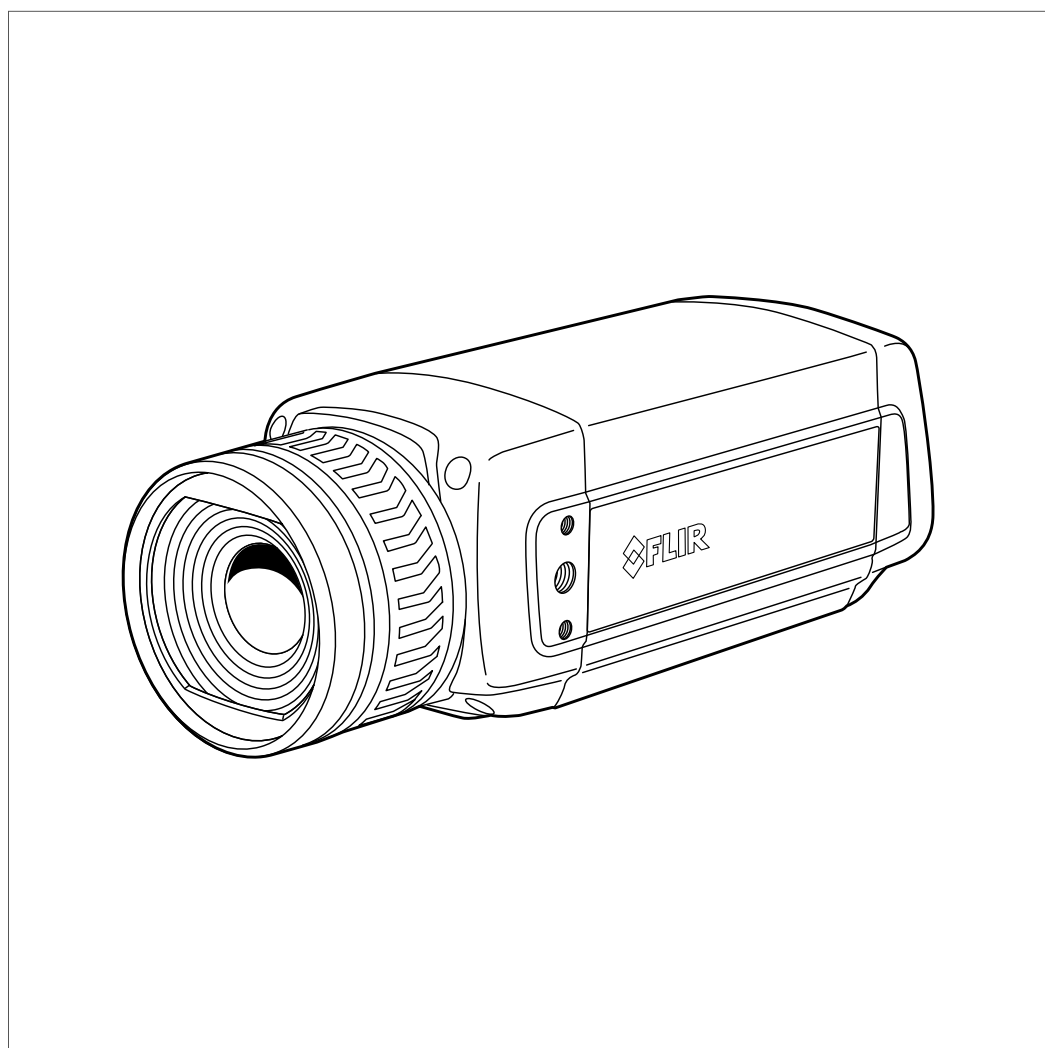


# User's manual FLIR A6xx series







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# User's manual FLIR A6xx series





# Table of contents

---

<b>1</b>	<b>Legal disclaimer</b> .....	<b>1</b>
1.1	Legal disclaimer .....	1
1.2	Usage statistics .....	1
1.3	Changes to registry .....	1
1.4	U.S. Government Regulations.....	1
1.5	Copyright .....	1
1.6	Quality assurance .....	2
1.7	Patents.....	2
1.8	EULA Terms .....	2
<b>2</b>	<b>Safety information</b> .....	<b>4</b>
<b>3</b>	<b>Notice to user</b> .....	<b>5</b>
3.1	User-to-user forums .....	5
3.2	Calibration.....	5
3.3	Accuracy .....	5
3.4	Disposal of electronic waste.....	5
3.5	Training .....	5
3.6	Documentation updates .....	5
3.7	Important note about this manual.....	5
3.8	Note about authoritative versions.....	5
<b>4</b>	<b>Customer help</b> .....	<b>6</b>
4.1	General .....	6
4.2	Submitting a question .....	6
4.3	Downloads .....	7
<b>5</b>	<b>Installation (FLIR A6xx cameras)</b> .....	<b>8</b>
5.1	General information.....	8
5.1.1	Explanation.....	8
5.1.2	Default installation paths.....	8
5.2	System requirements.....	8
5.2.1	Operating system .....	8
5.2.2	Hardware .....	8
5.2.3	Software .....	8
5.2.4	More information.....	8
5.3	Installation.....	9
5.3.1	General.....	9
5.3.2	Procedure .....	9
<b>6</b>	<b>Installation (FLIR A6xx sc cameras)</b> .....	<b>10</b>
<b>7</b>	<b>Quick start guide</b> .....	<b>11</b>
7.1	Quick start guide, FLIR A6xx series .....	11
7.1.1	Download FLIR Tools .....	11
7.2	Quick start guide, FLIR A6xx sc series.....	11
<b>8</b>	<b>List of accessories and services</b> .....	<b>12</b>
<b>9</b>	<b>Mechanical installation</b> .....	<b>13</b>
9.1	Mounting interfaces.....	13
9.2	Notes on permanent installation .....	13
9.3	Vibrations.....	13
9.4	Further information.....	13
9.5	Cable strain relief.....	13
<b>10</b>	<b>Mounting and removing lenses</b> .....	<b>15</b>
10.1	Removing an infrared lens .....	15
10.2	Procedure .....	15
10.3	Mounting an infrared lens .....	15
10.3.1	Procedure .....	15

## Table of contents

---

<b>11</b>	<b>Connectors, controls, and indicators</b> .....	<b>16</b>
11.1	Explanation .....	16
<b>12</b>	<b>Example system overviews</b> .....	<b>17</b>
12.1	FLIR A6xx series .....	17
12.1.1	Figure.....	17
12.1.2	Explanation.....	17
12.1.3	Figure.....	18
12.1.4	Explanation.....	18
12.1.5	Figure.....	18
12.1.6	Explanation.....	19
12.2	FLIR A6xx sc series.....	19
12.2.1	Figure.....	19
12.2.2	Explanation.....	19
<b>13</b>	<b>Digital I/O functionality</b> .....	<b>20</b>
13.1	FLIR A615 and A655sc .....	20
<b>14</b>	<b>Technical data</b> .....	<b>21</b>
14.1	Online field-of-view calculator .....	21
14.2	Note about technical data .....	21
14.3	Note about authoritative versions.....	21
14.4	FLIR A615 15° .....	22
14.5	FLIR A615 25° .....	26
14.6	FLIR A615 45° .....	30
14.7	FLIR A615 7° .....	34
14.8	FLIR A615 windowing 80°.....	38
14.9	FLIR A655sc 15° .....	42
14.10	FLIR A655sc 25° .....	46
14.11	FLIR A655sc 45° .....	50
14.12	FLIR A655sc 7° .....	54
14.13	FLIR A655sc 80° .....	58
<b>15</b>	<b>Pin configurations and schematics</b> .....	<b>62</b>
15.1	Pin configuration for camera I/O connector .....	62
15.2	LED indicators .....	62
<b>16</b>	<b>Mechanical drawings</b> .....	<b>63</b>
<b>17</b>	<b>CE Declaration of conformity</b> .....	<b>73</b>
<b>18</b>	<b>Network troubleshooting</b> .....	<b>75</b>
<b>19</b>	<b>Digital I/O connection diagrams</b> .....	<b>76</b>
<b>20</b>	<b>Cleaning the camera</b> .....	<b>78</b>
20.1	Camera housing, cables, and other items.....	78
20.1.1	Liquids.....	78
20.1.2	Equipment.....	78
20.1.3	Procedure .....	78
20.2	Infrared lens .....	78
20.2.1	Liquids.....	78
20.2.2	Equipment.....	78
20.2.3	Procedure .....	78
20.3	Infrared detector .....	78
20.3.1	General.....	78
20.3.2	Procedure .....	79
<b>21</b>	<b>About FLIR Systems</b> .....	<b>80</b>
21.1	More than just an infrared camera .....	81
21.2	Sharing our knowledge .....	81
21.3	Supporting our customers.....	81

## Table of contents

---

<b>22</b>	<b>Glossary .....</b>	<b>83</b>
<b>23</b>	<b>Thermographic measurement techniques .....</b>	<b>86</b>
23.1	Introduction .....	86
23.2	Emissivity.....	86
23.2.1	Finding the emissivity of a sample.....	86
23.3	Reflected apparent temperature.....	89
23.4	Distance .....	90
23.5	Relative humidity .....	90
23.6	Other parameters.....	90
<b>24</b>	<b>History of infrared technology.....</b>	<b>91</b>
<b>25</b>	<b>Theory of thermography.....</b>	<b>94</b>
25.1	Introduction .....	94
25.2	The electromagnetic spectrum.....	94
25.3	Blackbody radiation.....	94
25.3.1	Planck's law .....	95
25.3.2	Wien's displacement law.....	96
25.3.3	Stefan-Boltzmann's law .....	97
25.3.4	Non-blackbody emitters.....	98
25.4	Infrared semi-transparent materials.....	100
<b>26</b>	<b>The measurement formula.....</b>	<b>101</b>
<b>27</b>	<b>Emissivity tables .....</b>	<b>105</b>
27.1	References.....	105
27.2	Tables .....	105





# Legal disclaimer

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## 1.1 Legal disclaimer

All products manufactured by FLIR Systems are warranted against defective materials and workmanship for a period of one (1) year from the delivery date of the original purchase, provided such products have been under normal storage, use and service, and in accordance with FLIR Systems instruction.

Products which are not manufactured by FLIR Systems but included in systems delivered by FLIR Systems to the original purchaser, carry the warranty, if any, of the particular supplier only. FLIR Systems has no responsibility whatsoever for such products.

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In the case of a defect in a product covered by this warranty the product must not be further used in order to prevent additional damage. The purchaser shall promptly report any defect to FLIR Systems or this warranty will not apply.

FLIR Systems will, at its option, repair or replace any such defective product free of charge if, upon inspection, it proves to be defective in material or workmanship and provided that it is returned to FLIR Systems within the said one-year period.

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This warranty shall be governed by Swedish law.

Any dispute, controversy or claim arising out of or in connection with this warranty, shall be finally settled by arbitration in accordance with the Rules of the Arbitration Institute of the Stockholm Chamber of Commerce. The place of arbitration shall be Stockholm. The language to be used in the arbitral proceedings shall be English.

## 1.2 Usage statistics

FLIR Systems reserves the right to gather anonymous usage statistics to help maintain and improve the quality of our software and services.

## 1.3 Changes to registry

The registry entry HKEY\_LOCAL\_MACHINE\SYSTEM\CurrentControlSet\Control\Lsa\LmCompatibilityLevel will be automatically changed to level 2 if the FLIR Camera Monitor service detects a FLIR camera connected to the computer with a USB cable. The modification will only be executed if the camera device implements a remote network service that supports network logons.

## 1.4 U.S. Government Regulations

This product may be subject to U.S. Export Regulations. Please send any inquiries to [exportquestions@flir.com](mailto:exportquestions@flir.com).

## 1.5 Copyright

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### 1.6 Quality assurance

The Quality Management System under which these products are developed and manufactured has been certified in accordance with the ISO 9001 standard.

FLIR Systems is committed to a policy of continuous development; therefore we reserve the right to make changes and improvements on any of the products without prior notice.

### 1.7 Patents

One or several of the following patents and/or design patents may apply to the products and/or features. Additional pending patents and/or pending design patents may also apply.










000279476-0001; 000439161; 000499579-0001; 000653423; 000726344; 000859020; 001106306-0001; 001707738; 001707746; 001707787; 001776519; 001954074; 002021543; 002058180; 002249953; 002531178; 0600574-8; 1144833; 1182246; 1182620; 1285345; 1299699; 1325808; 1336775; 1391114; 1402918; 1404291; 1411581; 1415075; 1421497; 1458284; 1678485; 1732314; 2106017; 2107799; 2381417; 3006596; 3006597; 466540; 483782; 484155; 4889913; 5177595; 60122153.2; 602004011681.5-08; 6707044; 68657; 7034300; 7110035; 7154093; 7157705; 7237946; 7312822; 7332716; 7336823; 7544944; 7667198; 7809258 B2; 7826736; 8,153,971; 8,823,803; 8,853,631; 8018649 B2; 8212210 B2; 8289372; 8354639 B2; 8384783; 8520970; 8565547; 8595689; 8599262; 8654239; 8680468; 8803093; D540838; D549758; D579475; D584755; D599,392; D615,113; D664,580; D664,581; D665,004; D665,440; D677298; D710,424 S; D718801; DI6702302-9; DI6903617-9; DI7002221-6; DI7002891-5; DI7002892-3; DI7005799-0; DM/057692; DM/061609; EP 2115696 B1; EP2315433; SE 0700240-5; US 8340414 B2; ZL 201330267619.5; ZL01823221.3; ZL01823226.4; ZL02331553.9; ZL02331554.7; ZL200480034894.0; ZL200530120994.2; ZL200610088759.5; ZL200630130114.4; ZL200730151141.4; ZL200730339504.7; ZL200820105768.8; ZL200830128581.2; ZL200880105236.4; ZL200880105769.2; ZL200930190061.9; ZL201030176127.1; ZL201030176130.3; ZL201030176157.2; ZL201030595931.3; ZL201130442354.9; ZL201230471744.3; ZL201230620731.8.

### 1.8 EULA Terms

- You have acquired a device (“INFRARED CAMERA”) that includes software licensed by FLIR Systems AB from Microsoft Licensing, GP or its affiliates (“MS”). Those installed software products of MS origin, as well as associated media, printed materials, and “online” or electronic documentation (“SOFTWARE”) are protected by international intellectual property laws and treaties. The SOFTWARE is licensed, not sold. All rights reserved.
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# Safety information

	<b>WARNING</b>
Make sure that you read all applicable MSDS (Material Safety Data Sheets) and warning labels on containers before you use a liquid. The liquids can be dangerous. Injury to persons can occur.	
	<b>CAUTION</b>
Do not point the infrared camera (with or without the lens cover) at strong energy sources, for example, devices that cause laser radiation, or the sun. This can have an unwanted effect on the accuracy of the camera. It can also cause damage to the detector in the camera.	
	<b>CAUTION</b>
Do not use the camera in temperatures more than +50°C (+122°F), unless other information is specified in the user documentation or technical data. High temperatures can cause damage to the camera.	
	<b>CAUTION</b>
Do not apply solvents or equivalent liquids to the camera, the cables, or other items. Damage to the battery and injury to persons can occur.	
	<b>CAUTION</b>
Be careful when you clean the infrared lens. The lens has an anti-reflective coating which is easily damaged. Damage to the infrared lens can occur.	
	<b>CAUTION</b>
Do not use too much force to clean the infrared lens. This can cause damage to the anti-reflective coating.	
	<b>CAUTION</b>
<b>Applicability:</b> Cameras with an automatic shutter that can be disabled.	
Do not disable the automatic shutter in the camera for a long time period (a maximum of 30 minutes is typical). If you disable the shutter for a longer time period, damage to the detector can occur.	
	<b>NOTE</b>
The encapsulation rating is only applicable when all the openings on the camera are sealed with their correct covers, hatches, or caps. This includes the compartments for data storage, batteries, and connectors.	
	<b>CAUTION</b>
<b>Applicability:</b> Cameras where you can remove the lens and expose the infrared detector.	
Do not use the pressurized air from the pneumatic air systems in a workshop when you remove dust from the detector. The air contains oil mist to lubricate the pneumatic tools and the pressure is too high. Damage to the detector can occur.	

## 3.1 User-to-user forums

Exchange ideas, problems, and infrared solutions with fellow thermographers around the world in our user-to-user forums. To go to the forums, visit:

<http://www.infraredtraining.com/community/boards/>

## 3.2 Calibration

We recommend that you send in the camera for calibration once a year. Contact your local sales office for instructions on where to send the camera.

## 3.3 Accuracy

For very accurate results, we recommend that you wait 5 minutes after you have started the camera before measuring a temperature.

## 3.4 Disposal of electronic waste



As with most electronic products, this equipment must be disposed of in an environmentally friendly way, and in accordance with existing regulations for electronic waste.

Please contact your FLIR Systems representative for more details.

## 3.5 Training

To read about infrared training, visit:

- <http://www.infraredtraining.com>
- <http://www.irtraining.com>
- <http://www.irtraining.eu>

## 3.6 Documentation updates

Our manuals are updated several times per year, and we also issue product-critical notifications of changes on a regular basis.

To access the latest manuals and notifications, go to the Download tab at:

<http://support.flir.com>

It only takes a few minutes to register online. In the download area you will also find the latest releases of manuals for our other products, as well as manuals for our historical and obsolete products.

## 3.7 Important note about this manual

FLIR Systems issues generic manuals that cover several cameras within a model line.

This means that this manual may contain descriptions and explanations that do not apply to your particular camera model.

## 3.8 Note about authoritative versions

The authoritative version of this publication is English. In the event of divergences due to translation errors, the English text has precedence.

Any late changes are first implemented in English.

## FLIR Customer Support Center

Home | Answers | Ask a Question | Product Registration | Downloads | My Stuff | Service

### FLIR Customer support

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US Letter (28 Mb)  
A4 (27.4 Mb)

Important legal disclaimer, dangers, warnings, and cautions

**Accessories**



### 4.1 General

For customer help, visit:

<http://support.flir.com>

### 4.2 Submitting a question

To submit a question to the customer help team, you must be a registered user. It only takes a few minutes to register online. If you only want to search the knowledgebase for existing questions and answers, you do not need to be a registered user.

When you want to submit a question, make sure that you have the following information to hand:

- The camera model
- The camera serial number
- The communication protocol, or method, between the camera and your device (for example, HDMI, Ethernet, USB, or FireWire)
- Device type (PC/Mac/iPhone/iPad/Android device, etc.)
- Version of any programs from FLIR Systems
- Full name, publication number, and revision number of the manual

### 4.3 Downloads

On the customer help site you can also download the following, when applicable for the product:

- Firmware updates for your infrared camera.
- Program updates for your PC/Mac software.
- Freeware and evaluation versions of PC/Mac software.
- User documentation for current, obsolete, and historical products.
- Mechanical drawings (in \*.dxf and \*.pdf format).
- Cad data models (in \*.stp format).
- Application stories.
- Technical datasheets.
- Product catalogs.

## 5.1 General information

### 5.1.1 Explanation

The following programs are included on the ThermoVision System Tools & Utilities application CD:

- FLIR IP Config: A set-up and configuration program to detect and find FLIR automation and science cameras on a network and automatically assign or manually set IP addresses.
- FLIR IR Monitor: A program to control FLIR automation and science cameras on a network. You typically use FLIR IR Monitor to change camera settings, lay out measurement tools on the screen, set up alarms, etc.
- FLIR IR Camera Player: A PC-based remote control and video player for infrared cameras from FLIR Systems.
- A link to a web installation of FLIR Axxx Control & Image Interfaces: An installation that includes Interface Control Documents (ICDs), user documentation, and Ccode examples. We recommend that you read the documentation.

