0; 1 x USB 2.0; 1 x Mini-USB for a GoPro Hero 3+ and higher; RJ45 Ethernet (Gigabit Ethernet)
	HDMI 1.4a or Mini jack 2.5 mm Video composite (CVBS) PAL-B TV_{out}; 2 x Servo-connector (Uni, Graupner /JR); 2 x 4-screw terminal
Extensions	Micro SDHC card (up to 32 GB, Not exchangeable by user)
Additional functions	5 x Status-LED; Function button

2.2 Camera PI 400 / PI 450 / PI640 LW

2.2.1 General specifications

Environmental rating:	IP40
Ambient temperature:	0...50 °C [PI 400 LW & PI640 LW] / 0...70 °C [PI 450 LW]
Storage temperature:	-40...70 °C [PI 400 LW& PI640 LW]] / -40...85 °C [PI 450 LW]
Relative humidity:	10...95 %, non-condensing
Material (housing):	aluminum, anodized/ plastic
Dimensions:	46 x 56 x 84 - 88 mm (depending on lens)
Weight (incl. lens):	207 g
Cable length USB 2.0):	40 cm
Vibration[1)]:	IEC 60068-2-6 (sinus shaped) IEC 60068-2-64 (broad band noise)
Shock[1)]:	IEC 60068-2-27 (25 g and 50 g)

[1] Used standards:

IEC 60068-1:1988 + **Corr.** 1988 + **A1**: 1992 „Umweltprüfungen - Teil 1: Allgemeines und Leitfaden“	**DIN EN 60068-1**:1995-03
IEC 60068-2-6:2007 „Umgebungseinflüsse - Teil 2-6: Prüfverfahren - Prüfung Fc: Schwingen (sinusförmig)“	**DIN EN 60068-2-6; VDE 0468-2-6**:2008-10
IEC 60068-2-27:2008 „Umgebungseinflüsse - Teil 2-27: Prüfverfahren - Prüfung Ea und Leitfaden: Schocken“	**DIN EN 60068-2-27; VDE 0468-2-27**:2010-02
IEC 60068-2-47:2005 „Umgebungseinflüsse - Teil 2-47: Prüfverfahren - Befestigung von Prüflingen für Schwing-, Stoß- und ähnliche dynamische Prüfungen“	**DIN EN 60068-2-47**:2006-03
IEC 60068-2-64:2008 „Umgebungseinflüsse - Teil 2-64: Prüfverfahren - Prüfung Fh: Schwingen, Breitbandrauschen (digital geregelt) und Leitfaden“	**DIN EN 60068-2-64; VDE 0468-2-64**:2009-04

Figure 1: Used standards

Stress program (camera in operation):

Shock, half sinus 25 g – testing Ea 25 g (acc. IEC 60068-2-27)			
Acceleration	245 m/s^2	(25 g)	
Pulse duration	11 ms		
Number of directions	6	(3 axes with 2 directions each)	
Duration	600 Shocks	(100 Shocks each direction)	
Shock, half sinus 50 g – testing Ea 50 g (acc. IEC 60068-2-27)			
Acceleration	490 m/s^2	(50 g)	
Pulse duration	11 ms		
Number of directions	6	(3 axes with two directions each)	
Duration	18 Shocks	(3 Shocks each direction)	

Vibration, sinus shaped – testing Fc (acc. IEC60068-2-6)			
Frequency range	10-500 Hz		
Acceleration	29.42 m/s^2	(3 g)	
Frequency change	1 Octave/ min		
Number of axes	3		
Duration	1:30 h	(3 x 0.30 h)	
Vibration, broadband noise – testing Fh (acc. IEC60068-2-64)			
Frequency range	10-2000 Hz		
Acceleration	39.3 m/s2	(4,01 g_{RMS}))	
Frequency spectrum	10-106 Hz	0,9610 $(m/s^2)^2/Hz$	(0,010 g^2/Hz)
	106-150 Hz	+6 dB/ Octave	
	150-500 Hz	1,9230 $(m/s^2)^2/Hz$	(0,020 g^2/Hz)

	500-2000 Hz	-6 dB/ Octave	
	2000 Hz	0,1245 $(m/s^2)^2/Hz$	(0,00126 g^2/Hz)
Number of axes	3		
Duration	3 h	(3 x 1 h)	

2.2.2 Electrical specifications

Power Supply:	5 VDC (powered via USB 2.0 interface)
Current draw:	Max 500 mA
Digital interface:	USB 2.0

2.2.3 Measurement specifications

Temperature ranges:	-20...100 °C; 0...250 °C; 150...900 °C
Detector:	UFPA, 382 x 288 pixels (PI4xx) / 640 x 480 pixels (PI640)
Spectral range:	7.5...13 µm
Lenses (FOV):	13° x 10°; 38° x 29°; 62° x 49°; 80° x 58° [PI4xx] / 15° x 11°; 33° x 25°; 60°x 45°; 90° x 66° [PI640]
System accuracy [1]:	±2°C or ±2 %
Temperature resolution (NETD):	PI 400 LW [2]: 0.08 K
	P I450 LW [2]: 0.04 K
	PI640 LW [2]: 0.075 K
Frame rate:	27 & 80 Hz (PI4xx) / 32 Hz (PI640) / 125 Hz (PI640 in VGA sub-frame mode)
Software:	Pre-installed in Linux system

[1] At ambient temperature 23±5 °C; whichever is greater; [2] Value is valid at 40 Hz and 25°C room temperature

2.2.4 Optical specifications

Make sure that the focus of the infrared camera is adjusted correctly. For focusing turn the lens (Fehler! Verweisquelle konnte nicht gefunden werden.).

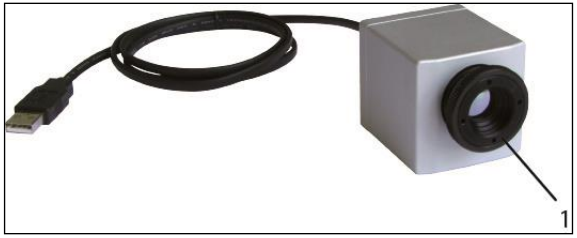


Figure 2: Focusing of the lens (1 – lens)

Different parameters are important if using infrared cameras. They display the connection between the distance of the measured object and the size of the pixel (see

PI 400 / 450 382 x 288 px	Focal length [mm]	Angle	Minimum measurement distance*		Distance to measurement object [m]											
					0.02	0.1	0.2	0.3	0.5	1	2	4	6	10	30	100
O38 Standard lens	15	38° 29° 49° 1.81 mrad	0.2 m	HFOV [m] VFOV [m] DFOV [m] IFOV [mm]	0.024 0.018 0.030 0.1	0.079 0.060 0.099 0.2	0.15 0.11 0.18 0.4	0.21 0.16 0.27 0.5	0.35 0.26 0.44 0.9	0.70 0.52 0.87 1.7	1.39 1.04 1.73 3.4	2.76 2.07 3.46 6.7	4.14 3.11 5.18 10.0	6.9 5.2 8.6 16.7	20.7 15.5 25.9 50.0	68.9 51.7 86.2 166.7
O13 Telephoto lens	41	13° 10° 17° 0.61 mrad	0.5 m	HFOV [m] VFOV [m] DFOV [m] IFOV [mm]					0.12 0.09 0.15 0.3	0.23 0.17 0.29 0.6	0.47 0.35 0.58 1.2	0.94 0.70 1.17 2.5	1.40 1.05 1.75 3.7	2.3 1.7 2.9 6.1	7.0 5.2 8.8 18.4	23.4 17.5 29.2 61.2
O62 Wide angle lens	11	62° 49° 74° 3.14 mrad	0.5 m	HFOV [m] VFOV [m] DFOV [m] IFOV [mm]	0.040 0.030 0.050 0.1	0.136 0.103 0.170 0.2	0.26 0.19 0.32 0.5	0.38 0.28 0.47 0.7	0.62 0.47 0.77 1.2	1.22 0.92 1.53 2.29	2.42 1.83 3.03 4.56	4.83 3.65 6.05 9.11	7.23 5.47 9.06 13.65	12.0 9.1 15.1 22.7	36.1 27.3 45.2 68.2	120.3 90.9 150.8 227.3
O80 Wide angle lens	7,7	80° 56° 97° 3.25 mrad	0.2 m	HFOV [m] VFOV [m] DFOV [m] IFOV [mm]		0.182 0.119 0.218 0.3	0.35 0.23 0.41 0.7	0.84 0.55 1.00 1.6	0.84 0.54 1.00 1.6	1.65 1.08 1.97 3.3	3.29 2.14 3.92 6.5	6.55 4.28 7.83 13.0	9.82 6.41 11.73 19.5	16.4 10.7 19.5 32.5	49.0 32.0 58.5 97.4	163.4 106.6 195.1 324.7

Table 1 & 2).