### 5.1.2 Default installation paths

- C:\Program Files\FLIR Systems\FLIR IP Config
- C:\Program Files\FLIR Systems\FLIR IR Monitor
- C:\Program Files\FLIR Systems\FLIR IR Camera Player
- C:\Program Files\FLIR Systems\AXXX Control & Image Interfaces

**Note** Functionality in the PC programs is dependent on the camera model.

## 5.2 System requirements

### 5.2.1 Operating system

- Microsoft Windows XP Professional, with Service Pack 2 (SP2).
- Microsoft Windows Vista Ultimate 32-bit.
- Microsoft Windows 7, 32-bit and 64-bit.

### 5.2.2 Hardware

- Personal computer with a 2 GHz 32-bit or 64-bit processor.
- 1 GB of RAM or more.
- 20 GB of hard disk space.
- Super VGA (1024 × 768) or higher-resolution monitor.
- Support for DirectX 9 graphics with:
  - WDDM driver
  - 128 MB of graphics memory (minimum)
  - Pixel Shader 2.0 (in hardware)
  - 32 bits per pixel.
- DVD-ROM drive.
- Audio output.
- Keyboard and Microsoft mouse, or a compatible pointing device.

### 5.2.3 Software

Microsoft Internet Explorer 6 or later.

### 5.2.4 More information

For specific information about system requirements for the operating systems mentioned above, visit <http://www.microsoft.com/windows/>.



### 5.3 Installation

#### 5.3.1 General

Last-minute changes and other important information can be found in the read-me file on the CD-ROM. We recommend that you read this file before you install the programs.

#### Note

- If you experience problems during the installation, visit our Customer Help at <http://support.flir.com>.
- You must be an Administrator or a user with Administrative Rights to install the programs.
- A complete installation consists of several subinstallations, some of which are from third-party vendors. Do not abort these subinstallations, as they are needed for the complete installation.
- A complete installation can take up to 10 minutes to complete.

#### 5.3.2 Procedure

##### **Follow this procedure:**

1. Close down all applications.
2. Insert the ThermoVision System Tools & Utilities CD-ROM into the CD drive on the computer. The installation should start automatically.

Should the installation not start automatically, start Windows Explorer and double-click SETUP.HTM on the CD-ROM.

3. Click one of the following:
  - Install FLIR IP Config.
  - Install FLIR IR Monitor.
  - Install FLIR IR Camera Player.
  - Install AXXX Control & Image Interfaces.
4. Follow the on-screen instructions.

## Installation (FLIR A6xx sc cameras)

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The FLIR A6xx sc cameras are supported by the FLIR ResearchIR software. A download card for this software is included in the camera package.

To install the software, follow the procedure in the user's manual for FLIR ResearchIR. The user's manual is available in the *User documentation > Software* folder on the User documentation CD-ROM that comes with the camera.

## 7.1 Quick start guide, FLIR A6xx series

Follow this procedure:

1. Connect the power and Ethernet cables to the camera.
2. Connect the power cable to a power supply.
3. Connect the camera to the network, using the Ethernet cable.
4. Use *FLIR Tools* to identify the unit in the network and set the IP address if necessary. Download from <http://tinyurl.com/o5wudd7>.
5. Use *FLIR Tools* to set up and control the camera. For more information, see section 7.1.1 *Download FLIR Tools*, page 11.

### 7.1.1 Download FLIR Tools

*FLIR Tools* lets you quickly create professional inspection reports that clearly show decision makers what you've found with your IR camera.

Import, analyze, and fine-tune images easily. Then incorporate them into concise documents to share findings and justify repairs.

Go to the following website to download *FLIR Tools*:

<http://support.flir.com/tools>

## 7.2 Quick start guide, FLIR A6xx sc series

Follow this procedure:

1. Go to <http://support.flir.com/rir4> and download *FLIR ResearchIR Max*.
2. Install *FLIR ResearchIR Max*.
3. Start *FLIR ResearchIR Max*.

When asked for the license key, enter the license key that is printed on the *FLIR ResearchIR Max* download card. The card is included with your camera.

4. Connect the camera to the computer using the provided Ethernet cable.
5. Start the camera. This displays a start-up dialog box in *FLIR ResearchIR Max*. If the start-up dialog box is not displayed, go to *View > Startup Dialog*.
6. In the start-up dialog box, click the camera you want to connect to.

For more information about the installation and connection processes, see the *FLIR ResearchIR Max* manual.

# List of accessories and services

IR lens, f=41.3 mm (15°) with case	T197914
IR lens, f=24.6 mm (25°) with case	T197922
IR lens, f=13.1 mm (45°) with case	T197915
Close-up IR lens, 2.9x (50 µm) with case	T198059
Close-up IR lens, 5.8x (100 µm) with case	T198060
IR lens, f=6.5 mm (80°) with case	T198065
IR lens, f=88.9 mm (7°) with case and support for A6xx/A6xxsc	T198165
Close-up IR lens, 1.5x (25 µm) with case	T198066
High temp option +300°C to 2000°C (+572°F to 3632°F) for FLIR A6xxsc and T6xx	T197896
Power cord EU	1910400
Power cord US	1910401
Power cord UK	1910402
Power supply, incl. multi plugs, for A3xx, A3xxsc, A6xx and A6xxsc	T910922
Power supply for A3xx f, IP66	T911182
USB cable Std A <-> Mini-B	1910423
Ethernet cable CAT-6, 2m/6.6 ft.	T951004ACC
Power cable, pigtailed	1910586ACC
Hard transport case for A3xx/A6xx series	T197871ACC
Cardboard box for A3xx/A6xx series	T197870ACC
Filter holder for A6xx lenses	T126889ACC
FLIR Tools	T198584
FLIR Tools+ (license only)	T198583
FLIR IR Camera Player	DSW-10000
FLIR ResearchIR 3 (license only)	T198578
FLIR ResearchIR 3 Max (license only)	T198574
FLIR ResearchIR Max + HSDR 4	T198697
FLIR ResearchIR Max + HSDR 4	T199014
FLIR ResearchIR Max + HSDR 4 Upgrade	T199044
FLIR ResearchIR Max 4	T198696
FLIR ResearchIR Max 4	T199013
FLIR ResearchIR Max 4 Upgrade	T199043
FLIR ResearchIR Standard 4	T198731
FLIR ResearchIR Standard 4	T199012
FLIR ResearchIR Standard 4 Upgrade	T199042
ThermoVision™ System Developers Kit Ver. 2.6	T198567
ThermoVision™ LabVIEW® Digital Toolkit Ver. 3.3	T198566
One year extended warranty for A6xx, A6xxsc series	T199827

**Note** FLIR Systems reserves the right to discontinue models, parts or accessories, and other items, or to change specifications at any time without prior notice.

## 9.1 Mounting interfaces

The camera unit has been designed to allow it to be installed in any position. The housing has three mounting interfaces—bottom, left, and right—each with the following threaded holes.

- 2 × M4 metric threaded holes.
- 1 × UNC ¼-20 standard tripod mount.

## 9.2 Notes on permanent installation

If the camera unit is to be permanently installed at the application site, certain steps are required.

The camera unit might need to be enclosed in a protective housing and, depending on the ambient conditions (e.g., temperature), the housing may need to be cooled or heated by water or air.

In very dusty conditions the installation might also need to have a stream of pressurized air directed at the lens, to prevent dust build-up.

## 9.3 Vibrations

When installing the camera unit in harsh industrial environments, every precaution should be taken when securing the unit.

If the environment exposes the unit to severe vibrations, there may be a need to secure the mounting screws by means of Loctite or another industrial brand of thread-locking liquid, as well as to dampen the vibrations by installing the camera unit on a specially designed base.

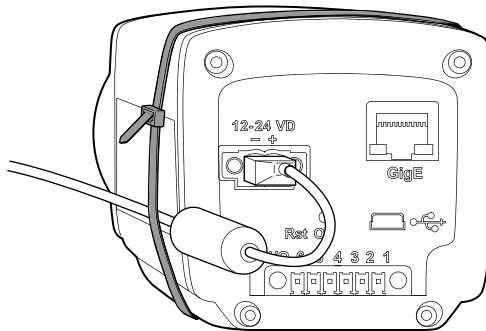
## 9.4 Further information

For further information regarding installation recommendations and environmental enclosures, contact FLIR Systems.

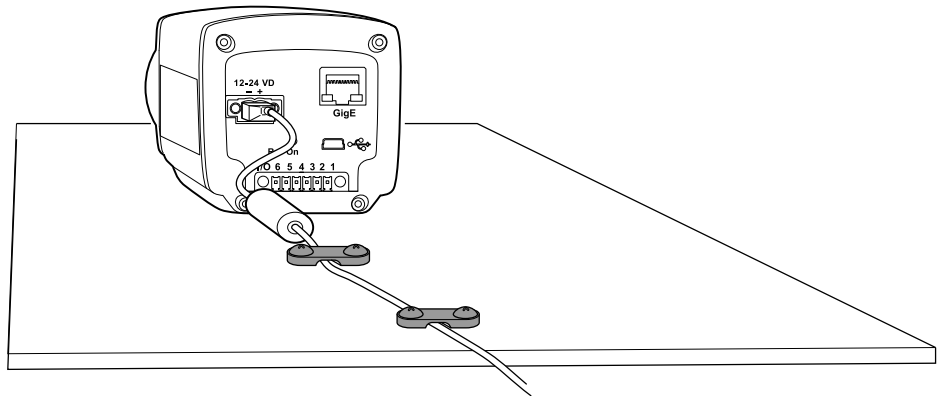
## 9.5 Cable strain relief

In installations where the camera is subject to vibrations or shocks the power cord may need an external strain relief arrangement to avoid power port failure.

The following pictures show two examples on how cable strain relief of the power cord can be solved.



Example 1, cable strain relief with zip ties.



Example 2, cable strain relief with cable clamps.

## 10.1 Removing an infrared lens

### Note

- Do not touch the lens surface when you remove an infrared lens. If this happens, clean the lens according to the instructions in section 20.2 *Infrared lens*, page 78.
- When you have removed the lens, put the lens caps on the lens immediately, to protect it from dust and fingerprints.

## 10.2 Procedure

### *Follow this procedure to remove an infrared lens:*

1. Rotate the lens counter-clockwise 30° (looking at the front of the lens).
2. Carefully pull out the lens from the bayonet ring.

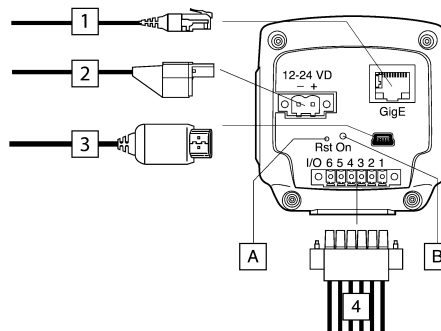
## 10.3 Mounting an infrared lens

**Note** Do not touch the lens surface when you mount an infrared lens. If this happens, clean the lens according to the instructions in section 20.2 *Infrared lens*, page 78.

### 10.3.1 Procedure

#### *Follow this procedure to mount an infrared lens:*

1. Correctly position the lens in front of the bayonet ring.
2. Carefully push the lens into position.
3. Rotate the lens 30° clockwise (looking at the front of the lens) until a click is heard.



## 11.1 Explanation

1. Network cable with an RJ45 connector for Ethernet connectivity and Power over Ethernet (PoE) (dependent on the camera model).

**Note** Only CAT-6 Ethernet cables should be used with this camera.

2. Power cable for 12–24 V DC power in.

**Note** The power connector on the camera is polarity protected.

3. USB cable with a USB mini-B connector for control and image transfer.
4. Digital I/O ports, opto-isolated (six-pole screw terminal).

- A. Hardware reset button (for a factory default reset).

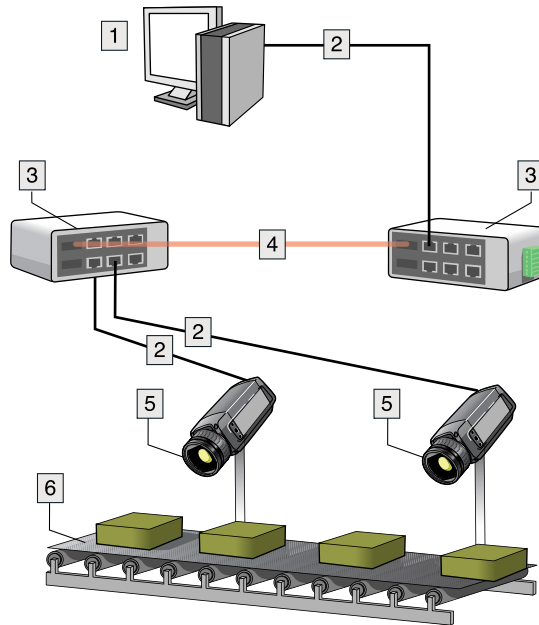
Use a straightened paper clip or a similar tool to press the reset button through the small hole on the back of the camera for 5 seconds, then release the button.

- B. Power indicator.



## 12.1 FLIR A6xx series

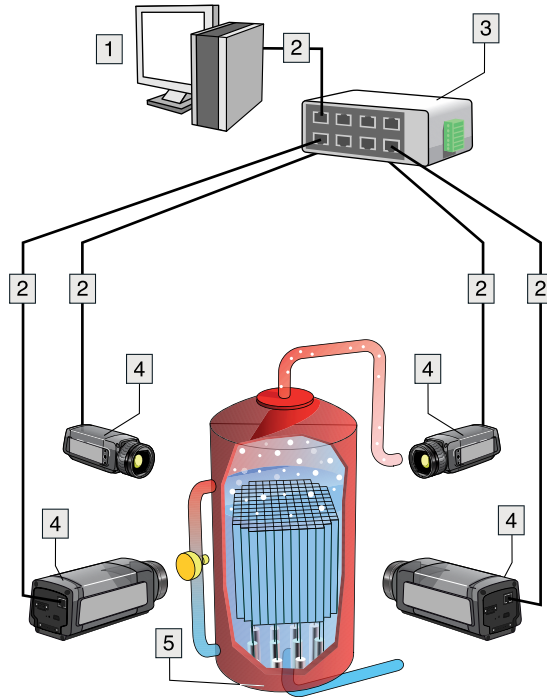
### 12.1.1 Figure



### 12.1.2 Explanation

1. Computer.
2. CAT-6 Ethernet cable with RJ45 connectors.
3. Industrial Ethernet switches with fiber-optic ports.
4. Fiber-optic cable.
5. FLIR A6xx cameras.
6. Industrial process to be monitored, e.g., items on a conveyor belt.

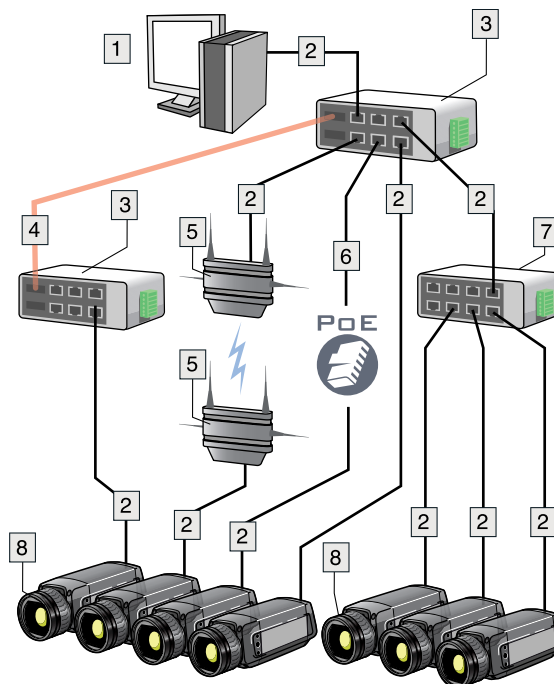
12.1.3 Figure



12.1.4 Explanation

1. Computer.
2. CAT-6 Ethernet cable with RJ45 connectors.
3. Industrial Ethernet switch.
4. FLIR A6xx cameras.
5. Industrial process to be monitored, e.g., a gasifier.

12.1.5 Figure



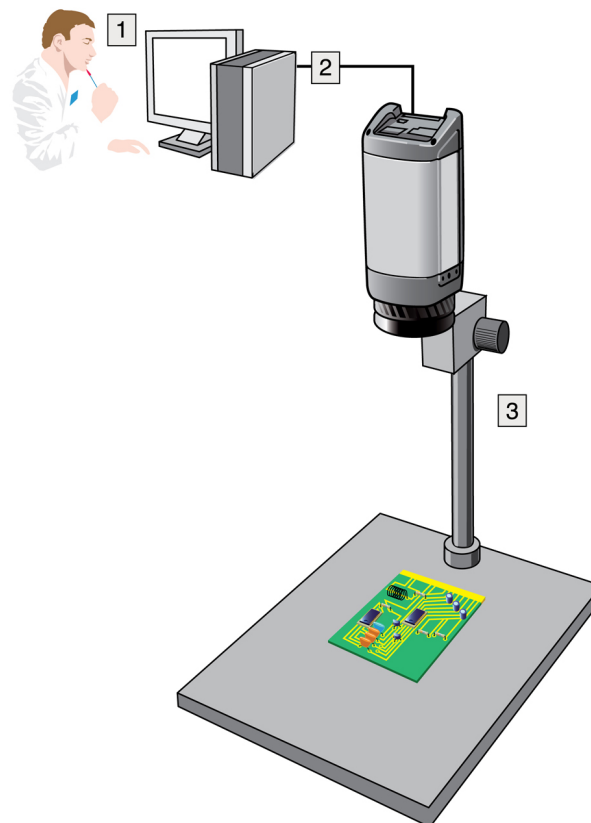
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### 12.1.6 Explanation

1. Computer.
2. CAT-6 Ethernet cable with RJ45 connectors.
3. Industrial Ethernet switches with fiber optic ports.
4. Fiber-optic cable.
5. Wireless access points.
6. CAT-6 Ethernet cable with RJ45 connectors—powering the camera using PoE (dependent on the camera model).
7. Industrial Ethernet switch.
8. FLIR A6xx cameras.

## 12.2 FLIR A6xx sc series

### 12.2.1 Figure



### 12.2.2 Explanation

1. Computer.
2. CAT-6 Ethernet cable with RJ45 connectors.
3. Laboratory set-up with a FLIR A6xx sc camera.

## 13.1 FLIR A615 and A655sc

- The state (high or low voltage) on an input pin is used to mark images for use by an application.
- The state (high or low voltage) on an output pin is controlled by an application.

See the section *Technical data* for details on voltages, etc.

## 14.1 Online field-of-view calculator

Please visit <http://support.flir.com> and click the photo of the camera series for field-of-view tables for all lens-camera combinations.

## 14.2 Note about technical data

FLIR Systems reserves the right to change specifications at any time without prior notice. Please check <http://support.flir.com> for latest changes.

## 14.3 Note about authoritative versions

The authoritative version of this publication is English. In the event of divergences due to translation errors, the English text has precedence.

Any late changes are first implemented in English.