PI 400 / 450 382 x 288 px	Focal length [mm]	Angle	Minimum measurement distance*	Distance to measurement object [m]												
					0.02	0.1	0.2	0.3	0.5	1	2	4	6	10	30	100
O38 Standard lens	15	38° 29° 49° 1.81 mrad	0.2 m	HFOV [m] VFOV [m] DFOV [m] IFOV [mm]	0.024 0.018 0.030 0.1	0.079 0.060 0.099 0.2	0.15 0.11 0.18 0.4	0.21 0.16 0.27 0.5	0.35 0.26 0.44 0.9	0.70 0.52 0.87 1.7	1.39 1.04 1.73 3.4	2.76 2.07 3.46 6.7	4.14 3.11 5.18 10.0	6.9 5.2 8.6 16.7	20.7 15.5 25.9 50.0	68.9 51.7 86.2 166.7
O13 Telephoto lens	41	13° 10° 17° 0.61 mrad	0.5 m	HFOV [m] VFOV [m] DFOV [m] IFOV [mm]					0.12 0.09 0.15 0.3	0.23 0.17 0.29 0.6	0.47 0.35 0.58 1.2	0.94 0.70 1.17 2.5	1.40 1.05 1.75 3.7	2.3 1.7 2.9 6.1	7.0 5.2 8.8 18.4	23.4 17.5 29.2 61.2
O62 Wide angle lens	11	62° 49° 74° 3.14 mrad	0.5 m	HFOV [m] VFOV [m] DFOV [m] IFOV [mm]	0.040 0.030 0.050 0.1	0.136 0.103 0.170 0.2	0.26 0.19 0.32 0.5	0.38 0.28 0.47 0.7	0.62 0.47 0.77 1.2	1.22 0.92 1.53 2.29	2.42 1.83 3.03 4.56	4.83 3.65 6.05 9.11	7.23 5.47 9.06 13.65	12.0 9.1 15.1 22.7	36.1 27.3 45.2 68.2	120.3 90.9 150.8 227.3
O80 Wide angle lens	7,7	80° 56° 97° 3.25 mrad	0.2 m	HFOV [m] VFOV [m] DFOV [m] IFOV [mm]		0.182 0.119 0.218 0.3	0.35 0.23 0.41 0.7	0.84 0.55 1.00 1.6	0.84 0.54 1.00 1.6	1.65 1.08 1.97 3.3	3.29 2.14 3.92 6.5	6.55 4.28 7.83 13.0	9.82 6.41 11.73 19.5	16.4 10.7 19.5 32.5	49.0 32.0 58.5 97.4	163.4 106.6 195.1 324.7

Table 1: Table with examples showing what spot sizes and pixel sizes will be reached in which distance (PI4xx). For individual configuration there are different lenses available. Wide angle lenses have a radial distortion due to their large opening angle.

PI 640 640 x 480 px	Focal length [mm]	Angle	Minimum measurement distance*	Distance to measurement object [m]											
					0.1	0.2	0.3	0.5	1	2	4	6	10	30	100
O33 Standard lens	18.7	33°	0.2 m	HFOV [m]	0.068	0.13	0.19	0.31	0.60	1.20	2.38	3.57	5.9	17.8	59.3
		25°		VFOV [m]	0.051	0.09	0.14	0.23	0.45	0.89	1.77	2.65	4.4	13.2	44.2
		41°		DFOV [m]	0.085	0.16	0.23	0.38	0.75	1.49	2.97	4.45	7.4	22.2	74.0
		0.91 mrad		IFOV [mm]	0.1	0.2	0.3	0.5	0.9	1.8	3.6	5.5	9.1	27.3	90.9
O15 Tele lens	41,5	15°	0,5 m	HFOV [m]				0.13	0.26	0.52	1.05	1.57	2.6	7.8	26.1
		11°		VFOV [m]				0.10	0.20	0.39	0.79	1.18	2.0	5.9	19.6
		19°		DFOV [m]				0.17	0.33	0.66	1.31	1.96	3.3	9.8	32.7
		0,41 mrad		IFOV [mm]				0.2	0.4	0.8	1.6	2.5	4.1	12.3	41.0
O60 Wide angle lens	10.5	60°	0.2 m	HFOV [m]	0.128	0.25	0.36	0.59	1.17	2.32	4.63	6.94	11.6	34.6	115.4
		45°		VFOV [m]	0.091	0.18	0.26	0.42	0.83	1.66	3.31	4.96	8.3	24.7	82.4
		75°		DFOV [m]	0.157	0.30	0.44	0.72	1.43	2.85	5.69	8.52	14.2	42.6	141.8
		1.62 mrad		IFOV [mm]	0.2	0.3	0.5	0.8	1.6	3.2	6.5	9.7	16.2	48.6	161.9
O90 Super wide angle lens	7.7	90°	0.2 m	HFOV [m]	0.220	0.43	0.63	1.03	2.03	4.04	8.06	12.07	20.1	60.3	200.8
		64°		VFOV [m]	0.138	0.27	0.39	0.64	1.27	2.53	5.05	7.57	12.6	37.8	125.9
		111°		DFOV [m]	0.260	0.50	0.73	1.21	2.39	4.76	9.50	14.24	23.7	71.1	237.0
		2.21 mrad		IFOV [mm]	0.2	0.4	0.7	1.1	2.2	4.4	8.8	13.2	22.1	66.2	220.8

Table 2: Table with examples showing what spot sizes and pixel sizes will be reached in which distance (**PI640**). For individual configuration there are different lenses available. Wide angle lenses have a radial distortion due to their large opening angle.

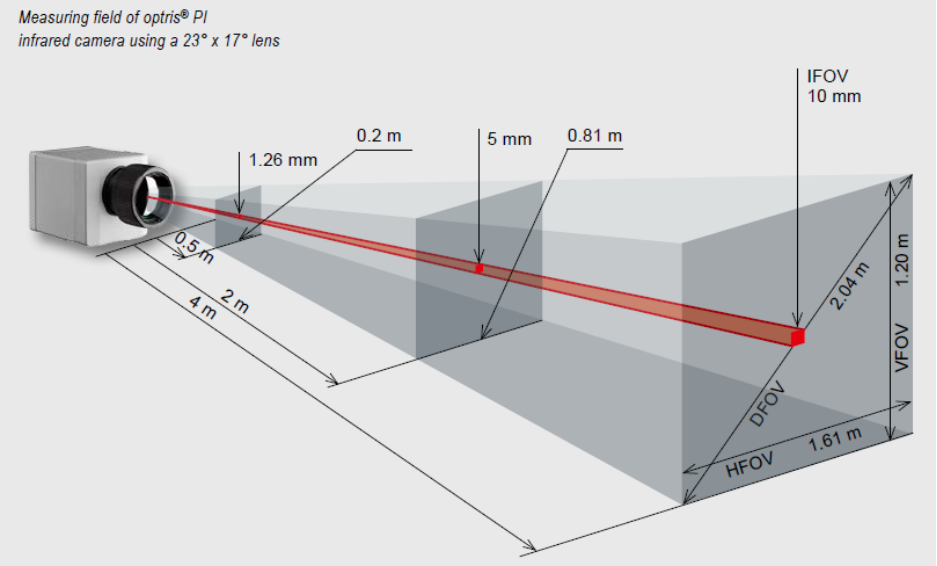


Figure 3: Example of measurement field of the infrared camera PI160 representing the 23° x 17° lens

- **HFOV**: Horizontal enlargement of the total measuring at object level
- **VFOV**: Vertical enlargement of the total measuring at object level
- **IFOV**: Size at the single pixel at object level
- **DFOV**: Diagonal dimension of the total measuring field at object level
- **MFOV**: Recommended, smallest measured object size of 3 x 3 pixel

3 Installation

3.1 Physical installation

The PI 400 LW/ 450 LW / 640 LW are equipped with two metric M4 thread holes on the bottom side (6 mm depth) and can be installed either directly via these threads or with the ¼'' photo tripod mount (also on bottom side). The separate PI camera sensing head can be mounted on the stabilization platform of a drone together with a visual camera (in the picture: GoPro camera). The Recording box can be mounted separately in different directions using the supplied and pre-assembled mounting bricks.