#### 14.4 FLIR A615 15°

P/N: 55001-0101

Rev.: 35207

General description	
<p>The FLIR A615 has features and functions that make it the natural choice for anyone who uses PC software to solve problems and needs 640 × 480 pixel resolution. Among its main features are GigE Vision and GenICam compliance, which makes it plug-and-play when used with software packages such as IMAQ Vision and Halcon.</p> <p>The camera is equipped with a 15° lens.</p>	
Key features:	
<ul style="list-style-type: none"> <li>• Affordable.</li> <li>• GigE compliant.</li> <li>• GenICam compliant.</li> <li>• Trigg/synchronization/GPIO.</li> <li>• 16-bit 640 × 480 pixel images at 50 Hz, signal, temperature linear, and radiometric.</li> <li>• Windowing mode: 640 × 240 pixels at 100 Hz or 640 × 120 pixels at 200 Hz.</li> <li>• Compliant with any software that supports GenICam, including National Instruments IMAQ Vision and Stemmers Common Vision Blox.</li> <li>• Open and well-described TCP/IP protocol for control and set-up.</li> </ul>	
Typical applications:	
<ul style="list-style-type: none"> <li>• High-end infrared machine vision that needs temperature measurement.</li> <li>• Slag detection.</li> <li>• Food processing.</li> <li>• Electronics testing.</li> <li>• Power resistor testing.</li> <li>• Automotive.</li> </ul>	
Imaging and optical data	
IR resolution	640 × 480 pixels
Thermal sensitivity/NETD	< 0.05°C @ +30°C (+86°F) / 50 mK
Field of view (FOV)	15° × 11° (19° diagonal)
Minimum focus distance	0.50 m (1.64 ft.)
Focal length	41.3 mm (1.63 in.)
Spatial resolution (IFOV)	0.41 mrad
Lens identification	Automatic
F-number	1.0
Image frequency	50 Hz (100/200 Hz with windowing)
Focus	Automatic or manual (built in motor)
Detector data	
Detector type	Focal plane array (FPA), uncooled microbolometer
Spectral range	7.5–14 μm
Detector pitch	17 μm
Detector time constant	Typical 8 ms
Measurement	
Object temperature range	<ul style="list-style-type: none"> <li>• -40°C to +150°C (-40°F to +302°F)</li> <li>• 100 to +650°C (+212 to +1202°F)</li> <li>• 300 to +2000°C (+572 to +3632°F)</li> </ul>
Accuracy	±2°C (±3.6°F) or ±2% of reading

<b>Measurement analysis</b>	
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on input of optics/window transmission and temperature
Measurement corrections	Global object parameters
<b>USB</b>	
USB	<ul style="list-style-type: none"> <li>Control and image</li> </ul>
USB, standard	USB 2 HS
USB, connector type	<ul style="list-style-type: none"> <li>USB Mini-B</li> </ul>
USB, communication	TCP/IP socket-based FLIR proprietary
USB, image streaming	16-bit 640 × 480 pixels @ 25 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul>
USB, protocols	TCP, UDP, SNMP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP
<b>Ethernet</b>	
Ethernet	Control and image
Ethernet, type	Gigabit Ethernet
Ethernet, standard	IEEE 802.3
Ethernet, connector type	RJ-45
Ethernet, communication	TCP/IP socket-based FLIR proprietary and GenI-Cam protocol
Ethernet, image streaming	16-bit 640 × 480 pixels @ 50 Hz 16-bit 640 × 240 pixels @ 100 Hz 16-bit 640 × 120 pixels @ 200 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul> GigE Vision and GenICam compatible
Ethernet, protocols	TCP, UDP, SNMP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP
<b>Digital input/output</b>	
Digital input, purpose	Image tag (start, stop, general), Image flow control, (stream on/off), Input ext. device (programmatically read)
Digital input	2 opto-isolated, 0–1.5 V = low, 3–25 V = high
Digital output, purpose	Output to ext. device (programmatically set)
Digital output	2 opto-isolated, ON = supply (max. 100 mA), OFF = open
Digital I/O, isolation voltage	500 VRMS

<b>Digital input/output</b>	
Digital I/O, supply voltage	6–24 VDC, max. 200 mA
Digital I/O, connector type	6-pole jackable screw terminal
<b>Power system</b>	
External power operation	12/24 VDC, 24 W absolute max.
External power, connector type	2-pole jackable screw terminal
Voltage	Allowed range 10–30 VDC
<b>Environmental data</b>	
Operating temperature range	–15°C to +50°C (+5°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25°C to +40°C (+77°F to +104°F)
EMC	<ul style="list-style-type: none"> <li>• EN 61000-6-2:2001 (Immunity)</li> <li>• EN 61000-6-3:2001 (Emission)</li> <li>• FCC 47 CFR Part 15 Class B (Emission)</li> </ul>
Encapsulation	IP 30 (IEC 60529)
Shock	25 g (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)
<b>Physical data</b>	
Weight	0.92 kg (2.03 lb.)
Camera size (L × W × H)	222 × 73 × 75 mm (8.7 × 2.9 × 3.0 in.)
Camera size, excl. lens (L × W × H)	203 × 73 × 75 mm (8.0 × 2.9 × 3.0 in.)
Tripod mounting	UNC ¼"-20 (on three sides)
Base mounting	2 × M4 thread mounting holes (on three sides)
Housing material	Aluminum
Comments to physical data	Outline dimensional drawings and STEP files can be found at <a href="http://support.flir.com">http://support.flir.com</a>
<b>Shipping information</b>	
Packaging, type	Cardboard box
List of contents	<ul style="list-style-type: none"> <li>• Infrared camera with lens</li> <li>• Ethernet cable</li> <li>• Mains cable</li> <li>• Power cable, pig-tailed</li> <li>• Power supply</li> <li>• Printed documentation</li> <li>• USB cable</li> <li>• Utility CD-ROM</li> </ul>
Packaging, weight	
Packaging, size	360 × 180 × 550 mm (14.2 × 7.1 × 21.7 in.)
EAN-13	7332558003244
UPC-12	845188002725
Country of origin	Sweden

**Supplies & accessories:**

- T197914; IR lens, f=41.3 mm (15°) with case
- T197922; IR lens, f=24.6 mm (25°) with case
- T197915; IR lens, f=13.1 mm (45°) with case
- T198065; IR lens, f=6.5 mm (80°) with case



- T198165; IR lens, f=88.9 mm (7°) with case and support for A6xx/A6xxsc
- T197896; High temperature option +300°C to 2000°C (+572°F to 3632°F)
- 1910400; Power cord EU
- 1910401; Power cord US
- 1910402; Power cord UK
- T910922; Power supply, incl. multi plugs, for A3xx, A3xxsc, A6xx and A6xxsc
- T911182; Power supply for A3xx f, IP66
- 1910423; USB cable Std A <-> Mini-B
- T951004ACC; Ethernet cable CAT6, 2 m/6.6 ft.
- 1910586ACC; Power cable, pigtailed
- T197871ACC; Hard transport case for A3xx/A6xx series
- T197870ACC; Cardboard box for A3xx/A6xx series
- T126889ACC; Filter holder for A6xx lenses
- T198584; FLIR Tools
- T198583; FLIR Tools+ (download card incl. license key)
- DSW-10000; FLIR IR Camera Player
- T199233; FLIR Atlas SDK for .NET
- T199234; FLIR Atlas SDK for MATLAB
- T198567; ThermoVision™ System Developers Kit Ver. 2.6
- T198566; ThermoVision™ LabVIEW® Digital Toolkit Ver. 3.3

## 14.5 FLIR A615 25°

P/N: 55001-0102

Rev.: 35207

General description	
<p>The FLIR A615 has features and functions that make it the natural choice for anyone who uses PC software to solve problems and needs 640 × 480 pixel resolution. Among its main features are GigE Vision and GenICam compliance, which makes it plug-and-play when used with software packages such as IMAQ Vision and Halcon.</p> <p>The camera is equipped with the standard 25° lens.</p>	
Key features:	
<ul style="list-style-type: none"> <li>• Affordable.</li> <li>• GigE compliant.</li> <li>• GenICam compliant.</li> <li>• Trigg/synchronization/GPIO.</li> <li>• 16-bit 640 × 480 pixel images at 50 Hz, signal, temperature linear, and radiometric.</li> <li>• Windowing mode: 640 × 240 pixels at 100 Hz or 640 × 120 pixels at 200 Hz.</li> <li>• Compliant with any software that supports GenICam, including National Instruments IMAQ Vision and Stemmers Common Vision Blox.</li> <li>• Open and well-described TCP/IP protocol for control and set-up.</li> </ul>	
Typical applications:	
<ul style="list-style-type: none"> <li>• High-end infrared machine vision that requires temperature measurement</li> <li>• Slag detection</li> <li>• Food processing</li> <li>• Electronics testing</li> <li>• Power resistor testing</li> <li>• Automotive</li> </ul>	
Imaging and optical data	
IR resolution	640 × 480 pixels
Thermal sensitivity/NETD	< 0.05°C @ +30°C (+86°F) / 50 mK
Field of view (FOV)	25° × 19° (31° diagonal)
Minimum focus distance	0.25 m (0.82 ft.)
Focal length	24.6 mm (0.97 in.)
Spatial resolution (IFOV)	0.68 mrad
Lens identification	Automatic
F-number	1.0
Image frequency	50 Hz (100/200 Hz with windowing)
Focus	Automatic or manual (built in motor)
Detector data	
Detector type	Focal plane array (FPA), uncooled microbolometer
Spectral range	7.5–14 μm
Detector pitch	17 μm
Detector time constant	Typical 8 ms
Measurement	
Object temperature range	<ul style="list-style-type: none"> <li>• -40°C to +150°C (-40°F to +302°F)</li> <li>• 100 to +650°C (+212 to +1202°F)</li> <li>• 300 to +2000°C (+572 to +3632°F)</li> </ul>
Accuracy	±2°C (±3.6°F) or ±2% of reading

<b>Measurement analysis</b>	
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on input of optics/window transmission and temperature
Measurement corrections	Global object parameters
<b>USB</b>	
USB	<ul style="list-style-type: none"> <li>Control and image</li> </ul>
USB, standard	USB 2 HS
USB, connector type	<ul style="list-style-type: none"> <li>USB Mini-B</li> </ul>
USB, communication	TCP/IP socket-based FLIR proprietary
USB, image streaming	16-bit 640 × 480 pixels @ 25 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul>
USB, protocols	TCP, UDP, SNMP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP
<b>Ethernet</b>	
Ethernet	Control and image
Ethernet, type	Gigabit Ethernet
Ethernet, standard	IEEE 802.3
Ethernet, connector type	RJ-45
Ethernet, communication	TCP/IP socket-based FLIR proprietary and GenI-Cam protocol
Ethernet, image streaming	16-bit 640 × 480 pixels @ 50 Hz 16-bit 640 × 240 pixels @ 100 Hz 16-bit 640 × 120 pixels @ 200 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul> GigE Vision and GenICam compatible
Ethernet, protocols	TCP, UDP, SNMP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP
<b>Digital input/output</b>	
Digital input, purpose	Image tag (start, stop, general), Image flow control, (stream on/off), Input ext. device (programmatically read)
Digital input	2 opto-isolated, 0–1.5 V = low, 3–25 V = high
Digital output, purpose	Output to ext. device (programmatically set)
Digital output	2 opto-isolated, ON = supply (max. 100 mA), OFF = open
Digital I/O, isolation voltage	500 VRMS

<b>Digital input/output</b>	
Digital I/O, supply voltage	6–24 VDC, max. 200 mA
Digital I/O, connector type	6-pole jackable screw terminal
<b>Power system</b>	
External power operation	12/24 VDC, 24 W absolute max.
External power, connector type	2-pole jackable screw terminal
Voltage	Allowed range 10–30 VDC
<b>Environmental data</b>	
Operating temperature range	–15°C to +50°C (+5°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25°C to +40°C (+77°F to +104°F)
EMC	<ul style="list-style-type: none"> <li>• EN 61000-6-2:2001 (Immunity)</li> <li>• EN 61000-6-3:2001 (Emission)</li> <li>• FCC 47 CFR Part 15 Class B (Emission)</li> </ul>
Encapsulation	IP 30 (IEC 60529)
Shock	25 g (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)
<b>Physical data</b>	
Weight	0.90 kg (1.98 lb.)
Camera size (L × W × H)	216 × 73 × 75 mm (8.5 × 2.9 × 3.0 in.)
Camera size, excl. lens (L × W × H)	203 × 73 × 75 mm (8.0 × 2.9 × 3.0 in.)
Tripod mounting	UNC ¼"-20 (on three sides)
Base mounting	2 × M4 thread mounting holes (on three sides)
Housing material	Aluminum
Comments to physical data	Outline dimensional drawings and STEP files can be found at <a href="http://support.flir.com">http://support.flir.com</a>
<b>Shipping information</b>	
Packaging, type	Cardboard box
List of contents	<ul style="list-style-type: none"> <li>• Infrared camera with lens</li> <li>• Ethernet cable</li> <li>• Mains cable</li> <li>• Power cable, pig-tailed</li> <li>• Power supply</li> <li>• Printed</li> <li>• Printed documentation</li> <li>• USB cable</li> <li>• Utility CD-ROM</li> </ul>
Packaging, weight	
Packaging, size	360 × 180 × 550 mm (14.2 × 7.1 × 21.7 in.)
EAN-13	7332558003251
UPC-12	845188002732
Country of origin	Sweden

**Supplies & accessories:**

- T197914; IR lens, f=41.3 mm (15°) with case
- T197922; IR lens, f=24.6 mm (25°) with case
- T197915; IR lens, f=13.1 mm (45°) with case

- T198059; Close-up IR lens, 2.9× (50 µm) with case
- T198060; Close-up IR lens, 5.8× (100 µm) with case
- T198065; IR lens, f=6.5 mm (80°) with case
- T198165; IR lens, f=88.9 mm (7°) with case and support for A6xx/A6xxsc
- T198066; Close-up IR lens, 1.5× (25 µm) with case
- T197896; High temperature option +300°C to 2000°C (+572°F to 3632°F)
- 1910400; Power cord EU
- 1910401; Power cord US
- 1910402; Power cord UK
- T910922; Power supply, incl. multi plugs, for A3xx, A3xxsc, A6xx and A6xxsc
- T911182; Power supply for A3xx f, IP66
- 1910423; USB cable Std A <-> Mini-B
- T951004ACC; Ethernet cable CAT6, 2 m/6.6 ft.
- 1910586ACC; Power cable, pigtailed
- T197871ACC; Hard transport case for A3xx/A6xx series
- T197870ACC; Cardboard box for A3xx/A6xx series
- T126889ACC; Filter holder for A6xx lenses
- T198584; FLIR Tools
- T198583; FLIR Tools+ (download card incl. license key)
- DSW-10000; FLIR IR Camera Player
- T199233; FLIR Atlas SDK for .NET
- T199234; FLIR Atlas SDK for MATLAB
- T198567; ThermoVision™ System Developers Kit Ver. 2.6
- T198566; ThermoVision™ LabVIEW® Digital Toolkit Ver. 3.3

## 14.6 FLIR A615 45°

P/N: 55001-0103

Rev.: 35207

General description	
<p>The FLIR A615 has features and functions that make it the natural choice for anyone who uses PC software to solve problems and needs 640 × 480 pixel resolution. Among its main features are GigE Vision and GenICam compliance, which makes it plug-and-play when used with software packages such as IMAQ Vision and Halcon.</p> <p>The camera is equipped with a 45° lens.</p>	
Key features:	
<ul style="list-style-type: none"> <li>• Affordable.</li> <li>• GigE compliant.</li> <li>• GenICam compliant.</li> <li>• Trigg/synchronization/GPIO.</li> <li>• 16-bit 640 × 480 pixel images at 50 Hz, signal, temperature linear, and radiometric.</li> <li>• Windowing mode: 640 × 240 pixels at 100 Hz or 640 × 120 pixels at 200 Hz.</li> <li>• Compliant with any software that supports GenICam, including National Instruments IMAQ Vision and Stammers Common Vision Blox.</li> <li>• Open and well-described TCP/IP protocol for control and set-up.</li> </ul>	
Typical applications:	
<ul style="list-style-type: none"> <li>• High-end infrared machine vision that requires temperature measurement.</li> <li>• Slag detection.</li> <li>• Food processing.</li> <li>• Electronics testing.</li> <li>• Power resistor testing.</li> <li>• Automotive.</li> </ul>	
Imaging and optical data	
IR resolution	640 × 480 pixels
Thermal sensitivity/NETD	< 0.05°C @ +30°C (+86°F) / 50 mK
Field of view (FOV)	45° × 34° (55° diagonal)
Minimum focus distance	0.15 m (0.49 ft.)
Focal length	13.1 mm (0.52 in.)
Spatial resolution (IFOV)	1.23 mrad
Lens identification	Automatic
F-number	1.0
Image frequency	50 Hz (100/200 Hz with windowing)
Focus	Automatic or manual (built in motor)
Detector data	
Detector type	Focal plane array (FPA), uncooled microbolometer
Spectral range	7.5–14 μm
Detector pitch	17 μm
Detector time constant	Typical 8 ms
Measurement	
Object temperature range	<ul style="list-style-type: none"> <li>• -40°C to +150°C (-40°F to +302°F)</li> <li>• 100 to +650°C (+212 to +1202°F)</li> <li>• 300 to +2000°C (+572 to +3632°F)</li> </ul>
Accuracy	±2°C (±3.6°F) or ±2% of reading

<b>Measurement analysis</b>	
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on input of optics/window transmission and temperature
Measurement corrections	Global object parameters
<b>USB</b>	
USB	<ul style="list-style-type: none"> <li>Control and image</li> </ul>
USB, standard	USB 2 HS
USB, connector type	<ul style="list-style-type: none"> <li>USB Mini-B</li> </ul>
USB, communication	TCP/IP socket-based FLIR proprietary
USB, image streaming	16-bit 640 × 480 pixels @ 25 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul>
USB, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP
<b>Ethernet</b>	
Ethernet	Control and image
Ethernet, type	Gigabit Ethernet
Ethernet, standard	IEEE 802.3
Ethernet, connector type	RJ-45
Ethernet, communication	TCP/IP socket-based FLIR proprietary and GenI-Cam protocol
Ethernet, image streaming	16-bit 640 × 480 pixels @ 50 Hz 16-bit 640 × 240 pixels @ 100 Hz 16-bit 640 × 120 pixels @ 200 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul> GigE Vision and GenICam compatible
Ethernet, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP
<b>Digital input/output</b>	
Digital input, purpose	Image tag (start, stop, general), Image flow control, (stream on/off), Input ext. device (programmatically read)
Digital input	2 opto-isolated, 0–1.5 V = low, 3–25 V = high
Digital output, purpose	Output to ext. device (programmatically set)
Digital output	2 opto-isolated, ON = supply (max. 100 mA), OFF = open
Digital I/O, isolation voltage	500 VRMS

<b>Digital input/output</b>	
Digital I/O, supply voltage	6–24 VDC, max. 200 mA
Digital I/O, connector type	6-pole jackable screw terminal
<b>Power system</b>	
External power operation	12/24 VDC, 24 W absolute max.
External power, connector type	2-pole jackable screw terminal
Voltage	Allowed range 10–30 VDC
<b>Environmental data</b>	
Operating temperature range	–15°C to +50°C (+5°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25°C to +40°C (+77°F to +104°F)
EMC	<ul style="list-style-type: none"> <li>• EN 61000-6-2:2001 (Immunity)</li> <li>• EN 61000-6-3:2001 (Emission)</li> <li>• FCC 47 CFR Part 15 Class B (Emission)</li> </ul>
Encapsulation	IP 30 (IEC 60529)
Shock	25 g (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)
<b>Physical data</b>	
Weight	0.94 kg (2.07 lb.)
Camera size (L × W × H)	225 × 73 × 75 mm (8.8 × 2.9 × 3.0 in.)
Camera size, excl. lens (L × W × H)	203 × 73 × 75 mm (8.0 × 2.9 × 3.0 in.)
Tripod mounting	UNC ¼"-20 (on three sides)
Base mounting	2 × M4 thread mounting holes (on three sides)
Housing material	Aluminum
Comments to physical data	Outline dimensional drawings and STEP files can be found at <a href="http://support.flir.com">http://support.flir.com</a>
<b>Shipping information</b>	
Packaging, type	Cardboard box
List of contents	<ul style="list-style-type: none"> <li>• Infrared camera with lens</li> <li>• Ethernet cable</li> <li>• Mains cable</li> <li>• Power cable, pig-tailed</li> <li>• Power supply</li> <li>• Printed documentation</li> <li>• USB cable</li> <li>• Utility CD-ROM</li> </ul>
Packaging, weight	
Packaging, size	360 × 180 × 550 mm (14.2 × 7.1 × 21.7 in.)
EAN-13	7332558003268
UPC-12	845188002749
Country of origin	Sweden