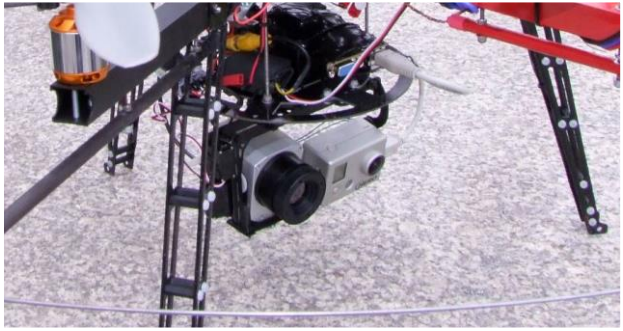


Figure 4: PI LightWeight on a drone together with a GoPro HD camera

3.2 Mechanical Data PI 400/ PI 450 / PI 640 LW

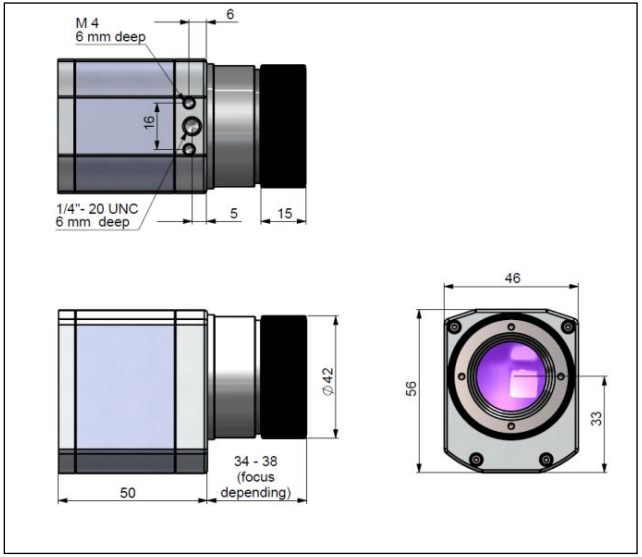


Figure 5: Dimensions PI400/ PI450 / PI640 LW (mm)

3.3 Dimensions Recording box

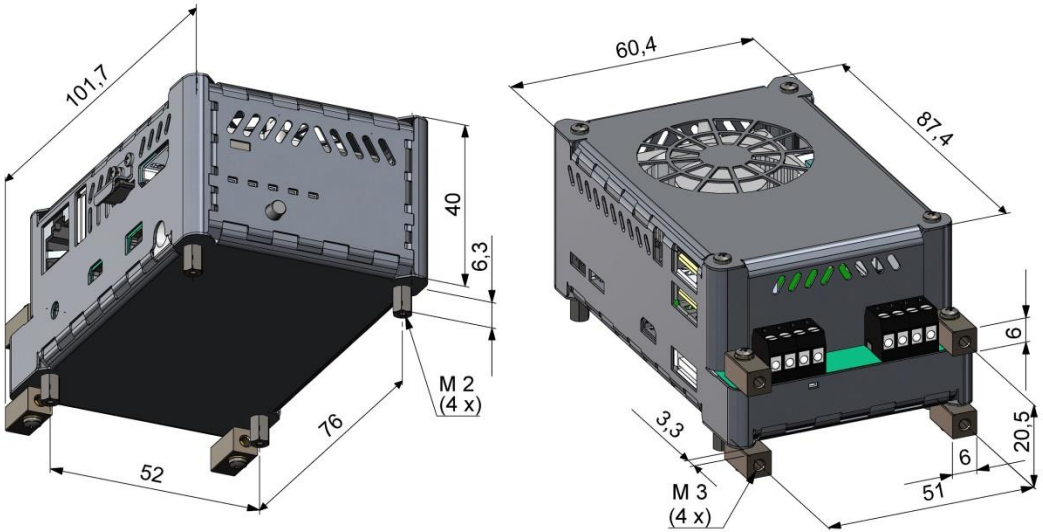


Figure 6: Dimensions Recording box (mm)

3.4 Functional interfaces Recording box

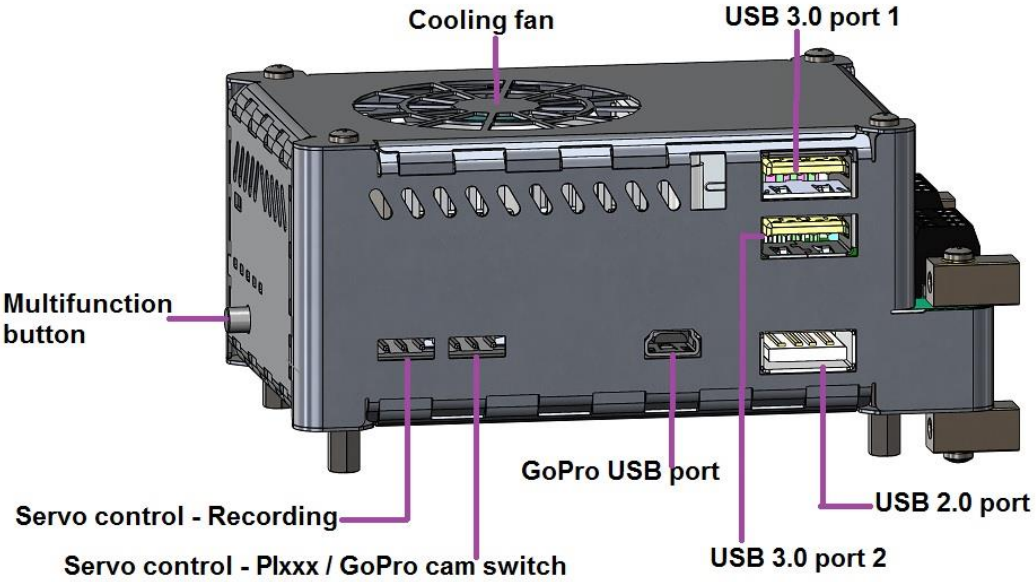


Figure 7: Controls and connections Recording box (1)

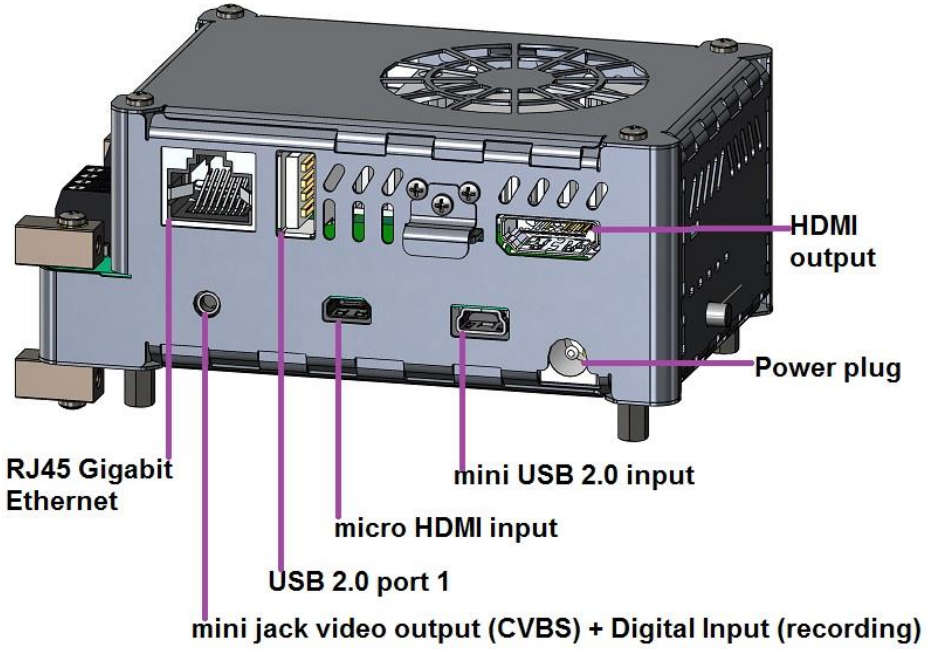


Figure 8: Controls and connections Recording box (2)