**Supplies & accessories:**

- T197914; IR lens, f=41.3 mm (15°) with case
- T197922; IR lens, f=24.6 mm (25°) with case
- T197915; IR lens, f=13.1 mm (45°) with case
- T198065; IR lens, f=6.5 mm (80°) with case



- T198165; IR lens, f=88.9 mm (7°) with case and support for A6xx/A6xxsc
- T198066; Close-up IR lens, 1.5× (25 μm) with case
- T197896; High temperature option +300°C to 2000°C (+572°F to 3632°F)
- 1910400; Power cord EU
- 1910401; Power cord US
- 1910402; Power cord UK
- T910922; Power supply, incl. multi plugs, for A3xx, A3xxsc, A6xx and A6xxsc
- T911182; Power supply for A3xx f, IP66
- 1910423; USB cable Std A <-> Mini-B
- T951004ACC; Ethernet cable CAT6, 2 m/6.6 ft.
- 1910586ACC; Power cable, pigtailed
- T197871ACC; Hard transport case for A3xx/A6xx series
- T197870ACC; Cardboard box for A3xx/A6xx series
- T126889ACC; Filter holder for A6xx lenses
- T198584; FLIR Tools
- T198583; FLIR Tools+ (download card incl. license key)
- DSW-10000; FLIR IR Camera Player
- T199233; FLIR Atlas SDK for .NET
- T199234; FLIR Atlas SDK for MATLAB
- T198567; ThermoVision™ System Developers Kit Ver. 2.6
- T198566; ThermoVision™ LabVIEW® Digital Toolkit Ver. 3.3

### 14.7 FLIR A615 7°

P/N: 55001-0104

Rev.: 35207

General description	
<p>The FLIR A615 has features and functions that make it the natural choice for anyone who uses PC software to solve problems and needs 640 × 480 pixel resolution. Among its main features are GigE Vision and GenICam compliance, which makes it plug-and-play when used with software packages such as IMAQ Vision and Halcon.</p> <p>The camera is equipped with a 7° lens.</p>	
Key features:	
<ul style="list-style-type: none"> <li>• Affordable.</li> <li>• GigE compliant.</li> <li>• GenICam compliant.</li> <li>• Trigg/synchronization/GPIO.</li> <li>• 16-bit 640 × 480 pixel images at 50 Hz, signal, temperature linear, and radiometric.</li> <li>• Windowing mode: 640 × 240 pixels at 100 Hz or 640 × 120 pixels at 200 Hz.</li> <li>• Compliant with any software that supports GenICam, including National Instruments IMAQ Vision and Stemmers Common Vision Blox.</li> <li>• Open and well-described TCP/IP protocol for control and set-up.</li> </ul>	
Typical applications:	
<ul style="list-style-type: none"> <li>• High-end infrared machine vision that requires temperature measurement.</li> <li>• Slag detection.</li> <li>• Food processing.</li> <li>• Electronics testing.</li> <li>• Power resistor testing.</li> <li>• Automotive.</li> </ul>	
Imaging and optical data	
IR resolution	640 × 480 pixels
Thermal sensitivity/NETD	< 0.05°C @ +30°C (+86°F) / 50 mK
Field of view (FOV)	7° × 5.3° (8.7° diagonally)
Minimum focus distance	2.0 m (6.6 ft.)
Focal length	88.9 mm (3.5 in.)
Spatial resolution (IFOV)	0.19 mrad
Lens identification	Automatic
F-number	1.3
Image frequency	50 Hz (100/200 Hz with windowing)
Focus	Automatic or manual (built in motor)
Detector data	
Detector type	Focal plane array (FPA), uncooled microbolometer
Spectral range	7.5–14 μm
Detector pitch	17 μm
Detector time constant	Typical 8 ms
Measurement	
Object temperature range	<ul style="list-style-type: none"> <li>• -40°C to +150°C (-40°F to +302°F)</li> <li>• 100 to +650°C (+212 to +1202°F)</li> <li>• 300 to +2000°C (+572 to +3632°F)</li> </ul>
Accuracy	±2°C (±3.6°F) or ±2% of reading

<b>Measurement analysis</b>	
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on input of optics/window transmission and temperature
Measurement corrections	Global object parameters
<b>USB</b>	
USB	<ul style="list-style-type: none"> <li>Control and image</li> </ul>
USB, standard	USB 2 HS
USB, connector type	<ul style="list-style-type: none"> <li>USB Mini-B</li> </ul>
USB, communication	TCP/IP socket-based FLIR proprietary
USB, image streaming	16-bit 640 × 480 pixels @ 25 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul>
USB, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP
<b>Ethernet</b>	
Ethernet	Control and image
Ethernet, type	Gigabit Ethernet
Ethernet, standard	IEEE 802.3
Ethernet, connector type	RJ-45
Ethernet, communication	TCP/IP socket-based FLIR proprietary and GenI-Cam protocol
Ethernet, image streaming	16-bit 640 × 480 pixels @ 50 Hz 16-bit 640 × 240 pixels @ 100 Hz 16-bit 640 × 120 pixels @ 200 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul> GigE Vision and GenICam compatible
Ethernet, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP
<b>Digital input/output</b>	
Digital input, purpose	Image tag (start, stop, general), Image flow control, (stream on/off), Input ext. device (programmatically read)
Digital input	2 opto-isolated, 0–1.5 V = low, 3–25 V = high
Digital output, purpose	Output to ext. device (programmatically set)
Digital output	2 opto-isolated, ON = supply (max. 100 mA), OFF = open
Digital I/O, isolation voltage	500 VRMS

<b>Digital input/output</b>	
Digital I/O, supply voltage	6–24 VDC, max. 200 mA
Digital I/O, connector type	6-pole jackable screw terminal
<b>Power system</b>	
External power operation	12/24 VDC, 24 W absolute max.
External power, connector type	2-pole jackable screw terminal
Voltage	Allowed range 10–30 VDC
<b>Environmental data</b>	
Operating temperature range	–15°C to +50°C (+5°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25°C to +40°C (+77°F to +104°F)
EMC	<ul style="list-style-type: none"> <li>• EN 61000-6-2:2001 (Immunity)</li> <li>• EN 61000-6-3:2001 (Emission)</li> <li>• FCC 47 CFR Part 15 Class B (Emission)</li> </ul>
Encapsulation	IP 30 (IEC 60529)
Shock	25 g (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)
<b>Physical data</b>	
Weight	1.61 kg (3.55 lb.)
Camera size (L × W × H)	271 × 126 × 128 mm (10.7 × 5.0 × 5.0 in.)
Camera size, excl. lens (L × W × H)	203 × 73 × 75 mm (8.0 × 2.9 × 3.0 in.)
Tripod mounting	UNC ¼"-20 (on three sides)
Base mounting	2 × M4 thread mounting holes (on three sides)
Housing material	Aluminum
Comments to physical data	Outline dimensional drawings and STEP files can be found at <a href="http://support.flir.com">http://support.flir.com</a>
<b>Shipping information</b>	
Packaging, type	Cardboard box
List of contents	<ul style="list-style-type: none"> <li>• Infrared camera with lens</li> <li>• Ethernet cable</li> <li>• Mains cable</li> <li>• Power cable, pig-tailed</li> <li>• Power supply</li> <li>• Printed documentation</li> <li>• USB cable</li> <li>• Utility CD-ROM</li> </ul>
Packaging, weight	5.8 kg (12.8 lb.)
Packaging, size	400 × 400 × 540 mm (15.7 × 15.7 × 21.3 in.)
EAN-13	7332558004685
UPC-12	845188004620
Country of origin	Sweden

**Supplies & accessories:**

- T197914; IR lens, f=41.3 mm (15°) with case
- T197922; IR lens, f=24.6 mm (25°) with case
- T197915; IR lens, f=13.1 mm (45°) with case
- T198065; IR lens, f=6.5 mm (80°) with case

- T198165; IR lens, f=88.9 mm (7°) with case and support for A6xx/A6xxsc
- T197896; High temperature option +300°C to 2000°C (+572°F to 3632°F)
- 1910400; Power cord EU
- 1910401; Power cord US
- 1910402; Power cord UK
- T910922; Power supply, incl. multi plugs, for A3xx, A3xxsc, A6xx and A6xxsc
- T911182; Power supply for A3xx f, IP66
- 1910423; USB cable Std A <-> Mini-B
- T951004ACC; Ethernet cable CAT6, 2 m/6.6 ft.
- 1910586ACC; Power cable, pigtailed
- T197871ACC; Hard transport case for A3xx/A6xx series
- T197870ACC; Cardboard box for A3xx/A6xx series
- T126889ACC; Filter holder for A6xx lenses
- T198584; FLIR Tools
- T198583; FLIR Tools+ (download card incl. license key)
- DSW-10000; FLIR IR Camera Player
- T199233; FLIR Atlas SDK for .NET
- T199234; FLIR Atlas SDK for MATLAB
- T198567; ThermoVision™ System Developers Kit Ver. 2.6
- T198566; ThermoVision™ LabVIEW® Digital Toolkit Ver. 3.3

## 14.8 FLIR A615 windowing 80°

P/N: 55001-0105

Rev.: 35207

General description	
<p>The FLIR A615 has features and functions that make it the natural choice for anyone who uses PC software to solve problems and needs 640 × 480 pixel resolution. Among its main features are GigE Vision and GenICam compliance, which makes it plug-and-play when used with software packages such as IMAQ Vision and Halcon.</p> <p>The camera is equipped with a 80° lens.</p>	
Key features:	
<ul style="list-style-type: none"> <li>• Affordable.</li> <li>• GigE compliant.</li> <li>• GenICam compliant.</li> <li>• Trigg/synchronization/GPIO.</li> <li>• 16-bit 640 × 480 pixel images at 50 Hz, signal, temperature linear, and radiometric.</li> <li>• Windowing mode: 640 × 240 pixels at 100 Hz or 640 × 120 pixels at 200 Hz.</li> <li>• Compliant with any software that supports GenICam, including National Instruments IMAQ Vision and Stemmers Common Vision Blox.</li> <li>• Open and well-described TCP/IP protocol for control and set-up.</li> </ul>	
Typical applications:	
<ul style="list-style-type: none"> <li>• High-end infrared machine vision that requires temperature measurement.</li> <li>• Slag detection.</li> <li>• Food processing.</li> <li>• Electronics testing.</li> <li>• Power resistor testing.</li> <li>• Automotive.</li> </ul>	
Imaging and optical data	
IR resolution	640 × 480 pixels
Thermal sensitivity/NETD	< 0.05°C @ +30°C (+86°F) / 50 mK
Field of view (FOV)	80° × 64.4° (92.8° diagonal)
Minimum focus distance	65 mm (2.6 in.)
Focal length	6.5 mm (0.26 in.)
Spatial resolution (IFOV)	2.62 mrad
Lens identification	Automatic
F-number	1.0
Image frequency	50 Hz (100/200 Hz with windowing)
Focus	Automatic or manual (built in motor)
Detector data	
Detector type	Focal plane array (FPA), uncooled microbolometer
Spectral range	7.5–14 μm
Detector pitch	17 μm
Detector time constant	Typical 8 ms
Measurement	
Object temperature range	<ul style="list-style-type: none"> <li>• -40°C to +150°C (-40°F to +302°F)</li> <li>• 100 to +650°C (+212 to +1202°F)</li> <li>• 300 to +2000°C (+572 to +3632°F)</li> </ul>
Accuracy	±2°C (±3.6°F) or ±2% of reading

<b>Measurement analysis</b>	
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on input of optics/window transmission and temperature
Measurement corrections	Global object parameters
<b>USB</b>	
USB	<ul style="list-style-type: none"> <li>Control and image</li> </ul>
USB, standard	USB 2 HS
USB, connector type	<ul style="list-style-type: none"> <li>USB Mini-B</li> </ul>
USB, communication	TCP/IP socket-based FLIR proprietary
USB, image streaming	16-bit 640 × 480 pixels @ 25 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul>
USB, protocols	TCP, UDP, SNMP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP
<b>Ethernet</b>	
Ethernet	Control and image
Ethernet, type	Gigabit Ethernet
Ethernet, standard	IEEE 802.3
Ethernet, connector type	RJ-45
Ethernet, communication	TCP/IP socket-based FLIR proprietary and GenI-Cam protocol
Ethernet, image streaming	16-bit 640 × 480 pixels @ 50 Hz 16-bit 640 × 240 pixels @ 100 Hz 16-bit 640 × 120 pixels @ 200 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul> GigE Vision and GenICam compatible
Ethernet, protocols	TCP, UDP, SNMP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP
<b>Digital input/output</b>	
Digital input, purpose	Image tag (start, stop, general), Image flow control, (stream on/off), Input ext. device (programmatically read)
Digital input	2 opto-isolated, 0–1.5 V = low, 3–25 V = high
Digital output, purpose	Output to ext. device (programmatically set)
Digital output	2 opto-isolated, ON = supply (max. 100 mA), OFF = open
Digital I/O, isolation voltage	500 VRMS

<b>Digital input/output</b>	
Digital I/O, supply voltage	6–24 VDC, max. 200 mA
Digital I/O, connector type	6-pole jackable screw terminal
<b>Power system</b>	
External power operation	12/24 VDC, 24 W absolute max.
External power, connector type	2-pole jackable screw terminal
Voltage	Allowed range 10–30 VDC
<b>Environmental data</b>	
Operating temperature range	–15°C to +50°C (+5°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25°C to +40°C (+77°F to +104°F)
EMC	<ul style="list-style-type: none"> <li>• EN 61000-6-2:2001 (Immunity)</li> <li>• EN 61000-6-3:2001 (Emission)</li> <li>• FCC 47 CFR Part 15 Class B (Emission)</li> </ul>
Encapsulation	IP 30 (IEC 60529)
Shock	25 g (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)
<b>Physical data</b>	
Weight	1.17 kg (2.58 lb.)
Camera size (L × W × H)	297 × 73 × 75 mm (11.7 × 2.9 × 3.0 in.)
Camera size, excl. lens (L × W × H)	203 × 73 × 75 mm (8.0 × 2.9 × 3.0 in.)
Tripod mounting	UNC ¼"-20 (on three sides)
Base mounting	2 × M4 thread mounting holes (on three sides)
Housing material	Aluminum
Comments to physical data	Outline dimensional drawings and STEP files can be found at <a href="http://support.flir.com">http://support.flir.com</a>
<b>Shipping information</b>	
Packaging, type	Cardboard box
List of contents	<ul style="list-style-type: none"> <li>• Infrared camera with lens</li> <li>• Ethernet cable</li> <li>• Mains cable</li> <li>• Power cable, pig-tailed</li> <li>• Printed documentation</li> <li>• USB cable</li> <li>• Utility CD-ROM</li> </ul>
Packaging, weight	3.8 kg (8.4 lb.)
Packaging, size	370 × 190 × 630 mm (14.6 × 7.5 × 24.8 in.)
EAN-13	7332558004760
UPC-12	845188004712
Country of origin	Sweden

**Supplies & accessories:**

- T197914; IR lens, f=41.3 mm (15°) with case
- T197922; IR lens, f=24.6 mm (25°) with case
- T197915; IR lens, f=13.1 mm (45°) with case
- T198065; IR lens, f=6.5 mm (80°) with case
- T198165; IR lens, f=88.9 mm (7°) with case and support for A6xx/A6xxsc



- T197896; High temperature option +300°C to 2000°C (+572°F to 3632°F)
- 1910400; Power cord EU
- 1910401; Power cord US
- 1910402; Power cord UK
- T910922; Power supply, incl. multi plugs, for A3xx, A3xxsc, A6xx and A6xxsc
- T911182; Power supply for A3xx f, IP66
- 1910423; USB cable Std A <-> Mini-B
- T951004ACC; Ethernet cable CAT6, 2 m/6.6 ft.
- 1910586ACC; Power cable, pigtailed
- T197871ACC; Hard transport case for A3xx/A6xx series
- T197870ACC; Cardboard box for A3xx/A6xx series
- T126889ACC; Filter holder for A6xx lenses
- T198584; FLIR Tools
- T198583; FLIR Tools+ (download card incl. license key)
- DSW-10000; FLIR IR Camera Player
- T199233; FLIR Atlas SDK for .NET
- T199234; FLIR Atlas SDK for MATLAB
- T198567; ThermoVision™ System Developers Kit Ver. 2.6
- T198566; ThermoVision™ LabVIEW® Digital Toolkit Ver. 3.3

### 14.9 FLIR A655sc 15°

P/N: 55001-0301

Rev.: 35207

General description	
<p>The FLIR A655sc is an excellent choice for those working in R&amp;D but don't need the highest frame rates but do require 640 × 480 pixel resolution. When using the camera in R&amp;D, it is highly recommended to use the FLIR ResearchIR software from FLIR Systems.</p> <p>The camera is equipped with a 15° lens.</p>	
Key features:	
<ul style="list-style-type: none"> <li>Affordable.</li> <li>16-bit 640 × 480 pixel images at 25 Hz.</li> <li>Start-and-stop recording in FLIR ResearchIR using digital input.</li> <li>Windowing mode: 640 × 240 pixels at 100 Hz or 640 × 120 pixels at 200 Hz.</li> </ul>	
Typical applications:	
<ul style="list-style-type: none"> <li>Mid- or high-end industrial R&amp;D.</li> </ul>	
Imaging and optical data	
IR resolution	640 × 480 pixels
Thermal sensitivity/NETD	< 0.03°C @ +30°C (+86°F) / 30 mK
Field of view (FOV)	15° × 11° (19° diagonal)
Minimum focus distance	0.50 m (1.64 ft.)
Focal length	41.3 mm (1.63 in.)
Spatial resolution (IFOV)	0.41 mrad
Lens identification	Automatic
F-number	1.0
Image frequency	50 Hz (100/200 Hz with windowing)
Focus	Automatic or manual (built in motor)
Detector data	
Detector type	Focal plane array (FPA), uncooled microbolometer
Spectral range	7.5–14 μm
Detector pitch	17 μm
Detector time constant	Typical 8 ms
Measurement	
Object temperature range	<ul style="list-style-type: none"> <li>–40°C to +150°C (–40°F to +302°F)</li> <li>100 to +650°C (+212 to +1202°F)</li> </ul>
Accuracy	±2°C (±3.6°F) or ±2% of reading
Measurement analysis	
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on input of optics/window transmission and temperature
Measurement corrections	Global object parameters

<b>USB</b>	
USB	<ul style="list-style-type: none"> <li>Control and image</li> </ul>
USB, standard	USB 2 HS
USB, connector type	<ul style="list-style-type: none"> <li>USB Mini-B</li> </ul>
USB, communication	TCP/IP socket-based FLIR proprietary
USB, image streaming	16-bit 640 × 480 pixels @ 25 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul>
USB, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP

<b>Ethernet</b>	
Ethernet	Control and image
Ethernet, type	Gigabit Ethernet
Ethernet, standard	IEEE 802.3
Ethernet, connector type	RJ-45
Ethernet, communication	TCP/IP socket-based FLIR proprietary and Genl-Cam protocol
Ethernet, image streaming	16-bit 640 × 480 pixels @ 50 Hz 16-bit 640 × 240 pixels @ 100 Hz 16-bit 640 × 120 pixels @ 200 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul> GigE Vision and GenlCam compatible
Ethernet, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP

<b>Digital input/output</b>	
Digital input, purpose	Image tag (start, stop, general), Image flow control, (stream on/off), Input ext. device (programmatically read)
Digital input	2 opto-isolated, 0–1.5 V = low, 3–25 V = high
Digital output, purpose	Output to ext. device (programmatically set)
Digital output	2 opto-isolated, ON = supply (max. 100 mA), OFF = open
Digital I/O, isolation voltage	500 VRMS
Digital I/O, supply voltage	6–24 VDC, max. 200 mA
Digital I/O, connector type	6-pole jackable screw terminal

<b>Power system</b>	
External power operation	12/24 VDC, 24 W absolute max.
External power, connector type	2-pole jackable screw terminal
Voltage	Allowed range 10–30 VDC

<b>Environmental data</b>	
Operating temperature range	–15°C to +50°C (+5°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)

Environmental data	
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25°C to +40°C (+77°F to +104°F)
EMC	<ul style="list-style-type: none"> <li>• EN 61000-6-2:2001 (Immunity)</li> <li>• EN 61000-6-3:2001 (Emission)</li> <li>• FCC 47 CFR Part 15 Class B (Emission)</li> </ul>
Encapsulation	IP 30 (IEC 60529)
Shock	25 g (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)
Physical data	
Weight	0.92 kg (2.03 lb.)
Camera size (L × W × H)	222× 73 × 75 mm (8.7 × 2.9 × 3.0 in.)
Camera size, excl. lens (L × W × H)	203× 73 × 75 mm (8.0 × 2.9 × 3.0 in.)
Tripod mounting	UNC ¼"-20 (on three sides)
Base mounting	2 × M4 thread mounting holes (on three sides)
Housing material	Aluminum
Comments to physical data	Outline dimensional drawings and STEP files can be found at <a href="http://support.flir.com">http://support.flir.com</a>
Shipping information	
Packaging, type	Cardboard box
List of contents	<ul style="list-style-type: none"> <li>• Infrared camera with lens</li> <li>• Ethernet cable</li> <li>• FLIR ResearchIR Max 4 (licence only)</li> <li>• Hard transport case</li> <li>• Mains cable</li> <li>• Power cable, pig-tailed</li> <li>• Power supply</li> <li>• Printed documentation</li> <li>• USB cable</li> </ul>
Packaging, weight	
Packaging, size	360 × 180 × 550 mm (14.2 × 7.1 × 21.7 in.)
EAN-13	7332558003305
UPC-12	845188002787
Country of origin	Sweden

**Supplies & accessories:**

- T197914; IR lens, f=41.3 mm (15°) with case
- T197922; IR lens, f=24.6 mm (25°) with case
- T197915; IR lens, f=13.1 mm (45°) with case
- T198065; IR lens, f=6.5 mm (80°) with case
- T198165; IR lens, f=88.9 mm (7°) with case and support for A6xx/A6xxsc
- T197896; High temperature option +300°C to 2000°C (+572°F to 3632°F)
- 1910400; Power cord EU
- 1910401; Power cord US
- 1910402; Power cord UK
- T910922; Power supply, incl. multi plugs, for A3xx, A3xxsc, A6xx and A6xxsc
- T911182; Power supply for A3xx f, IP66
- 1910423; USB cable Std A <-> Mini-B
- T951004ACC; Ethernet cable CAT6, 2 m/6.6 ft.
- 1910586ACC; Power cable, pigtailed
- T197871ACC; Hard transport case for A3xx/A6xx series
- T197870ACC; Cardboard box for A3xx/A6xx series
- T126889ACC; Filter holder for A6xx lenses

- T198584; FLIR Tools
- T198583; FLIR Tools+ (download card incl. license key)
- DSW-10000; FLIR IR Camera Player
- T198697; FLIR ResearchIR Max + HSDR 4 (hardware sec. dev.)
- T199014; FLIR ResearchIR Max + HSDR 4 (printed license key)
- T199044; FLIR ResearchIR Max + HSDR 4 Upgrade (printed license key)
- T198696; FLIR ResearchIR Max 4 (hardware sec. dev.)
- T199013; FLIR ResearchIR Max 4 (printed license key)
- T199043; FLIR ResearchIR Max 4 Upgrade (printed license key)
- T198731; FLIR ResearchIR Standard 4 (hardware sec. dev.)
- T199012; FLIR ResearchIR Standard 4 (printed license key)
- T199042; FLIR ResearchIR Standard 4 Upgrade (printed license key)
- T199233; FLIR Atlas SDK for .NET
- T199234; FLIR Atlas SDK for MATLAB
- T198567; ThermoVision™ System Developers Kit Ver. 2.6
- T198566; ThermoVision™ LabVIEW® Digital Toolkit Ver. 3.3

### 14.10 FLIR A655sc 25°

P/N: 55001-0302

Rev.: 35207

General description	
<p>The FLIR A655sc is an excellent choice for those working in R&amp;D and require the highest frame rates and 640 × 480 pixel resolution. When using the camera in R&amp;D, it is highly recommended to use the FLIR ResearchIR software from FLIR Systems.</p> <p>The camera is equipped with the standard 25° lens.</p>	
Key features:	
<ul style="list-style-type: none"> <li>• Affordable.</li> <li>• 16-bit 640 × 480 pixel images at 50 Hz.</li> <li>• Start-and-stop recording in FLIR ResearchIR using digital input.</li> <li>• Windowing mode: 640 × 240 pixels at 100 Hz or 640 × 120 pixels at 200 Hz.</li> </ul>	
Typical applications:	
<ul style="list-style-type: none"> <li>• Mid- or high-end industrial R&amp;D.</li> </ul>	
Imaging and optical data	
IR resolution	640 × 480 pixels
Thermal sensitivity/NETD	< 0.03°C @ +30°C (+86°F) / 30 mK
Field of view (FOV)	25° × 19° (31° diagonal)
Minimum focus distance	0.25 m (0.82 ft.)
Focal length	24.6 mm (0.97 in.)
Spatial resolution (IFOV)	0.68 mrad
Lens identification	Automatic
F-number	1.0
Image frequency	50 Hz (100/200 Hz with windowing)
Focus	Automatic or manual (built in motor)
Detector data	
Detector type	Focal plane array (FPA), uncooled microbolometer
Spectral range	7.5–14 μm
Detector pitch	17 μm
Detector time constant	Typical 8 ms
Measurement	
Object temperature range	<ul style="list-style-type: none"> <li>• -40°C to +150°C (-40°F to +302°F)</li> <li>• 100 to +650°C (+212 to +1202°F)</li> </ul>
Accuracy	±2°C (±3.6°F) or ±2% of reading
Measurement analysis	
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on input of optics/window transmission and temperature
Measurement corrections	Global object parameters

<b>USB</b>	
USB	<ul style="list-style-type: none"> <li>Control and image</li> </ul>
USB, standard	USB 2 HS
USB, connector type	<ul style="list-style-type: none"> <li>USB Mini-B</li> </ul>
USB, communication	TCP/IP socket-based FLIR proprietary
USB, image streaming	16-bit 640 × 480 pixels @ 25 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul>
USB, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP

<b>Ethernet</b>	
Ethernet	Control and image
Ethernet, type	Gigabit Ethernet
Ethernet, standard	IEEE 802.3
Ethernet, connector type	RJ-45
Ethernet, communication	TCP/IP socket-based FLIR proprietary and Genl-Cam protocol
Ethernet, image streaming	16-bit 640 × 480 pixels @ 50 Hz 16-bit 640 × 240 pixels @ 100 Hz 16-bit 640 × 120 pixels @ 200 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul> GigE Vision and GenlCam compatible
Ethernet, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP

<b>Digital input/output</b>	
Digital input, purpose	Image tag (start, stop, general), Image flow control, (stream on/off), Input ext. device (programmatically read)
Digital input	2 opto-isolated, 0–1.5 V = low, 3–25 V = high
Digital output, purpose	Output to ext. device (programmatically set)
Digital output	2 opto-isolated, ON = supply (max. 100 mA), OFF = open
Digital I/O, isolation voltage	500 VRMS
Digital I/O, supply voltage	6–24 VDC, max. 200 mA
Digital I/O, connector type	6-pole jackable screw terminal

<b>Power system</b>	
External power operation	12/24 VDC, 24 W absolute max.
External power, connector type	2-pole jackable screw terminal
Voltage	Allowed range 10–30 VDC

<b>Environmental data</b>	
Operating temperature range	–15°C to +50°C (+5°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)

Environmental data	
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25°C to +40°C (+77°F to +104°F)
EMC	<ul style="list-style-type: none"> <li>• EN 61000-6-2:2001 (Immunity)</li> <li>• EN 61000-6-3:2001 (Emission)</li> <li>• FCC 47 CFR Part 15 Class B (Emission)</li> </ul>
Encapsulation	IP 30 (IEC 60529)
Shock	25 g (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)
Physical data	
Weight	0.90 kg (1.98 lb.)
Camera size (L × W × H)	216 × 73 × 75 mm (8.5 × 2.9 × 3.0 in.)
Camera size, excl. lens (L × W × H)	203 × 73 × 75 mm (8.0 × 2.9 × 3.0 in.)
Tripod mounting	UNC ¼"-20 (on three sides)
Base mounting	2 × M4 thread mounting holes (on three sides)
Housing material	Aluminum
Comments to physical data	Outline dimensional drawings and STEP files can be found at <a href="http://support.flir.com">http://support.flir.com</a>
Shipping information	
Packaging, type	Cardboard box
List of contents	<ul style="list-style-type: none"> <li>• Infrared camera with lens</li> <li>• Ethernet cable</li> <li>• FLIR ResearchIR Max 4 (licence only)</li> <li>• Hard transport case</li> <li>• Mains cable</li> <li>• Power cable, pig-tailed</li> <li>• Power supply</li> <li>• Printed documentation</li> <li>• USB cable</li> </ul>
Packaging, weight	5.4 kg (11.9 lb.)
Packaging, size	360 × 180 × 550 mm (14.2 × 7.1 × 21.7 in.)
EAN-13	7332558003312
UPC-12	845188002794
Country of origin	Sweden

#### Supplies & accessories:

- T197914; IR lens, f=41.3 mm (15°) with case
- T197922; IR lens, f=24.6 mm (25°) with case
- T197915; IR lens, f=13.1 mm (45°) with case
- T198059; Close-up IR lens, 2.9× (50 µm) with case
- T198060; Close-up IR lens, 5.8× (100 µm) with case
- T198065; IR lens, f=6.5 mm (80°) with case
- T198165; IR lens, f=88.9 mm (7°) with case and support for A6xx/A6xxsc
- T198066; Close-up IR lens, 1.5× (25 µm) with case
- T197896; High temperature option +300°C to 2000°C (+572°F to 3632°F)
- 1910400; Power cord EU
- 1910401; Power cord US
- 1910402; Power cord UK
- T910922; Power supply, incl. multi plugs, for A3xx, A3xxsc, A6xx and A6xxsc
- T911182; Power supply for A3xx f, IP66
- 1910423; USB cable Std A <-> Mini-B
- T951004ACC; Ethernet cable CAT6, 2 m/6.6 ft.
- 1910586ACC; Power cable, pigtailed



- T197871ACC; Hard transport case for A3xx/A6xx series
- T197870ACC; Cardboard box for A3xx/A6xx series
- T126889ACC; Filter holder for A6xx lenses
- T198584; FLIR Tools
- T198583; FLIR Tools+ (download card incl. license key)
- DSW-10000; FLIR IR Camera Player
- T198697; FLIR ResearchIR Max + HSDR 4 (hardware sec. dev.)
- T199014; FLIR ResearchIR Max + HSDR 4 (printed license key)
- T199044; FLIR ResearchIR Max + HSDR 4 Upgrade (printed license key)
- T198696; FLIR ResearchIR Max 4 (hardware sec. dev.)
- T199013; FLIR ResearchIR Max 4 (printed license key)
- T199043; FLIR ResearchIR Max 4 Upgrade (printed license key)
- T198731; FLIR ResearchIR Standard 4 (hardware sec. dev.)
- T199012; FLIR ResearchIR Standard 4 (printed license key)
- T199042; FLIR ResearchIR Standard 4 Upgrade (printed license key)
- T199233; FLIR Atlas SDK for .NET
- T199234; FLIR Atlas SDK for MATLAB
- T198567; ThermoVision™ System Developers Kit Ver. 2.6
- T198566; ThermoVision™ LabVIEW® Digital Toolkit Ver. 3.3

### 14.11 FLIR A655sc 45°

P/N: 55001-0303

Rev.: 35207

General description	
<p>The FLIR A655sc is an excellent choice for those working in R&amp;D and require the highest frame rates and 640 × 480 pixel resolution. When using the camera in R&amp;D, it is highly recommended to use the FLIR ResearchIR software from FLIR Systems.</p> <p>The camera is equipped with a 45° lens.</p>	
Key features:	
<ul style="list-style-type: none"> <li>• Affordable.</li> <li>• 16-bit 640 × 480 pixel images at 50 Hz.</li> <li>• Start-and-stop recording in FLIR ResearchIR using digital input.</li> <li>• Windowing mode: 640 × 240 pixels at 100 Hz or 640 × 120 pixels at 200 Hz.</li> </ul>	
Typical applications:	
<ul style="list-style-type: none"> <li>• Mid- or high-end industrial R&amp;D.</li> </ul>	
Imaging and optical data	
IR resolution	640 × 480 pixels
Thermal sensitivity/NETD	< 0.03°C @ +30°C (+86°F) / 30 mK
Field of view (FOV)	45° × 34° (55° diagonal)
Minimum focus distance	0.15 m (0.49 ft.)
Focal length	13.1 mm (0.52 in.)
Spatial resolution (IFOV)	1.23 mrad
Lens identification	Automatic
F-number	1.0
Image frequency	50 Hz (100/200 Hz with windowing)
Focus	Automatic or manual (built in motor)
Detector data	
Detector type	Focal plane array (FPA), uncooled microbolometer
Spectral range	7.5–14 μm
Detector pitch	17 μm
Detector time constant	Typical 8 ms
Measurement	
Object temperature range	<ul style="list-style-type: none"> <li>• -40°C to +150°C (-40°F to +302°F)</li> <li>• 100 to +650°C (+212 to +1202°F)</li> </ul>
Accuracy	±2°C (±3.6°F) or ±2% of reading
Measurement analysis	
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on input of optics/window transmission and temperature
Measurement corrections	Global object parameters

<b>USB</b>	
USB	<ul style="list-style-type: none"> <li>Control and image</li> </ul>
USB, standard	USB 2 HS
USB, connector type	<ul style="list-style-type: none"> <li>USB Mini-B</li> </ul>
USB, communication	TCP/IP socket-based FLIR proprietary
USB, image streaming	16-bit 640 × 480 pixels @ 25 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul>
USB, protocols	TCP, UDP, SNMP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP

<b>Ethernet</b>	
Ethernet	Control and image
Ethernet, type	Gigabit Ethernet
Ethernet, standard	IEEE 802.3
Ethernet, connector type	RJ-45
Ethernet, communication	TCP/IP socket-based FLIR proprietary and Genl-Cam protocol
Ethernet, image streaming	16-bit 640 × 480 pixels @ 50 Hz 16-bit 640 × 240 pixels @ 100 Hz 16-bit 640 × 120 pixels @ 200 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul> GigE Vision and GenlCam compatible
Ethernet, protocols	TCP, UDP, SNMP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP

<b>Digital input/output</b>	
Digital input, purpose	Image tag (start, stop, general), Image flow control, (stream on/off), Input ext. device (programmatically read)
Digital input	2 opto-isolated, 0–1.5 V = low, 3–25 V = high
Digital output, purpose	Output to ext. device (programmatically set)
Digital output	2 opto-isolated, ON = supply (max. 100 mA), OFF = open
Digital I/O, isolation voltage	500 VRMS
Digital I/O, supply voltage	6–24 VDC, max. 200 mA
Digital I/O, connector type	6-pole jackable screw terminal

<b>Power system</b>	
External power operation	12/24 VDC, 24 W absolute max.
External power, connector type	2-pole jackable screw terminal
Voltage	Allowed range 10–30 VDC

<b>Environmental data</b>	
Operating temperature range	–15°C to +50°C (+5°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)

Environmental data	
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25°C to +40°C (+77°F to +104°F)
EMC	<ul style="list-style-type: none"> <li>• EN 61000-6-2:2001 (Immunity)</li> <li>• EN 61000-6-3:2001 (Emission)</li> <li>• FCC 47 CFR Part 15 Class B (Emission)</li> </ul>
Encapsulation	IP 30 (IEC 60529)
Shock	25 g (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)
Physical data	
Weight	0.94 kg (2.07 lb.)
Camera size (L × W × H)	225 × 73 × 75 mm (8.8 × 2.9 × 3.0 in.)
Camera size, excl. lens (L × W × H)	203 × 73 × 75 mm (8.0 × 2.9 × 3.0 in.)
Tripod mounting	UNC ¼"-20 (on three sides)
Base mounting	2 × M4 thread mounting holes (on three sides)
Housing material	Aluminum
Comments to physical data	Outline dimensional drawings and STEP files can be found at <a href="http://support.flir.com">http://support.flir.com</a>
Shipping information	
Packaging, type	Cardboard box
List of contents	<ul style="list-style-type: none"> <li>• Infrared camera with lens</li> <li>• Ethernet cable</li> <li>• FLIR ResearchIR Max 4 (licence only)</li> <li>• Hard transport case</li> <li>• Mains cable</li> <li>• Power cable, pig-tailed</li> <li>• Power supply</li> <li>• Printed documentation</li> <li>• USB cable</li> </ul>
Packaging, weight	
Packaging, size	360 × 180 × 550 mm (14.2 × 7.1 × 21.7 in.)
EAN-13	7332558003329
UPC-12	845188002800
Country of origin	Sweden

**Supplies & accessories:**

- T197914; IR lens, f=41.3 mm (15°) with case
- T197922; IR lens, f=24.6 mm (25°) with case
- T197915; IR lens, f=13.1 mm (45°) with case
- T198065; IR lens, f=6.5 mm (80°) with case
- T198165; IR lens, f=88.9 mm (7°) with case and support for A6xx/A6xxsc
- T198066; Close-up IR lens, 1.5× (25 µm) with case
- T197896; High temperature option +300°C to 2000°C (+572°F to 3632°F)
- 1910400; Power cord EU
- 1910401; Power cord US
- 1910402; Power cord UK
- T910922; Power supply, incl. multi plugs, for A3xx, A3xxsc, A6xx and A6xxsc
- T911182; Power supply for A3xx f, IP66
- 1910423; USB cable Std A <-> Mini-B
- T951004ACC; Ethernet cable CAT6, 2 m/6.6 ft.
- 1910586ACC; Power cable, pigtailed
- T197871ACC; Hard transport case for A3xx/A6xx series
- T197870ACC; Cardboard box for A3xx/A6xx series