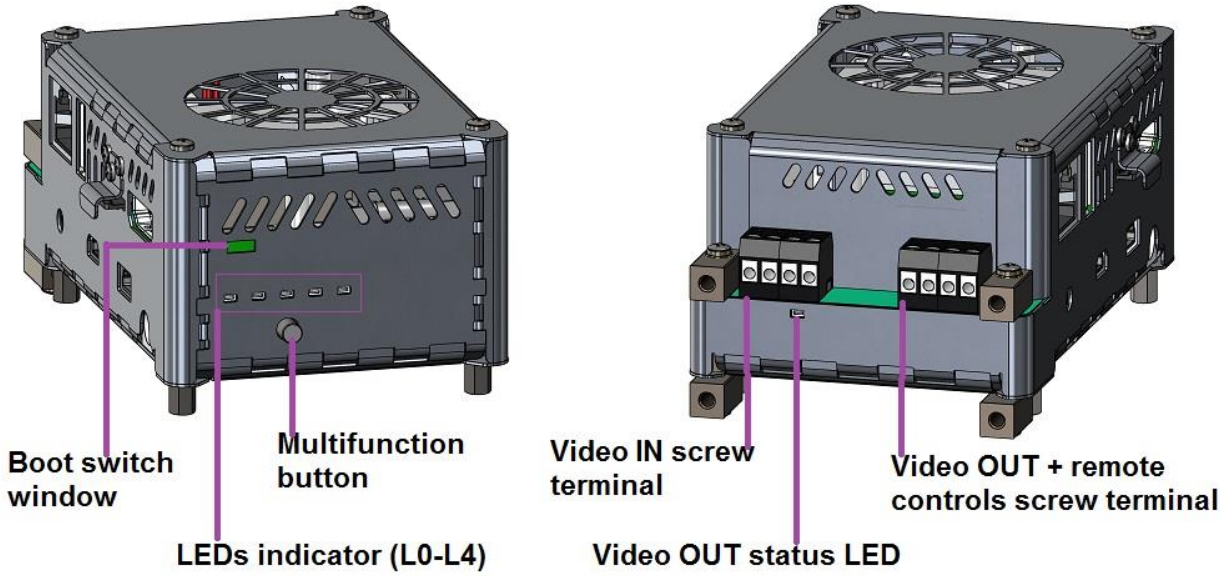


Figure 9: Controls and connections Recording box (3)

3.5 Recording box operating modes

The PI LightWeight Recording box has a modular conception so that it is possible to use it in different ways:

- Infrared PIxxx camera only on HDMI video output
- Infrared PIxxx camera only on analog CVBS TV output
- Infrared PIxxx camera and visible GoPro Hero3+ (and above) camera, on analog CVBS TV output, switched by button, or remote control
- Infrared PIxxx camera on HDMI video output and GoPro camera on analog CVBS TV output, simultaneously

The use of an external GPS USB stick is optional, if it is connected to an USB 2.0 port, geo data will be recorded in video file.

Optionally the recording can be remotely controlled by servo command or by a switch “dry contact”.

3.5.1 Configuration for PI on HDMI output

It is the simplest configuration mode to connect the PIxxx to an USB 3.0 port (blue), the U-Blox USB GPS to an USB 2.0 port (optionally), and the video output is the HDMI port.

3.5.2 Configuration for PI on CVBS analog output

In this case connect the HDMI output to the micro HDMI input with the provided cable bridge (see Figure 9: Controls and connections Recording box (3)).

The infrared image will be available on the mini jack CVBS TV output between the thick black wire and the red wire of the cable provided (see chapter 4.4.2)

Connect the PIxxx to an USB 3.0 port (blue), the U-Blox USB GPS to the USB 2.0 port (optionally).

3.5.3 Configuration for PI + GoPro on TV output

Connect the HDMI output to the micro HDMI input with the provided cable bridge,
connect the USB 2.0 port (1) to the mini USB 2.0 port input with the provided cable bridge (see Figure 9: Controls and connections Recording box (3))

Connect the PIxxx to an USB 3.0 port (blue), the GoPro Hero 3+ to the GoPro USB port (see Figure 7: Controls and connections Recording box (1)), and the U-Blox USB GPS to an USB 2.0 port (optionally).

In this case the video output is available on the mini jack port (see chapter 4.4.2), it is possible to switch from infrared image to visible image and *vice-versa* (see chapter 4.3)

3.5.4 Configuration for PI on HDMI output + GoPro on TV output

It is possible to have both images (IR & visible) simultaneously on the two video output:

- The infrared will be permanently on the HDMI output
- The visible image will be permanently on the TV output (mini jack)

Connect the PIxxx to an USB 3.0 port (blue), the GoPro Hero 3+ to the GoPro USB port (see Figure 7: Controls and connections Recording box (1)), and the U-Blox USB GPS to an USB 2.0 port (optionally).

Connect the USB 2.0 port (1) to the mini USB 2.0 port input with the provided cable bridge (see Figure 9: Controls and connections Recording box (3)).

4 Operation

4.1 Startup of the Recording box

The PI LightWeight Recording box is a Linux system but should be considered as a “Black Box” where there is nothing to modify.

To startup PI LightWeight, connect all the cables according to the desired operating mode and simply plug the provided power supply, there is not ON/OFF switch.

Before to power on the Recording box, the **HDMI output must be connected** either to the Video input conversion socket, or to a powered monitor to ensure a correct **initialization of the video output.**

To power off the system, unplug the power supply (no need to connect a keyboard to properly shutdown).

If an Ethernet connection is active with internet access at startup, the system will be set to the current time and date, and if necessary the calibration files will be downloaded from the internet.

4.2 Stand-Alone operation

For a self-contained power supply, we recommend a lithium-polymer battery with a voltage from 11 to 25 VDC (LiPo 3S to LiPo 6S).

After powering the Recording box, the system boots and is ready in about 30 seconds. A video monitor connected to the system via the video adapter cable, shows then the IR live picture of the camera in full screen mode.

Please note that even if the IR video is displayed as soon as the system starts, a good image and reliable temperature measurement will be possible only after a while, especially in cold environment (up to 10 minutes at 0 °C ambient temperature).

4.3 Multifunction button

The multifunction button (see Figure 9: Controls and connections Recording box (3)) has the following functions:

Context	Function
Recording box is running	Press > 5s => shutdown the system
Recording box is running without IR image	Press for 1 s => start application
Recording box is running with IR image	Press for 1 s => start/stop recording
Message “PRESS BUTTON TO TRANSFER FILES TO USB STICK”	Press for 1 s => transfer *.raw files to the mounted USB 3.0 stick, and copy GoPro video files if any

- A short press < 1 s can have no effect
- 1 s press functions are also duplicated by the servo control (left connector) and remote control contact (mini jack and screw connector)

4.4 Start a recording

4.4.1 Recording time duration autonomy

The maximum recording time depends of the camera and speed mode:

PI640 LW	32 Hz	~35 minutes (640 x 480 pixels)
PI640 LW	125Hz	~35 minutes (640 x 120 pixels)
PI4xx LW	27 Hz	~100 minutes
PI4xx LW	80 Hz	~35 minutes

There are four possibilities to start a recording:

- Using an electrical contact (open/close) via the analog video cable
- Using the Recording box multifunction button
- Using a servo control (Uni, Graupner /JR) or

4.4.2 Recording command with an electrical switch

To start the recording remotely by an electrical contact, connect the supplied video cable (**Order No.: ACPILKVCB2**), see **Figure 10** left, to the mini jack video output :

black (thick)	GND (common to the two other wires)
black (thin)	Recording trigger (Input)
red	Video signal (TV output: PAL B CVBS)

The recording starts if the trigger is connected to GND during one second, and stops doing the same again.

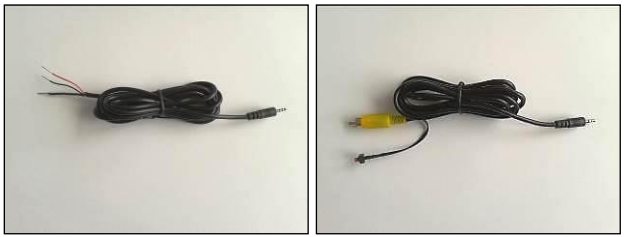


Figure 10: Video cable (**Order No.: ACPILKVCB2**) left, and video cable (**Order No.: ACPILKVCB2C**) right

The second video cable (**not supplied - Order No.: ACPILKVCB2C**) can be used for a direct connection of the system to a monitor – the recording can be started by the micro switch.

4.4.3 Recording command with the Recording box multifunction button

The Recording box button is a multipurpose command button. When the IR image is displayed pressing this button during one second starts a recording, and during a recording session pressing it during one second stops the recording.

4.4.4 Recording command with a servo control

By connecting a servo control (Uni, Graupner /JR, type) to the Recording box servo control input, it is possible to remote control the recording.

4.4.5 Recording command via screw terminal block

The “ext. Sw3“ of the right screw terminal is Low-active and must be tied to ground (a simple switch to ground is recommended) to start/ stop a recording (see 4.13).