- T126889ACC; Filter holder for A6xx lenses
- T198584; FLIR Tools
- T198583; FLIR Tools+ (download card incl. license key)
- DSW-10000; FLIR IR Camera Player
- T198697; FLIR ResearchIR Max + HSDR 4 (hardware sec. dev.)
- T199014; FLIR ResearchIR Max + HSDR 4 (printed license key)
- T199044; FLIR ResearchIR Max + HSDR 4 Upgrade (printed license key)
- T198696; FLIR ResearchIR Max 4 (hardware sec. dev.)
- T199013; FLIR ResearchIR Max 4 (printed license key)
- T199043; FLIR ResearchIR Max 4 Upgrade (printed license key)
- T198731; FLIR ResearchIR Standard 4 (hardware sec. dev.)
- T199012; FLIR ResearchIR Standard 4 (printed license key)
- T199042; FLIR ResearchIR Standard 4 Upgrade (printed license key)
- T199233; FLIR Atlas SDK for .NET
- T199234; FLIR Atlas SDK for MATLAB
- T198567; ThermoVision™ System Developers Kit Ver. 2.6
- T198566; ThermoVision™ LabVIEW® Digital Toolkit Ver. 3.3

### 14.12 FLIR A655sc 7°

P/N: 55001-0304

Rev.: 35207

General description	
<p>The FLIR A655sc is an excellent choice for those working in R&amp;D and require the highest frame rates and 640 × 480 pixel resolution. When using the camera in R&amp;D, it is highly recommended to use the FLIR ResearchIR software from FLIR Systems.</p> <p>The camera is equipped with a 7° lens.</p>	
Key features:	
<ul style="list-style-type: none"> <li>• Affordable.</li> <li>• 16-bit 640 × 480 pixel images at 50 Hz.</li> <li>• Start-and-stop recording in FLIR ResearchIR using digital input.</li> <li>• Windowing mode: 640 × 240 pixels at 100 Hz or 640 × 120 pixels at 200 Hz.</li> </ul>	
Typical applications:	
<ul style="list-style-type: none"> <li>• Mid- or high-end industrial R&amp;D.</li> </ul>	
Imaging and optical data	
IR resolution	640 × 480 pixels
Thermal sensitivity/NETD	< 0.03°C @ +30°C (+86°F) / 30 mK
Field of view (FOV)	7° × 5.3° (8.7° diagonally)
Minimum focus distance	2.0 m (6.6 ft.)
Focal length	88.9 mm (3.5 in.)
Spatial resolution (IFOV)	0.19 mrad
Lens identification	Automatic
F-number	1.3
Image frequency	50 Hz (100/200 Hz with windowing)
Focus	Automatic or manual (built in motor)
Detector data	
Detector type	Focal plane array (FPA), uncooled microbolometer
Spectral range	7.5–14 μm
Detector pitch	17 μm
Detector time constant	Typical 8 ms
Measurement	
Object temperature range	<ul style="list-style-type: none"> <li>• -40°C to +150°C (-40°F to +302°F)</li> <li>• 100 to +650°C (+212 to +1202°F)</li> </ul>
Accuracy	±2°C (±3.6°F) or ±2% of reading
Measurement analysis	
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on input of optics/window transmission and temperature
Measurement corrections	Global object parameters

<b>USB</b>	
USB	<ul style="list-style-type: none"> <li>Control and image</li> </ul>
USB, standard	USB 2 HS
USB, connector type	<ul style="list-style-type: none"> <li>USB Mini-B</li> </ul>
USB, communication	TCP/IP socket-based FLIR proprietary
USB, image streaming	16-bit 640 × 480 pixels @ 25 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul>
USB, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP

<b>Ethernet</b>	
Ethernet	Control and image
Ethernet, type	Gigabit Ethernet
Ethernet, standard	IEEE 802.3
Ethernet, connector type	RJ-45
Ethernet, communication	TCP/IP socket-based FLIR proprietary and GenI-Cam protocol
Ethernet, image streaming	16-bit 640 × 480 pixels @ 50 Hz 16-bit 640 × 240 pixels @ 100 Hz 16-bit 640 × 120 pixels @ 200 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul> GigE Vision and GenICam compatible
Ethernet, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP

<b>Digital input/output</b>	
Digital input, purpose	Image tag (start, stop, general), Image flow control, (stream on/off), Input ext. device (programmatically read)
Digital input	2 opto-isolated, 0–1.5 V = low, 3–25 V = high
Digital output, purpose	Output to ext. device (programmatically set)
Digital output	2 opto-isolated, ON = supply (max. 100 mA), OFF = open
Digital I/O, isolation voltage	500 VRMS
Digital I/O, supply voltage	6–24 VDC, max. 200 mA
Digital I/O, connector type	6-pole jackable screw terminal

<b>Power system</b>	
External power operation	12/24 VDC, 24 W absolute max.
External power, connector type	2-pole jackable screw terminal
Voltage	Allowed range 10–30 VDC

<b>Environmental data</b>	
Operating temperature range	–15°C to +50°C (+5°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)

<b>Environmental data</b>	
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25°C to +40°C (+77°F to +104°F)
EMC	<ul style="list-style-type: none"> <li>• EN 61000-6-2:2001 (Immunity)</li> <li>• EN 61000-6-3:2001 (Emission)</li> <li>• FCC 47 CFR Part 15 Class B (Emission)</li> </ul>
Encapsulation	IP 30 (IEC 60529)
Shock	25 g (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)
<b>Physical data</b>	
Weight	1.61 kg (3.55 lb.)
Camera size (L x W x H)	271 x 126 x 128 mm (10.7 x 5.0 x 5.0 in.)
Camera size, excl. lens (L x W x H)	203 x 73 x 75 mm (8.0 x 2.9 x 3.0 in.)
Tripod mounting	UNC ¼"-20 (on three sides)
Base mounting	2 x M4 thread mounting holes (on three sides)
Housing material	Aluminum
Comments to physical data	Outline dimensional drawings and STEP files can be found at <a href="http://support.flir.com">http://support.flir.com</a>
<b>Shipping information</b>	
Packaging, type	Cardboard box
List of contents	<ul style="list-style-type: none"> <li>• Infrared camera with lens</li> <li>• Ethernet cable</li> <li>• FLIR ResearchIR Max 4 (licence only)</li> <li>• Hard transport case</li> <li>• Mains cable</li> <li>• Power cable, pig-tailed</li> <li>• Power supply</li> <li>• Printed documentation</li> <li>• USB cable</li> </ul>
Packaging, weight	
Packaging, size	
EAN-13	7332558004715
UPC-12	845188004651
Country of origin	Sweden

**Supplies & accessories:**

- T197914; IR lens, f=41.3 mm (15°) with case
- T197922; IR lens, f=24.6 mm (25°) with case
- T197915; IR lens, f=13.1 mm (45°) with case
- T198065; IR lens, f=6.5 mm (80°) with case
- T198165; IR lens, f=88.9 mm (7°) with case and support for A6xx/A6xxsc
- T197896; High temperature option +300°C to 2000°C (+572°F to 3632°F)
- 1910400; Power cord EU
- 1910401; Power cord US
- 1910402; Power cord UK
- T910922; Power supply, incl. multi plugs, for A3xx, A3xxsc, A6xx and A6xxsc
- T911182; Power supply for A3xx f, IP66
- 1910423; USB cable Std A <-> Mini-B
- T951004ACC; Ethernet cable CAT6, 2 m/6.6 ft.
- 1910586ACC; Power cable, pigtailed
- T197871ACC; Hard transport case for A3xx/A6xx series
- T197870ACC; Cardboard box for A3xx/A6xx series
- T126889ACC; Filter holder for A6xx lenses



- T198584; FLIR Tools
- T198583; FLIR Tools+ (download card incl. license key)
- DSW-10000; FLIR IR Camera Player
- T198697; FLIR ResearchIR Max + HSDR 4 (hardware sec. dev.)
- T199014; FLIR ResearchIR Max + HSDR 4 (printed license key)
- T199044; FLIR ResearchIR Max + HSDR 4 Upgrade (printed license key)
- T198696; FLIR ResearchIR Max 4 (hardware sec. dev.)
- T199013; FLIR ResearchIR Max 4 (printed license key)
- T199043; FLIR ResearchIR Max 4 Upgrade (printed license key)
- T198731; FLIR ResearchIR Standard 4 (hardware sec. dev.)
- T199012; FLIR ResearchIR Standard 4 (printed license key)
- T199042; FLIR ResearchIR Standard 4 Upgrade (printed license key)
- T199233; FLIR Atlas SDK for .NET
- T199234; FLIR Atlas SDK for MATLAB
- T198567; ThermoVision™ System Developers Kit Ver. 2.6
- T198566; ThermoVision™ LabVIEW® Digital Toolkit Ver. 3.3

### 14.13 FLIR A655sc 80°

P/N: 55001-0305

Rev.: 35207

General description	
<p>The FLIR A655sc is an excellent choice for those working in R&amp;D and require the highest frame rates and 640 × 480 pixel resolution. When using the camera in R&amp;D, it is highly recommended to use the FLIR ResearchIR software from FLIR Systems.</p> <p>The camera is equipped with a 80° lens.</p>	
Key features:	
<ul style="list-style-type: none"> <li>Affordable.</li> <li>16-bit 640 × 480 pixel images at 50 Hz.</li> <li>Start-and-stop recording in FLIR ResearchIR using digital input.</li> <li>Windowing mode: 640 × 240 pixels at 100 Hz or 640 × 120 pixels at 200 Hz.</li> </ul>	
Typical applications:	
<ul style="list-style-type: none"> <li>Mid- or high-end industrial R&amp;D.</li> </ul>	
Imaging and optical data	
IR resolution	640 × 480 pixels
Thermal sensitivity/NETD	< 0.03°C @ +30°C (+86°F) / 30 mK
Field of view (FOV)	80° × 64.4° (92.8° diagonal)
Minimum focus distance	65 mm (2.6 in.)
Focal length	6.5 mm (0.26 in.)
Spatial resolution (IFOV)	2.62 mrad
Lens identification	Automatic
F-number	1.0
Image frequency	50 Hz (100/200 Hz with windowing)
Focus	Automatic or manual (built in motor)
Detector data	
Detector type	Focal plane array (FPA), uncooled microbolometer
Spectral range	7.5–14 μm
Detector pitch	17 μm
Detector time constant	Typical 8 ms
Measurement	
Object temperature range	<ul style="list-style-type: none"> <li>–40°C to +150°C (–40°F to +302°F)</li> <li>100 to +650°C (+212 to +1202°F)</li> </ul>
Accuracy	±2°C (±3.6°F) or ±2% of reading
Measurement analysis	
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on input of optics/window transmission and temperature
Measurement corrections	Global object parameters

<b>USB</b>	
USB	<ul style="list-style-type: none"> <li>Control and image</li> </ul>
USB, standard	USB 2 HS
USB, connector type	<ul style="list-style-type: none"> <li>USB Mini-B</li> </ul>
USB, communication	TCP/IP socket-based FLIR proprietary
USB, image streaming	16-bit 640 × 480 pixels @ 25 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul>
USB, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP

<b>Ethernet</b>	
Ethernet	Control and image
Ethernet, type	Gigabit Ethernet
Ethernet, standard	IEEE 802.3
Ethernet, connector type	RJ-45
Ethernet, communication	TCP/IP socket-based FLIR proprietary and GenI-Cam protocol
Ethernet, image streaming	16-bit 640 × 480 pixels @ 50 Hz 16-bit 640 × 240 pixels @ 100 Hz 16-bit 640 × 120 pixels @ 200 Hz <ul style="list-style-type: none"> <li>Signal linear</li> <li>Temperature linear</li> <li>Radiometric</li> </ul> GigE Vision and GenICam compatible
Ethernet, protocols	TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP

<b>Digital input/output</b>	
Digital input, purpose	Image tag (start, stop, general), Image flow control, (stream on/off), Input ext. device (programmatically read)
Digital input	2 opto-isolated, 0–1.5 V = low, 3–25 V = high
Digital output, purpose	Output to ext. device (programmatically set)
Digital output	2 opto-isolated, ON = supply (max. 100 mA), OFF = open
Digital I/O, isolation voltage	500 VRMS
Digital I/O, supply voltage	6–24 VDC, max. 200 mA
Digital I/O, connector type	6-pole jackable screw terminal

<b>Power system</b>	
External power operation	12/24 VDC, 24 W absolute max.
External power, connector type	2-pole jackable screw terminal
Voltage	Allowed range 10–30 VDC

<b>Environmental data</b>	
Operating temperature range	–15°C to +50°C (+5°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)

Environmental data	
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25°C to +40°C (+77°F to +104°F)
EMC	<ul style="list-style-type: none"> <li>• EN 61000-6-2:2001 (Immunity)</li> <li>• EN 61000-6-3:2001 (Emission)</li> <li>• FCC 47 CFR Part 15 Class B (Emission)</li> </ul>
Encapsulation	IP 30 (IEC 60529)
Shock	25 g (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)
Physical data	
Weight	1.17 kg (2.58 lb.)
Camera size (L × W × H)	297 × 73 × 75 mm (11.7 × 2.9 × 3.0 in.)
Camera size, excl. lens (L × W × H)	203 × 73 × 75 mm (8.0 × 2.9 × 3.0 in.)
Tripod mounting	UNC ¼"-20 (on three sides)
Base mounting	2 × M4 thread mounting holes (on three sides)
Housing material	Aluminum
Comments to physical data	Outline dimensional drawings and STEP files can be found at <a href="http://support.flir.com">http://support.flir.com</a>
Shipping information	
Packaging, type	Cardboard box
List of contents	<ul style="list-style-type: none"> <li>• Infrared camera with lens</li> <li>• Ethernet cable</li> <li>• FLIR ResearchIR Max 4 (licence only)</li> <li>• Hard transport case</li> <li>• Mains cable</li> <li>• Power cable, pig-tailed</li> <li>• Power supply</li> <li>• Printed documentation</li> <li>• USB cable</li> </ul>
Packaging, weight	
Packaging, size	
EAN-13	7332558006054
UPC-12	845188006266
Country of origin	Sweden

**Supplies & accessories:**

- T197914; IR lens, f=41.3 mm (15°) with case
- T197922; IR lens, f=24.6 mm (25°) with case
- T197915; IR lens, f=13.1 mm (45°) with case
- T198065; IR lens, f=6.5 mm (80°) with case
- T198165; IR lens, f=88.9 mm (7°) with case and support for A6xx/A6xxsc
- T197896; High temperature option +300°C to 2000°C (+572°F to 3632°F)
- 1910400; Power cord EU
- 1910401; Power cord US
- 1910402; Power cord UK
- T910922; Power supply, incl. multi plugs, for A3xx, A3xxsc, A6xx and A6xxsc
- T911182; Power supply for A3xx f, IP66
- 1910423; USB cable Std A <-> Mini-B
- T951004ACC; Ethernet cable CAT6, 2 m/6.6 ft.
- 1910586ACC; Power cable, pigtailed
- T197871ACC; Hard transport case for A3xx/A6xx series
- T197870ACC; Cardboard box for A3xx/A6xx series
- T126889ACC; Filter holder for A6xx lenses

- T198584; FLIR Tools
- T198583; FLIR Tools+ (download card incl. license key)
- DSW-10000; FLIR IR Camera Player
- T198697; FLIR ResearchIR Max + HSDR 4 (hardware sec. dev.)
- T199014; FLIR ResearchIR Max + HSDR 4 (printed license key)
- T199044; FLIR ResearchIR Max + HSDR 4 Upgrade (printed license key)
- T198696; FLIR ResearchIR Max 4 (hardware sec. dev.)
- T199013; FLIR ResearchIR Max 4 (printed license key)
- T199043; FLIR ResearchIR Max 4 Upgrade (printed license key)
- T198731; FLIR ResearchIR Standard 4 (hardware sec. dev.)
- T199012; FLIR ResearchIR Standard 4 (printed license key)
- T199042; FLIR ResearchIR Standard 4 Upgrade (printed license key)
- T199233; FLIR Atlas SDK for .NET
- T199234; FLIR Atlas SDK for MATLAB
- T198567; ThermoVision™ System Developers Kit Ver. 2.6
- T198566; ThermoVision™ LabVIEW® Digital Toolkit Ver. 3.3

# Pin configurations and schematics

## 15.1 Pin configuration for camera I/O connector

Pin	Function	Data
1	IN 1	opto-isolated, 0–1.5 V = low, 3–25 V = high
2	IN 2	opto-isolated, 0–1.5 V = low, 3–25 V = high
3	OUT 1	opto-isolated, ON = supply (max. 100 mA), OFF = open
4	OUT 2	opto-isolated, ON = supply (max. 100 mA), OFF = open
5	Supply VCC	6–24 VDC, max. 200 mA
6	Supply Gnd	Gnd

**Note** Cables for digital I/O ports should be 100 m (328') maximum.

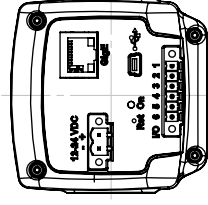
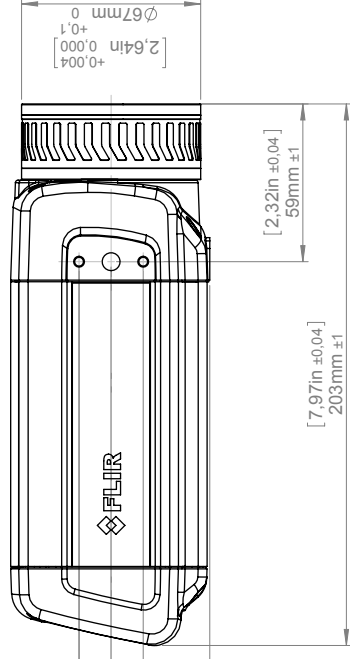
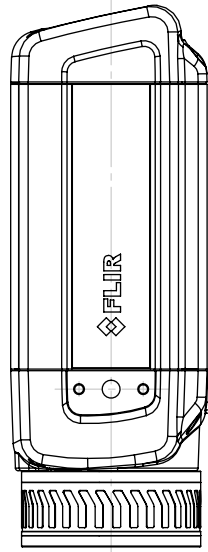
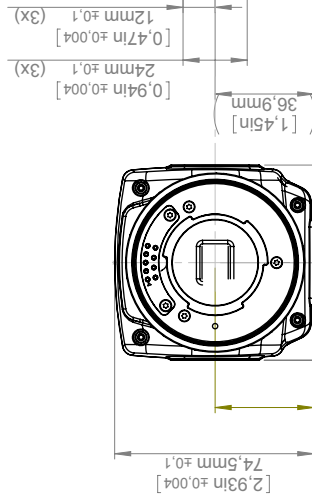
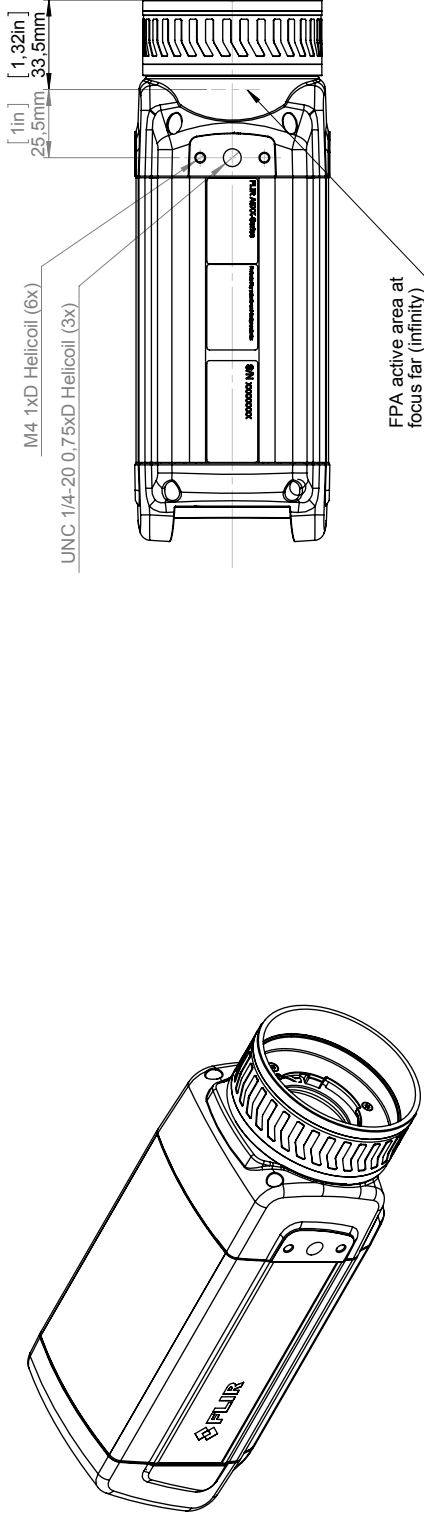
## 15.2 LED indicators

The LEDs indicate the following:

Type of signal	Explanation
The LED glows continuously orange.	The camera is starting up.
The LED glows continuously red.	An error has been detected. Contact service.
The LED glows continuously green.	The camera has started.
The LED flashes 10 times per second.	An error has been detected. Contact service.



# Camera housing

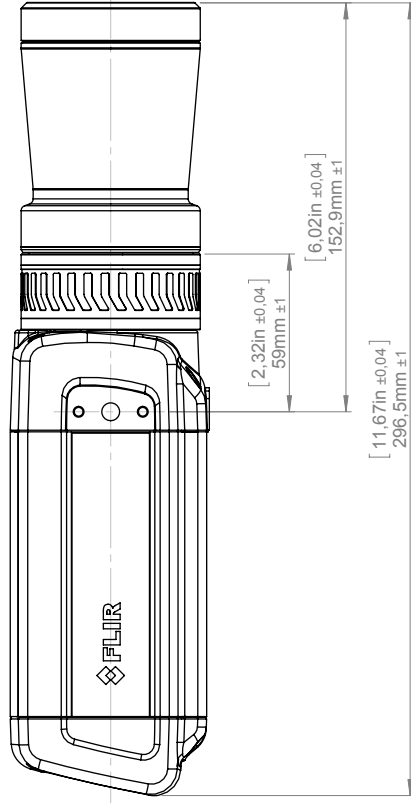
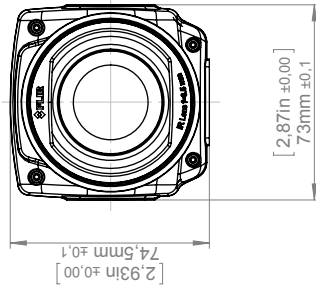
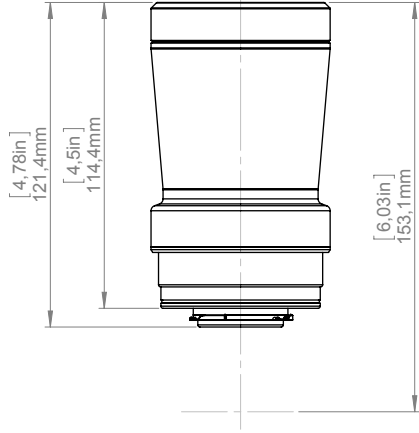
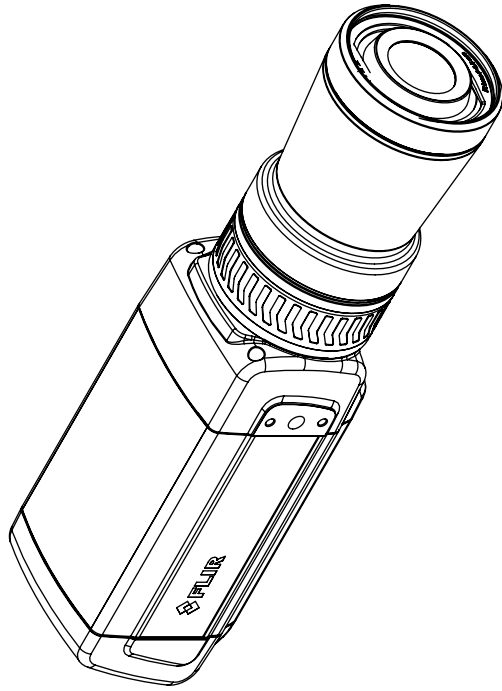


Modified 2012-04-18	Check CAHA	Drawn by R&D Thermography	<b>FLIR</b>
Denomination Basic dimensions FLIR A/SC 6xx			Size A3
			Scale 1:2
			Sheet 1(9)
			Drawing No. T126925
			Size A

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# Camera with Lens IR f=6,5 mm (80°)

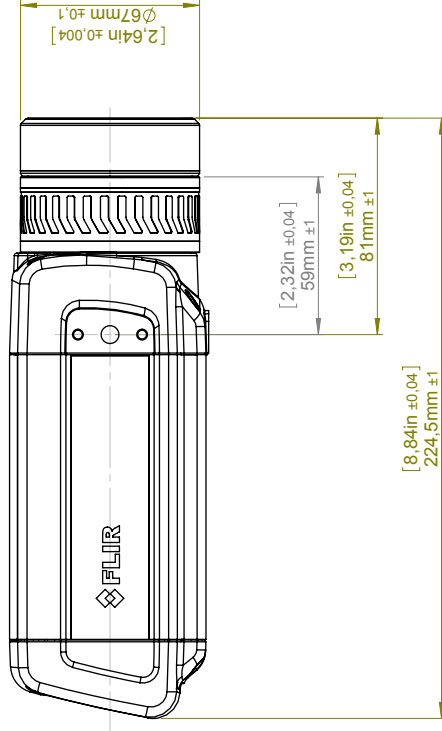
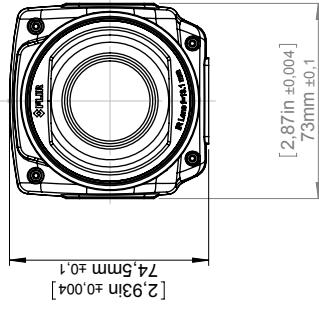
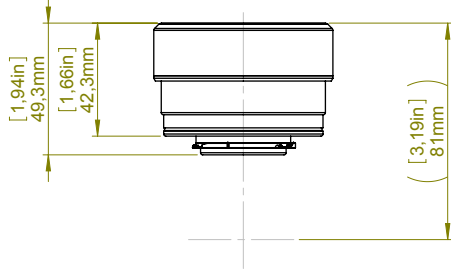
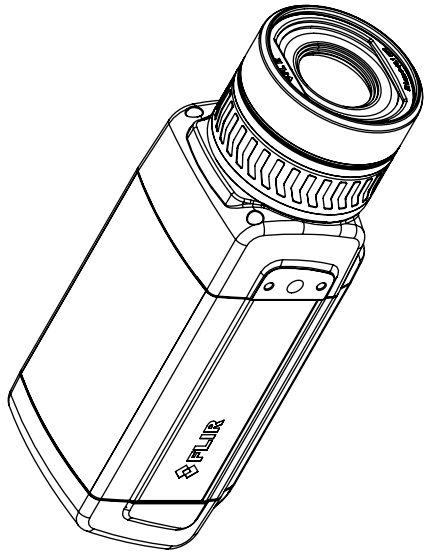


For additional dimensions see page 1

Modified 2012-04-18 Denomination	Check CAHA	Drawn by R&D Thermography	Size A3	Sheet 2(9)	Size A
Basic dimensions FLIR A/SC 6xx			Scale 1:2	Drawing No. T126925	



# Camera with Lens IR f=13,1 mm (45°)

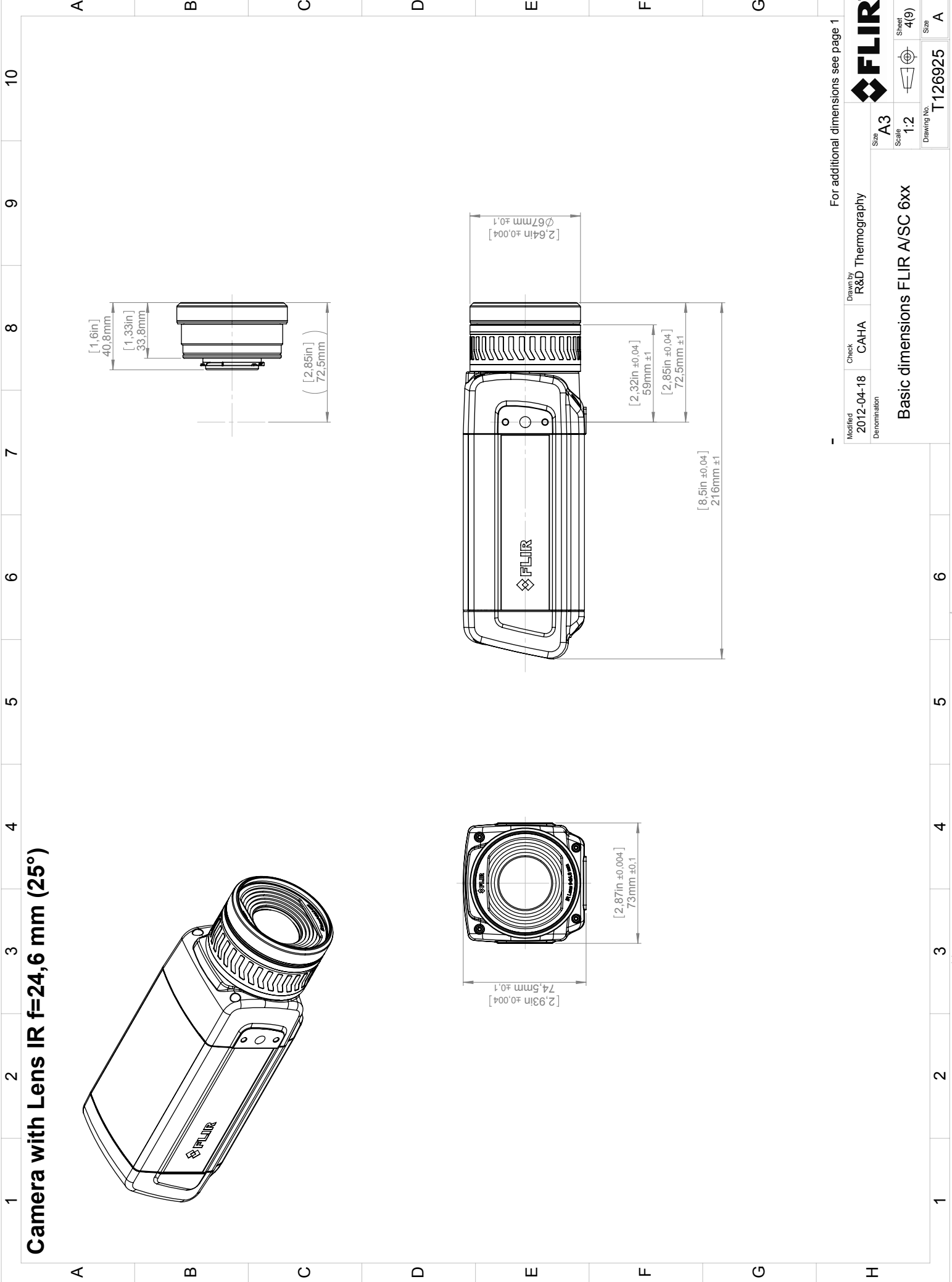
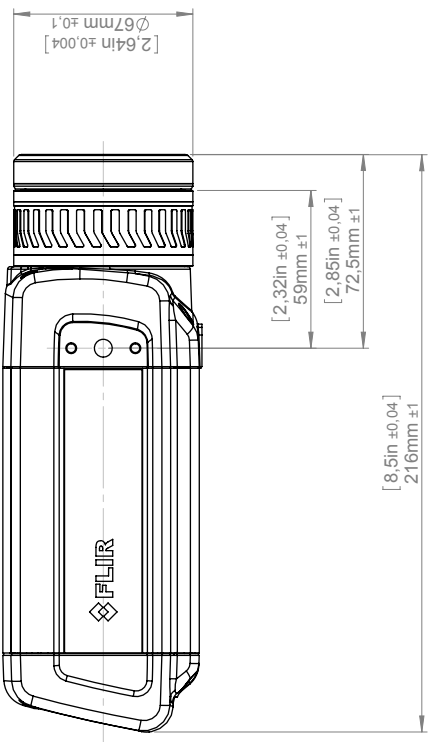
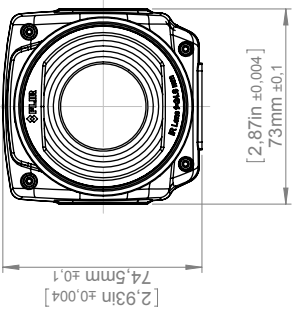
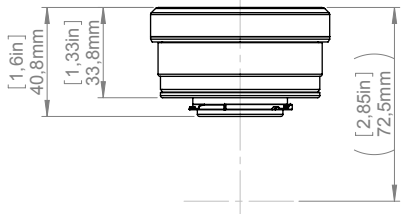
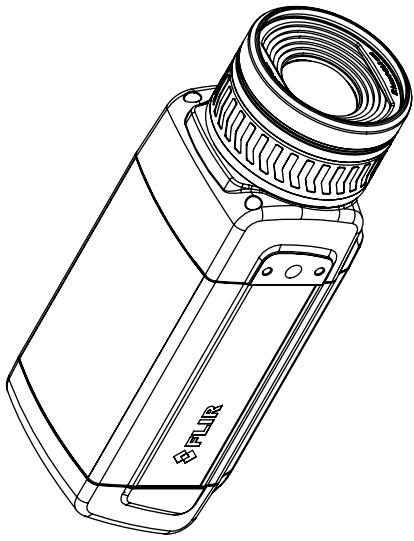


For additional dimensions see page 1

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Basic dimensions FLIR A/SC 6xx			Scale 1:2	Drawing No. T126925	



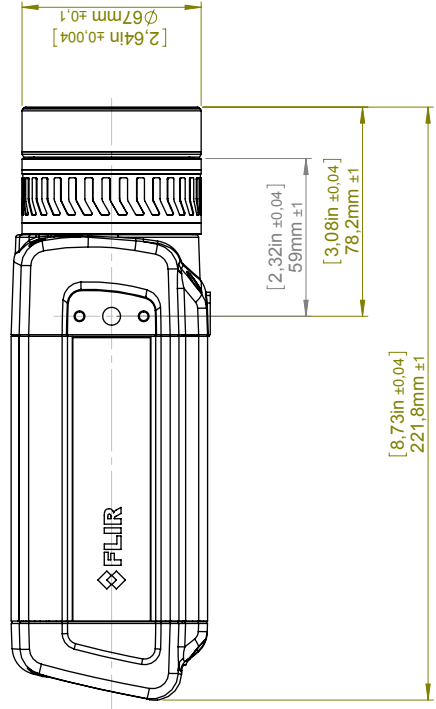
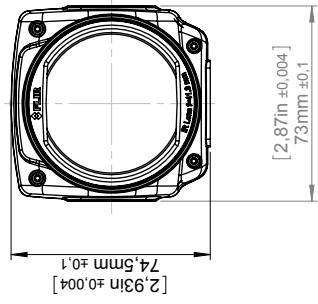
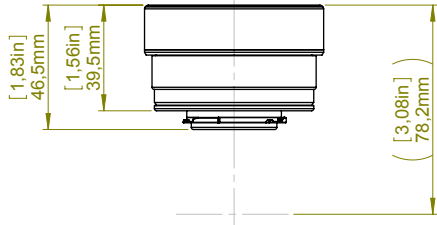
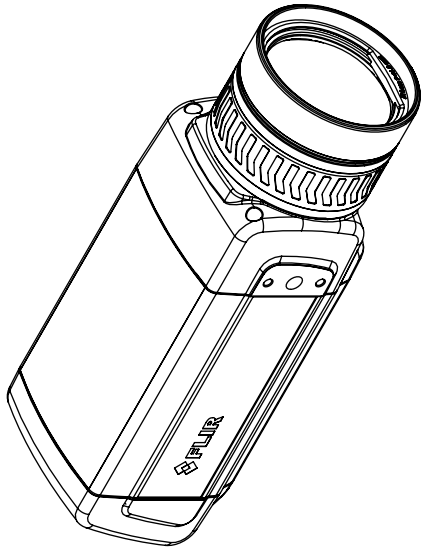
# Camera with Lens IR f=24,6 mm (25°)



For additional dimensions see page 1			
Modified 2012-04-18	Check CAHA	Drawn by R&D Thermography	Size A3
Denomination		Scale 1:2	
Basic dimensions FLIR A/SC 6xx		Sheet 4(9)	Size A
		Drawing No. T126925	

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# Camera with Lens IR f=41,3 mm (15°)



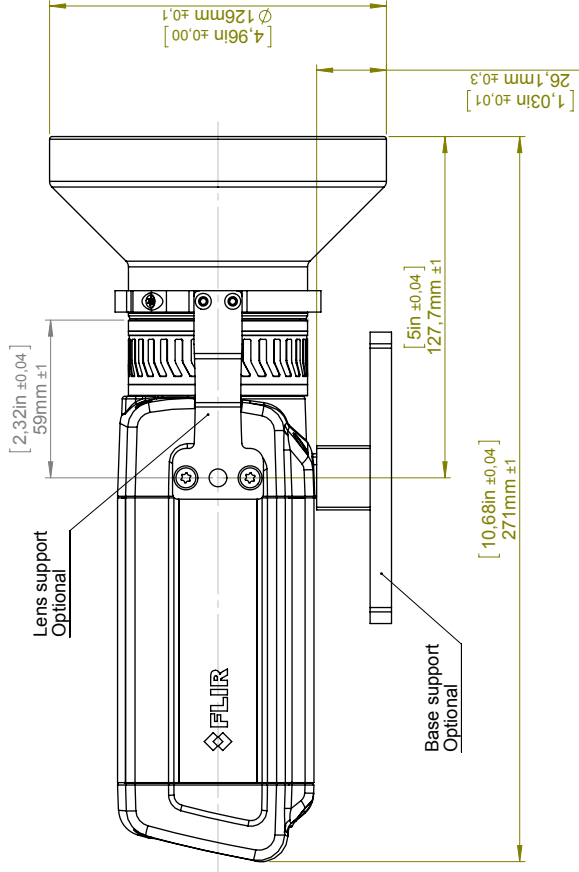
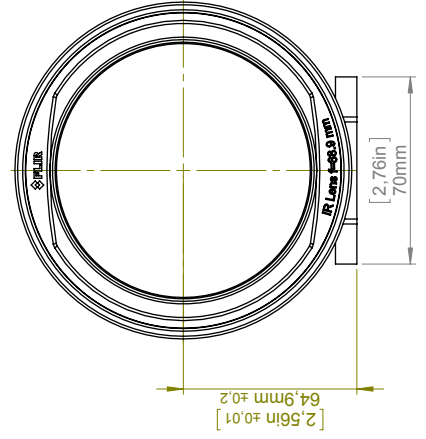
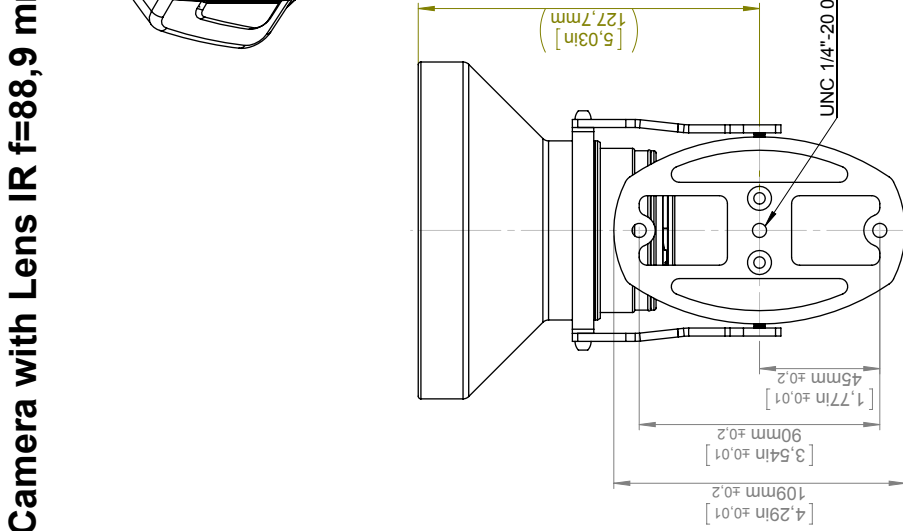
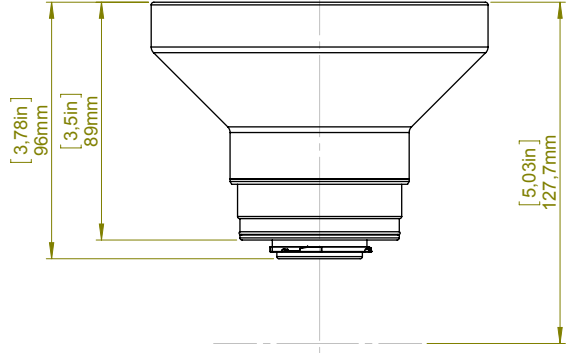
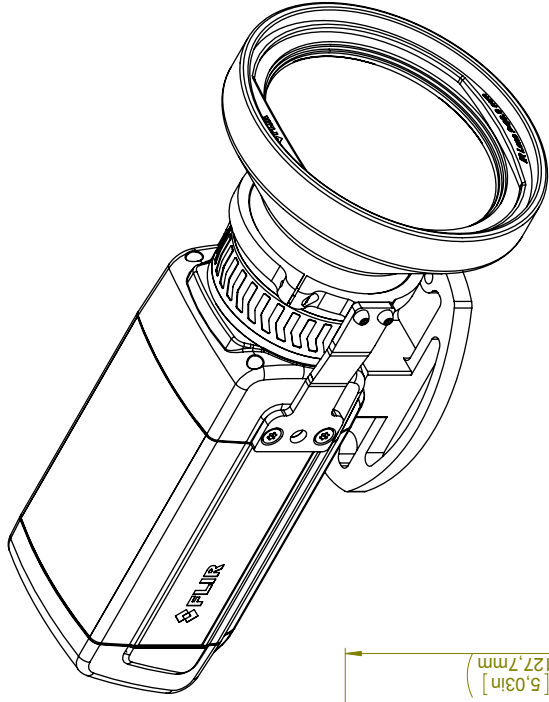
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Denomination Basic dimensions FLIR A/SC 6xx			Scale 1:2	Drawing No. T126925
			Size A	