4.5 Displayed messages

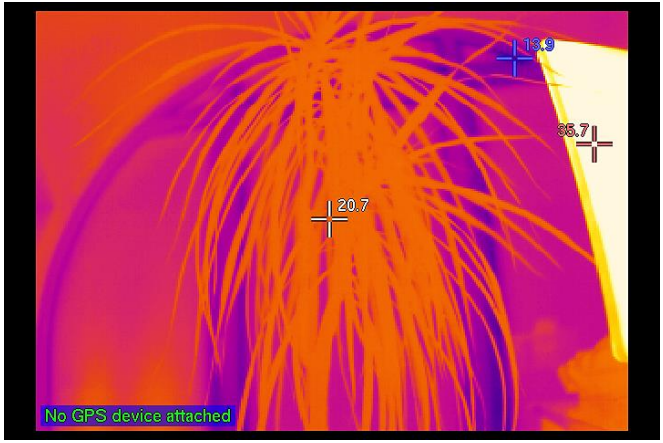
PI LightWeight is a very simple system to use, as all thermal analysis is to be done with PIConnect software running on a PC, there are only a few messages displayed during operation:

4.5.1 PI camera not detected

When the application software cannot detect the PI infrared camera (should be connected to an USB 3.0 port (blue)), the message "***No connection to imager***" is displayed. In this case, check the right connection of the PIxxx to an USB 3.0 port.

After a right connection of the PIxxx to the Recording box the following image should be displayed (see 4.5.2)

4.5.2 Minimum system display

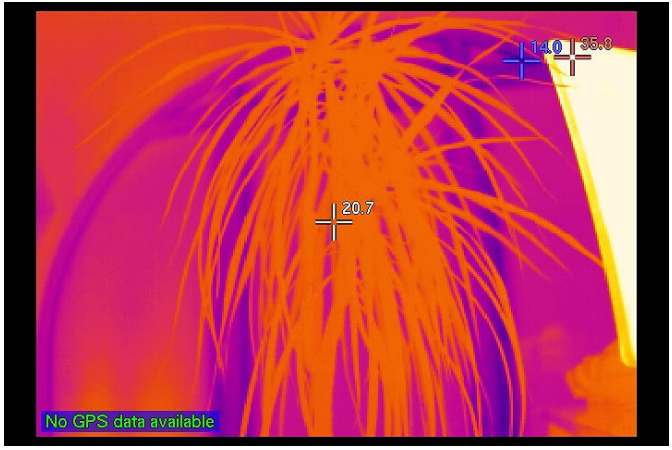


When a PI camera is connected to the Recording box and running, this screen is displayed:

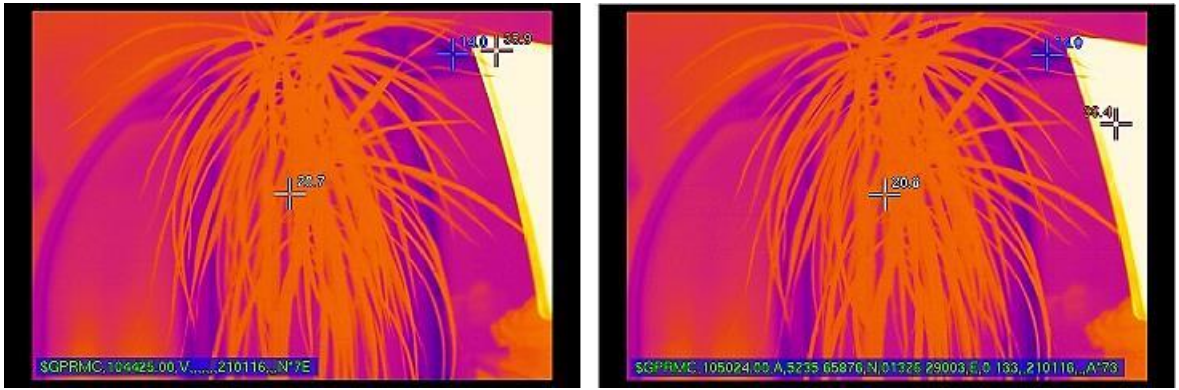
- A central image spot (white) shows this local temperature

- Two automatic targets display the location and temperature values for the minimum (blue=cold spot) and maximum (red=hot spot) temperatures in the live image
- The text "***No GPS device attached***" indicates that there is not GPS connected (or detected) by the Recording box

4.5.3 System with GPS connected



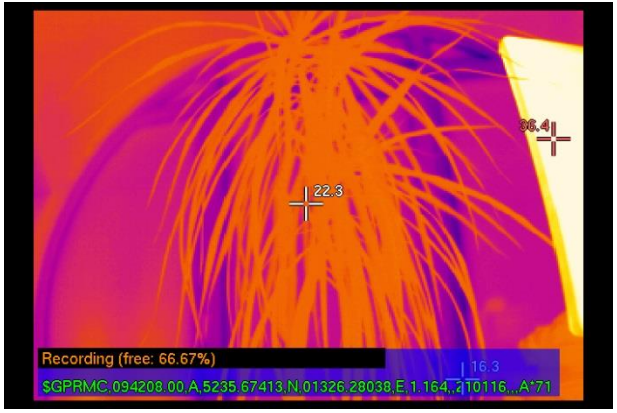
If a compatible GPS (see info page 53) is connected to the USB 2.0 port, and detected, and before valid GPS data are received, the message "***No GPS data available***" is displayed.



As soon as valid GPS “sentences” are received, the incomplete “RMC” frame is displayed at first (left figure): only UTC time and date are present.

When the fix has been done, the full RMC sentence is present, (see chapter 4.8 to interpret the data).

4.5.4 Recording message



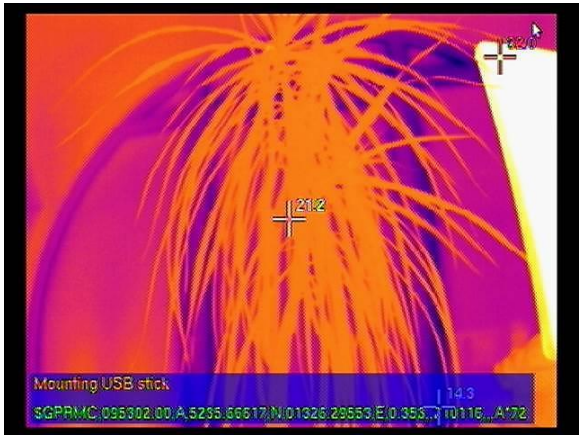
After a recording has started by any of the three options (see chapter 4.3), the message "***Recording (free: xx.xx%)***" is added to the current message. It indicates the free memory available in the Recording box for the IR records. The black bar graph shows the decreasing free space.

The GPS data are recorded together with the infrared video frames in the *.raw file

4.6 Video export

Once a recording has been done, the way to export video files is to insert an USB 3.0 memory stick in one of the USB 3.0 port (blue color).

If the USB stick is well detected by the system it displays "***Mounting USB stick***". If there is at least one record to copy the data transfer to the USB stick starts. A progress bar shows the downloading percentage "***Writing (progress: xx.xx%)***".



After that the download is finished (duration time depending of the speed capability of the USB stick and of the size of the files to download) the system displays "***USB stick attached***". It is then possible to withdraw the USB stick safely.

Due to the large amount of data to transfer, we recommend to use a fast type USB 3.0 memory stick (class: 100 MB/s write speed)

The data transfer moves all video files from the Recording box to the USB stick, freeing the memory space for next recording.

If a GoPro Hero 3+ (and above) visible camera is connected to the Recording box, GoPro video files are also copied to the memory stick.

- If there is not enough free space on the USB stick, the data transfer will not start
- It is also possible to use an external USB 3.0 hard disk

4.7 Display of the radiometric video file on a PC computer

The radiometric infrared files copied in the USB stick contain raw thermal IR energy data and geo data.

Extension of these files is *.raw and they have to be first converted by PIConnect software to the *.ravi format to enable further analysis in PIConnect.

The file name format of the raw files is:

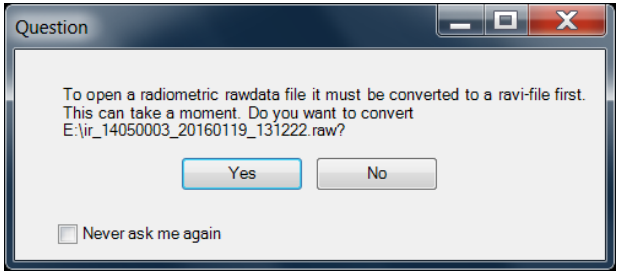
ir_xxxxxxxx_yyyymmdd_hhmmss.raw

xxxxxxxx	Serial number of the PI camera
yyyymmdd	Date of recording
hhmmss	Time of recording

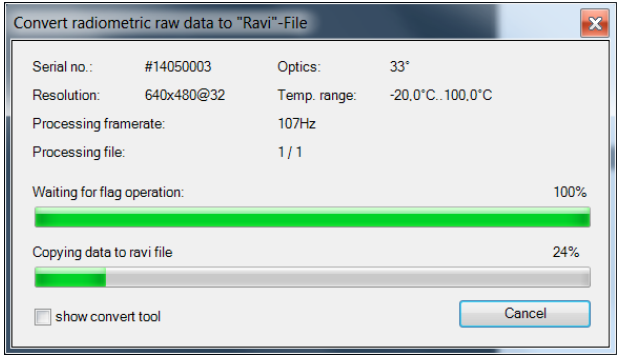
4.7.1 RAW to RAVI conversion

In PIConnect software, select in the menu: “File/ Open” and then “Radiometric raw data files” as file type.

Select the raw file you want to use. Depending on the length of the recording it is possible that the raw file is split into several sub files with the same file name but different extensions (raw.1, raw.2, raw.3, ...). For a conversion you only have to select the main file (extension: raw).
Then you get a message window:



Validate, and there is the conversion window displayed:



Give a name for the ravi file to be saved. Then you should have a display as below:

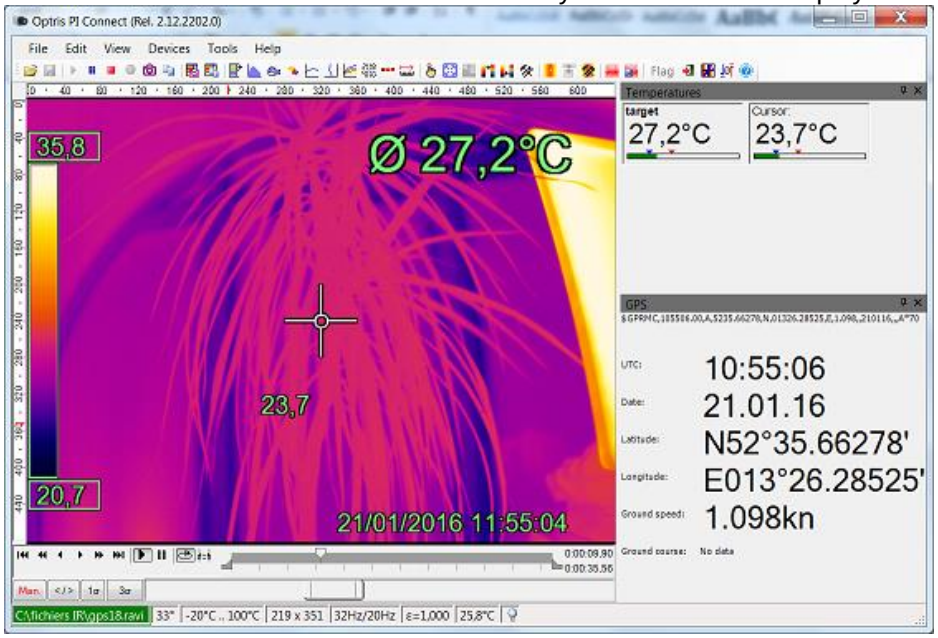


Figure 11: Screenshot of PIConnect displaying the GPS data embedded in radiometric file.

4.8 Change the recording configuration

Only 3 recording parameters can be adjusted by the user with the PI LightWeight (the other parameters can be adjusted later with PIConnect software):

- Recording speed (27 or 80 Hz for a PI4xx camera; 32 or 125 Hz for a PI640)
- Measuring temperature range (-20 to 100 °C or 0 to 250 °C or 150 to 900 °C)
- Lens in use (only if this PI camera has been calibrated with more than one lens)

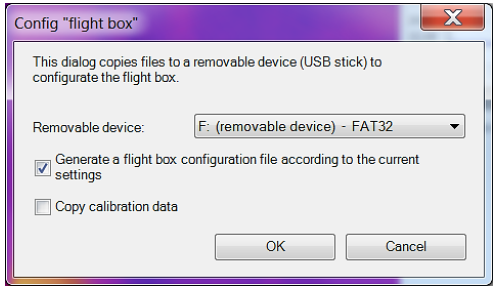
The default configuration is 27 Hz for PI4xx, 32 Hz for PI640, and -20 to 100 °C

To change the Recording box parameters you first have to generate a configuration file in PIConnect software. This file has to be loaded then into the Recording box.

4.8.1 Change recording parameters

1) Connect the PI camera to the PC where PIConnect software is installed,
2) Adjust the configuration in PIConnect as desired (only the 3 parameters above will be used in the configuration file),
3) Export a configuration file to an USB stick: PIConnect menu "***Tools/ Extended/ Config "Flight Box…"***", check "***Generate a flight box configuration according to the current settings***",

(it is possible to embed the calibration files too, if they are not present in the Recording box: check "***Copy calibration data***" and select the USB flash memory where you want to copy these files).



4) Connect the PI camera and USB stick to an USB 3.0 USB port of the Recording box, the configuration file is automatically loaded to set the recording parameters.

As PIConnect software detects the connected PI camera and adjusts the available options to this camera, it is necessary to connect this camera to the PC before to set a new configuration file.

4.9 Using a GPS

The PI LightWeight system can work with *U-Blox* USB GPS chipsets to embed the geo data in the radiometric video file, with each video frame.
The GPS NMEA sentence recorded by the system is “RMC” which includes all basics data for time and global positioning.

RMC - Recommended Minimum Navigation Information

Below is the format of the RMC sentence as it is recorded in the radiometric infrared video file with each frame.
All fields are separated by a comma:

```
                                                                  12
        1          2 3       4 5         6 7   8   9       10  11|  13
        |          | |       | |         | |   |   |       |   | |  |
 $GP RMC,hhmmss.ss,A,llll.ll,a,yyyyy.yy,a,s.s,x.x,xxxxxx,x.x,a,m,*hh
```

Field number:

1.	Universal Time Coordinated	(HHMMSS.SS)
2.	Status,	(V=invalid data; A=Valid)
3.	Latitude	(ddmm.mmmm)
4.	N or S	(North / South)
5.	Longitude	(dddmm.mmmm)
6.	E or W	(East / West)
7.	Speed over ground,	(knots)
8.	Track made good,	(degrees true)
9.	Date,	(DDMMYY)
10.	Magnetic Variation,	(degrees)
11.	E or W	(East / West)
12.	FAA mode indicator	(A=Autonomous, D=Differential, E=Dead Reckoning, N=None)
13.	Checksum	

We recommend the NL-601US USB GPS receiver based on a u-blox 6 chipset.

http://www.navilock.de/produkte/G_60123/merkmale.html

4.10 Micro SD card

The Recording box is provided with a 32 GB micro SDHC card embedded in the computer.

This memory card must not be replaced as it contains part of the operating system.

4.11 LED indicators

The Recording box is equipped with a total of 6 LED indicators:

- 5 status LEDs (L0-L4, above the multifunction button) see Figure 9: Controls and connections Recording box (3):

LED	Function	LED is ON, if:
L0	Power indicator	Recording box is powered via a power supply (via power connector)
L1	Flight-recorder service	Software basic functions are running
L2	PI camera status	Flight-recorder software and the thermal imager are running
L3	Video recording	IR data is being recorded in the internal memory (flashing)

L4	Data transfer	IR files are being copied to a USB-Stick (flashing)

Table 3: Recording box status information

- One LED under the left screw connector: this LED is ON when the analog video output retransmits the GoPro video signal, and OFF when it is the PI IR image.

4.12 Using servo control

Two remote control inputs are available with the Recording box, see Figure 7: Controls and connections Recording box (1):

- Left socket allows to remotely control the start and stop recording
- Right socket allows to remotely toggle the analog CVBS video output between infrared image from PI camera, and visible image from the GoPro camera

4.12.1 Servo connector wiring

Left (black) GND
Middle (red) +5 V output
Right (yellow) Signal input

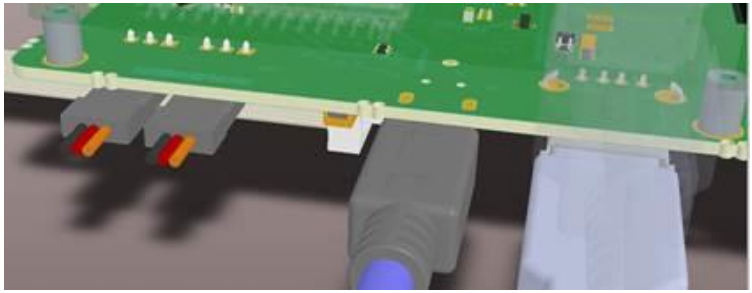


Figure 12: Servo-connector wiring (the two left connectors)

We recommend the use of Servo-connector (Uni,Graupner and JR) type

4.13 Screw connectors interfaces

The Recording box is equipped with two screw block terminals:

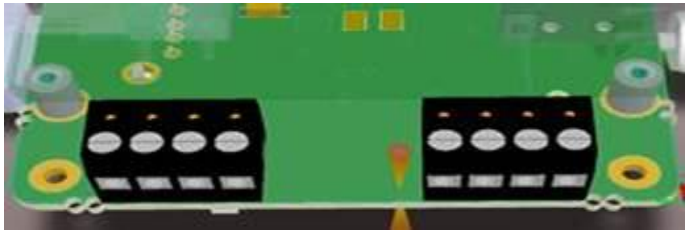


Figure 13: Screw block terminals

4.13.1 Left connector functionalities

Four connections, from the left to the right: GND | +5V output (100 mA max.) | GND | Video in (visible camera)

The analog PAL B video IN excludes the use of the GoPro camera.

4.13.2 Right connector functionalities

Four connections, from the left to the right: ext. Sw3 | ext. Sw2 | GND | TVout

The “ext. Sw2” and “ext. Sw3“ are Low-active and must be tied to ground (a simple switch to ground is recommended)

Ext.Sw3 : Start and Stop recording

Ext.Sw2 : switch IR or visible cam (e.g. GoPro) to TVout connector

5 System Recovery

In case of software failure or non-booting system, it could be necessary to re-install the whole system image on the Recording box.

PI LightWeight Recording box has two boot devices:

- Onboard eMMC (normal use)
- Micro-SD card (recovery system)

A two positions micro switch allows selecting the boot device for the next startup (see the boot switch window location on Figure 9: Controls and connections Recording box (3)).

- Switch on the right = boot from the eMMC (normal daily use)
- Switch on the left = boot from the Micro-SD card to recover the whole system

5.1 Recovery procedure

Turn OFF the Recording box, move the boot micro switch to the left position, connect a keyboard to one of the top USB ports, connect a screen monitor to the HDMI output, power ON the system.

The Linux system loads and after a while the question "***Do you really want to reset the PI LightWeight?***" is displayed.

Select "YES" and so the recovery process starts. The process takes around 10 minutes to copy the system image from the Micro-SD card to the eMMC. **Do not interrupt the process.**

When the message "***Process ended!***" is displayed, press ENTER to validate "OK", then disconnect the power supply, move the micro switch to the right position.

At the next startup the system will boot normally.

5.2 Software updates

If you have an USB stick with an update of the recorder software please plug the stick into one free USB port. The updates will be installed automatically. After the update process the system will restart automatically.

5.3 Installation of the calibration files

The PI cameras are not only infrared imagers, they are mainly thermal measuring devices and so they need calibration files to work properly.

These calibration files are specific to each camera and lens and are installed at factory on the Recording box, but after a recovery it is necessary to install them again in the system.

When the calibration files are missing a black image is displayed with the message "***Calibration missing (use USB stick or Internet connection)***"

5.3.1 Installing the calibration files through Internet

Connect the Ethernet RJ45 port to a network connected to Internet, if there is a DHCP server on the local network, the IP communication setup will be done automatically at startup.

Connect the PIxxx camera to an USB 3.0 port (blue), and power ON the system.

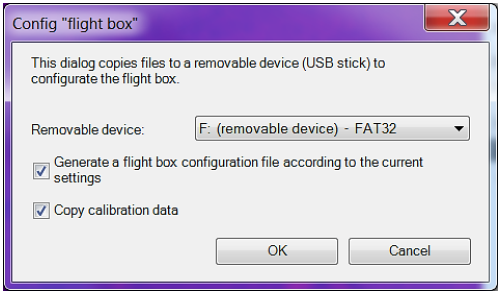
After the system boot, the software identifies the PI camera serial number and downloads automatically the right calibrations files from the internet. Then the Recording box is working normally.

5.3.2 Installing the calibration files with an USB flash memory

Two options are possible:

1/ Copy the directory named “Califiles SNxxxxxxxx” from the PIConnect CD-ROM provided with the PI camera to an USB stick manually (where SNxxxxxxxx is the serial number of the connected PI camera).

2/ Use PIConnect software to copy automatically the correct calibration files corresponding to the PI camera currently connected to this PC where PIConnect is running:
Menu “***Tools/ Extended/ Config “Flight Box…”***”, check “***Copy calibration data***” and select the USB flash memory where you want to copy these files.



Press OK.

Plug this USB stick to the Recording box, connect the PI camera SNxxxxxxxx to an USB 3.0 port (blue) and power ON the system.

The calibration files are automatically loaded to the system and the infrared image is displayed showing that the calibration files are in use.

This installation process has to be done only once per camera running with this Recording box.

6 Backup battery replacement

The Recording box is equipped with a Real Time Clock battery. Here is the process to replace it if necessary.

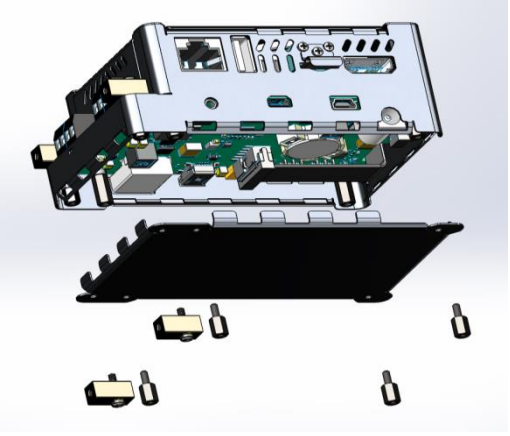
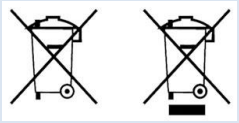


Figure 14: Open view for the localization of the RTC battery

Unscrew the four screws under the Recording box and the battery is accessible. Replace it only with a 3 V lithium battery CR 1632 or equivalent.



Do not throw away the battery, please recycle.

7 Basics of Infrared Thermometry

Depending on the temperature each object emits a certain amount of infrared radiation. A change in the temperature of the object is accompanied by a change in the intensity of the radiation.

Searching for new optical material William Herschel by chance found the infrared radiation in 1800.

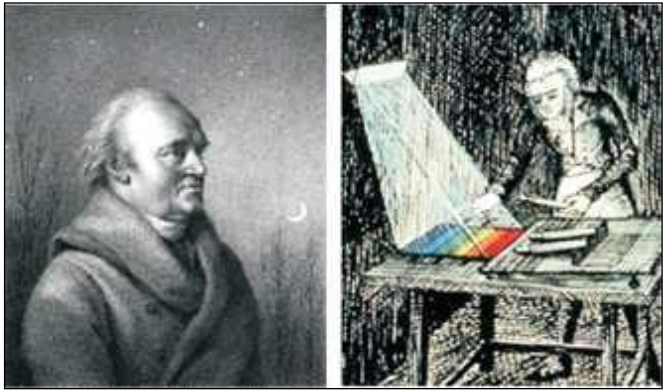


Figure 15: William Herschel (1738-1822)

He blackened the peak of a sensitive mercury thermometer. This thermometer, a glass prism that led sun rays onto a table made his measuring arrangement. With this, he tested the heating of different colors of the spectrum. Slowly moving the peak of the blackened thermometer through the colors of the spectrum, he noticed the increasing temperature from violet to red. The temperature rose even more in the area behind the red end of the spectrum. Finally he found the maximum temperature far behind the red area.

Nowadays this area is called “infrared wavelength area”.

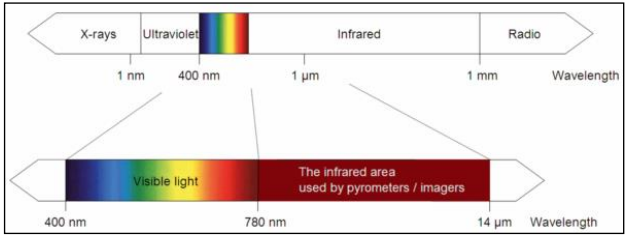


Figure 16: The electromagnetic spectrum and the area used for temperature measurement

For the measurement of “thermal radiation” infrared thermometry uses a wave-length ranging between 1 µ and 20 µm. The intensity of the emitted radiation depends on the material. This material contingent constant is described with the help of the emissivity which is a known value for most materials (see enclosed table emissivity).

Infrared thermometers are optoelectronic sensors. They calculate the surface temperature on the basis of the emitted infrared radiation from an object. The most important feature of infrared thermometers is that they enable the user to measure objects contactless. Consequently, these products help to measure the temperature of inaccessible or moving objects without difficulties.

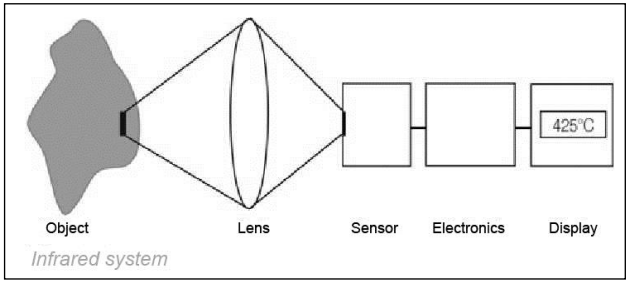


Figure 17: Main principle of noncontact thermometry

Infrared thermometers basically consist of the following components:

- Lens
- Spectral filter
- Detector
- Electronics(amplifier/ linearization/ signal processing)

The specifications of the lens decisively determine the optical path of the infrared thermometer, which is characterized by the ratio Distance to Spot size. The spectral filter selects the wavelength range, which is relevant for the temperature measurement. The detector in cooperation with the processing electronics transforms the emitted infrared radiation into electrical signals.

The advantages of noncontact thermometry are clear - it supports:

- temperature measurements of moving or overheated objects and of objects in hazardous surroundings
- very fast response and exposure times
- measurement without inter-reaction, no influence on the
- measuring object
- non-destructive measurement
- long lasting measurement, no mechanical wear

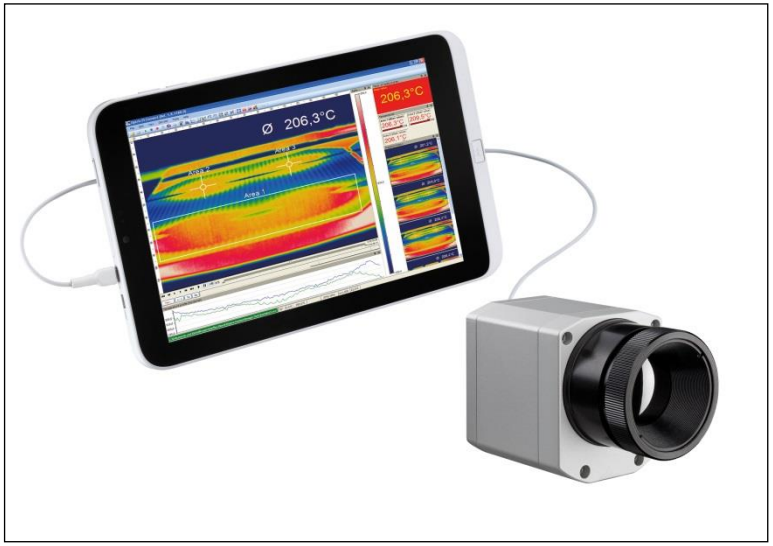
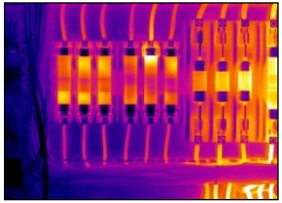
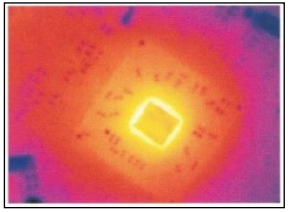


Figure 18: Contactless thermometry

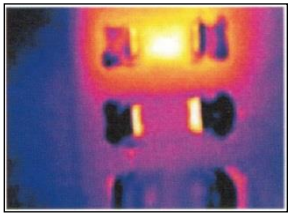
Application fields:



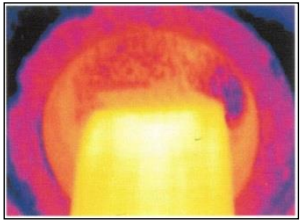
Monitoring of electronic cabinets



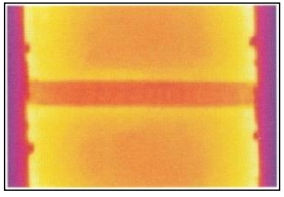
R&D of electronics



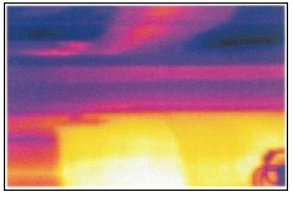
R&D of electronic parts



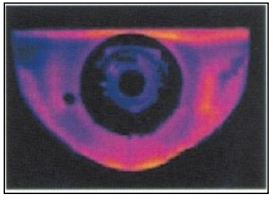
Process control extruding plastic parts



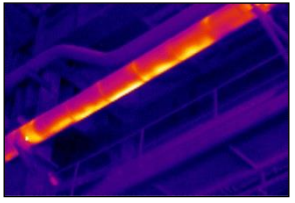
Process control manufacturing solar modules



Process control at calendering



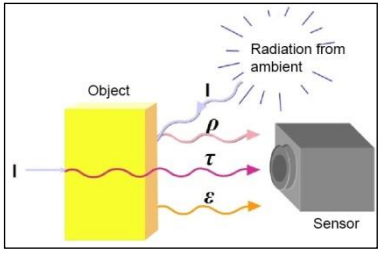
R&D of mechanical parts



Monitoring of cables

7.3 Emissivity

Definition: The intensity of infrared radiation, which is emitted by each body, depends on the temperature as well as on the radiation features of the surface material of the measuring object. The emissivity (ε – Epsilon) is used as a material constant factor to describe the ability of the body to emit infrared energy. It can range between 0 and 100 %. A “blackbody” is the ideal radiation source with an emissivity of 1.0 whereas a mirror shows an emissivity of 0.1. If the emissivity chosen is too high, the infrared thermometer may display a temperature value which is much lower than the real temperature – assuming the measuring object is warmer than its surroundings. A low emissivity (reflective surfaces) carries the risk of inaccurate measuring results by interfering infrared radiation emitted by background objects (flames, heating systems, chamottes). To minimize measuring errors in such cases, the handling should be performed very carefully and the unit should be protected against reflecting radiation sources.



I	Passed radiation
ε	Reflection
ρ	Transmission
τ	Emissivity=Absorption

ε + ρ+ τ = 1

Figure 19: Capability of an object to emit radiation

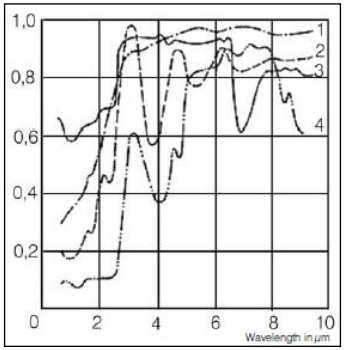


Figure 20: Spectral emissivity of several materials: **1** Enamel, **2** Plaster, **3** Concrete, **4** Chamotte

EG-Konformitätserklärung
EU Declaration of Conformity

optris infrared thermometers

Wir / We

Optris GmbH
Ferdinand Buisson Str. 14
D-13127 Berlin

erklären in alleiniger Verantwortung, dass
declare on our own responsibility that

die Produktserie optris PI
the product group optris PI

den Anforderungen der EMV-Richtlinie **2014/30/EU** und der Niederspannungsrichtlinie **2014/35/EU** entspricht.
meets the provisions of the EMC Directive **2014/30/EU** and the Low Voltage Directive **2014/35/EU**.

Angewandte harmonisierte Normen:
Applied harmonized standards:

EMV Anforderungen / EMC General Requirements:

EN 61326-1:2013 (Grundlegende Prüfanforderungen / Basic requirements)
EN 61326-2-3:2013

Gerätesicherheit von Messgeräten / Safety of measurement devices:

EN 61010-1:2010
EN 60825-1:2015 (Lasersicherheit / Laser safety)

Dieses Produkt erfüllt die Vorschriften der Richtlinie **2011/65/EU** (RoHS) des Europäischen Parlaments und des Rates vom 8. Juni 2011 zur Beschränkung der Verwendung bestimmter gefährlicher Stoffe in Elektro- und Elektronikgeräten.
This product is in conformity with Directive **2011/65/EU** (RoHS) of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Berlin, 04.11.2015

Ort, Datum / place, date

Dr. Ulrich Kienitz
Geschäftsführer / General Manager

optris PI LightWeight kit -MA-E2016-02-C