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# Camera with Lens IR f=88,9 mm (7°) incl support



For additional dimensions see page 1

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 Denomination

Check CAHA

Drawn by R&D Thermography

Size A3

Scale 1:2

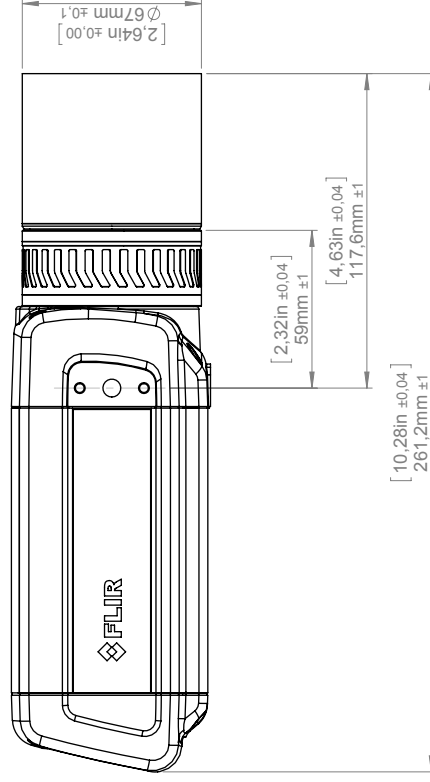
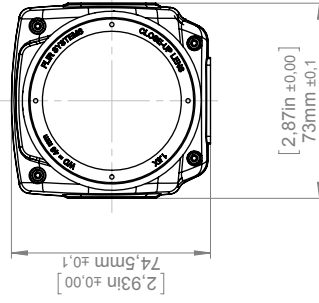
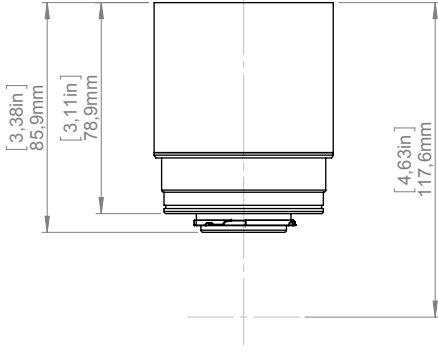
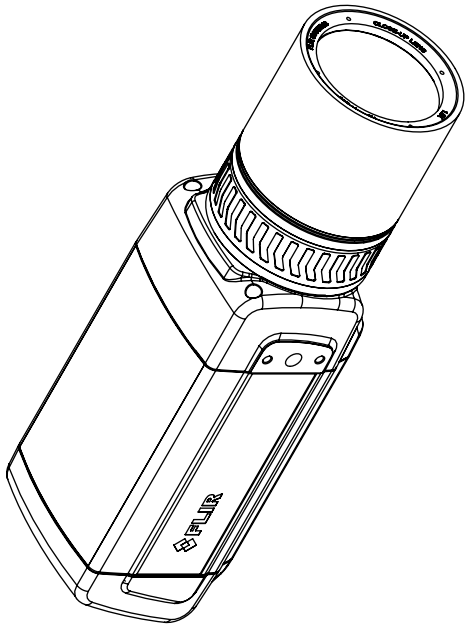
Sheet 6(9)



Basic dimensions FLIR A/SC 6xx

Drawing No. T126925  
 Size A

# Camera with Close-up lens 1,5X (25 µm)



For additional dimensions see page 1

Modified 2012-04-18  
Denomination

Check CAHA

Drawn by R&D Thermography

Size A3

Scale 1:2

Sheet 7(9)

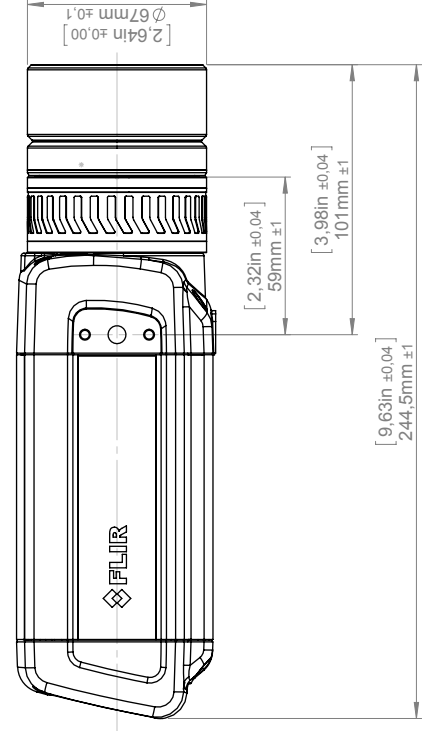
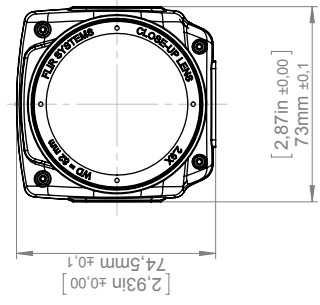
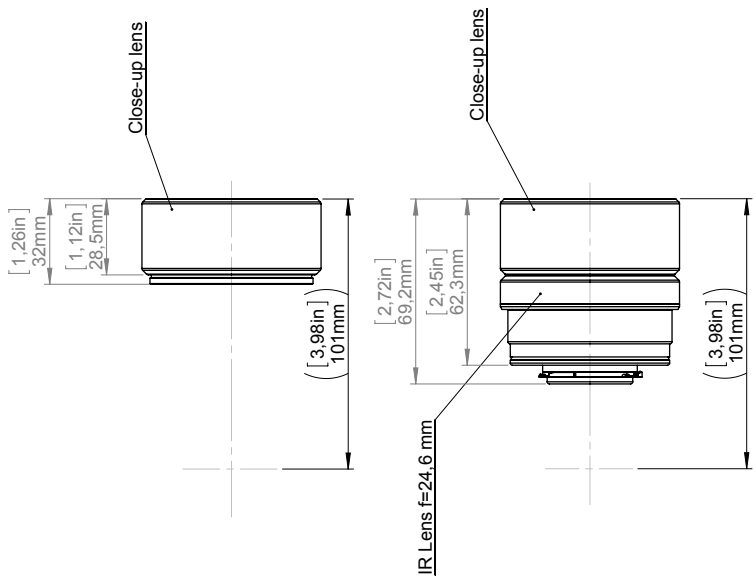
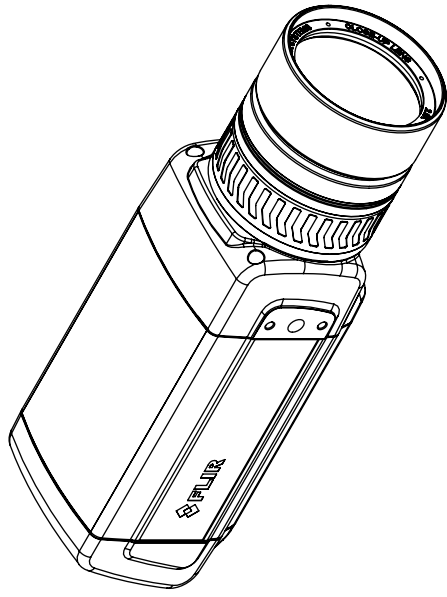


Basic dimensions FLIR A/SC 6xx

Drawing No. T126925

Size A

# Camera with Close-up lens (50 μm)

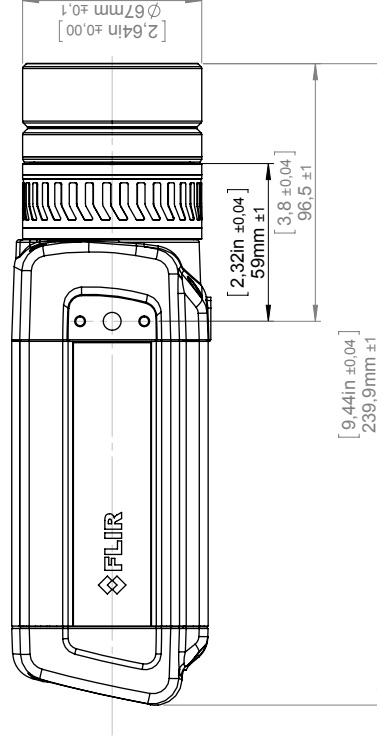
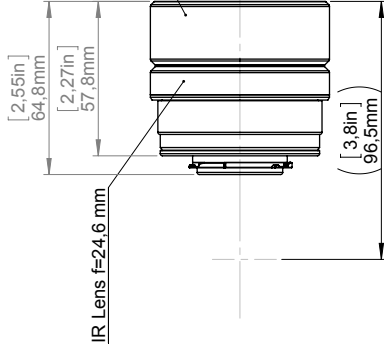
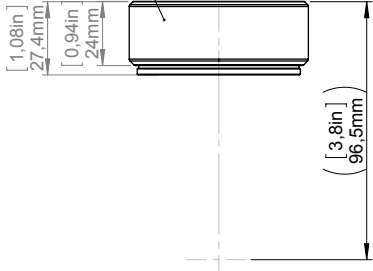
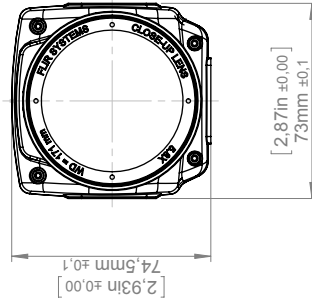
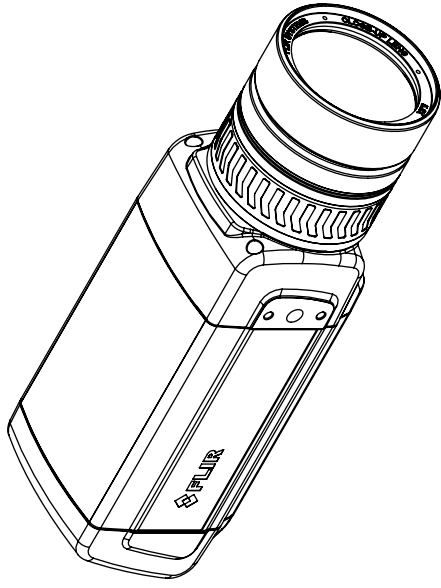


For additional dimensions see page 1

Modified	2012-04-18	Check	CAHA	Drawn by	R&D Thermography	Size	A3	
Denomination						Scale	1:2	
Basic dimensions FLIR A/SC 6xx							Sheet	8(9)
							Drawing No.	T126925
							Size	A

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# Camera with Close-up lens 5,8X (100 μm)



Modified 2012-04-18		Check CAHA	Drawn by R&D Thermography	For additional dimensions see page 1	
Denomination		Basic dimensions FLIR A/SC 6xx		Size A3	Sheet 9(9)
				Scale 1:2	Size A
				Drawing No. T126925	



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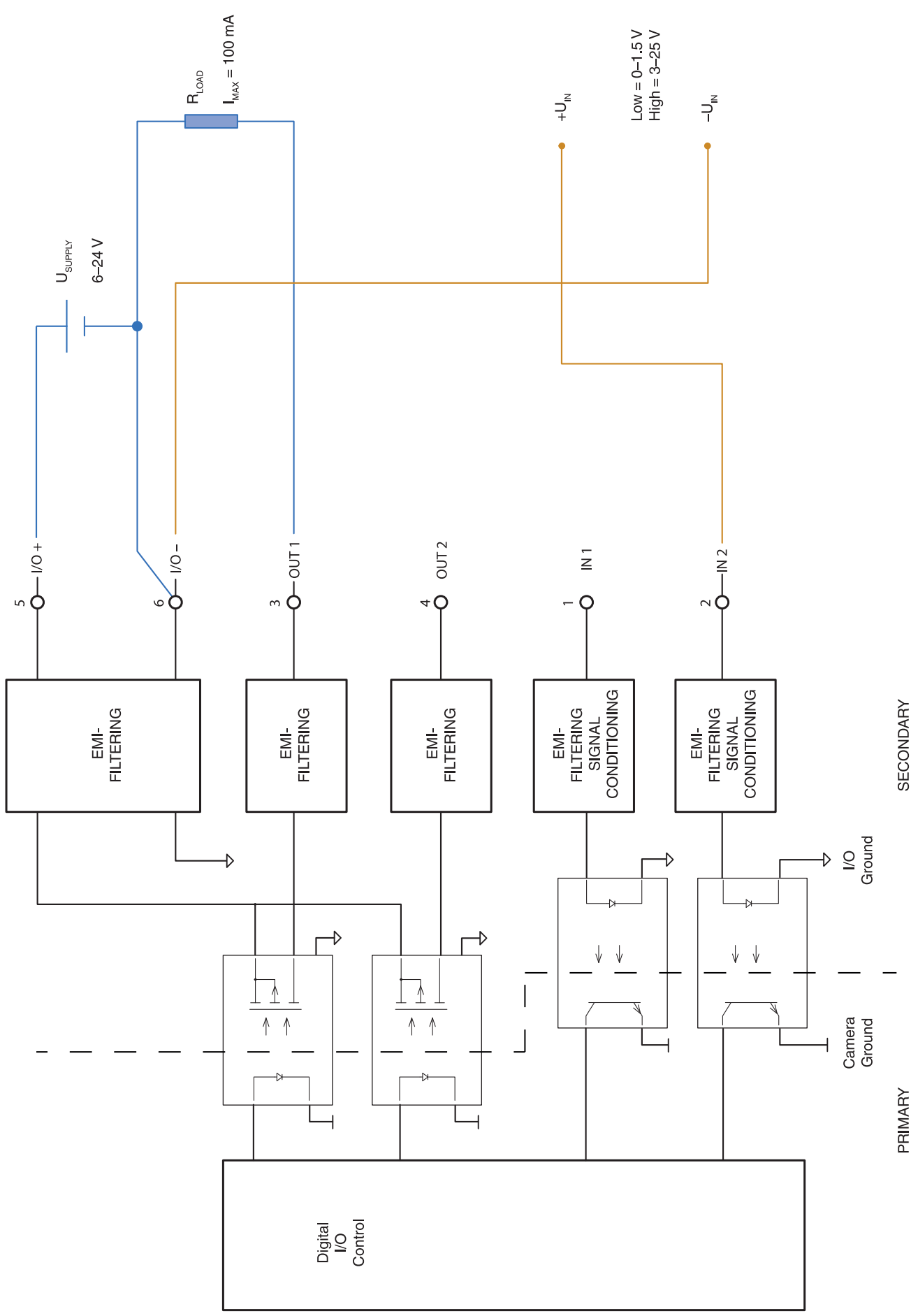
Try one of the following if you experience network problems:

- Reset the modem and unplug and replug the Ethernet cable at both ends.
- Reboot the computer with the cables connected.
- Swap your Ethernet cable with another cable that is either brand new or known to be in working condition.
- Connect your Ethernet cable to a different wall socket. If you are still not able to get online, you are probably experiencing a configuration issue.
- Verify your IP address.
- Disable network bridging.
- Disable your Wi-Fi connectivity (if you use it) to ensure that the wired Ethernet port is open.
- Renew the DHCP license.
- Make sure that the firewall is turned off when you troubleshoot.
- Make sure that your wireless adapter is switched off. If not, the search for the camera might only look for a wireless connection.
- Normally a computer will handle both crossed and uncrossed cable types automatically, but for troubleshooting purposes try both or use a switch.
- Turn off any network adapters that are not connected to the camera.
- For troubleshooting purposes, power both the camera and the computer using a mains adapter. Some laptops turn off the network card to save power when using the battery.

If none of these steps help you, contact your ISP.



# Digital I/O connection diagrams for FLIR A3xx/A6xx series



## 20.1 Camera housing, cables, and other items

### 20.1.1 Liquids

Use one of these liquids:

- Warm water
- A weak detergent solution

### 20.1.2 Equipment

A soft cloth

### 20.1.3 Procedure

Follow this procedure:

1. Soak the cloth in the liquid.
2. Twist the cloth to remove excess liquid.
3. Clean the part with the cloth.



#### CAUTION

Do not apply solvents or similar liquids to the camera, the cables, or other items. This can cause damage.

## 20.2 Infrared lens

### 20.2.1 Liquids

Use one of these liquids:

- A commercial lens cleaning liquid with more than 30% isopropyl alcohol.
- 96% ethyl alcohol (C<sub>2</sub>H<sub>5</sub>OH).

### 20.2.2 Equipment

Cotton wool

### 20.2.3 Procedure

Follow this procedure:

1. Soak the cotton wool in the liquid.
2. Twist the cotton wool to remove excess liquid.
3. Clean the lens one time only and discard the cotton wool.



#### WARNING

Make sure that you read all applicable MSDS (Material Safety Data Sheets) and warning labels on containers before you use a liquid: the liquids can be dangerous.



#### CAUTION

- Be careful when you clean the infrared lens. The lens has a delicate anti-reflective coating.
- Do not clean the infrared lens too vigorously. This can damage the anti-reflective coating.

## 20.3 Infrared detector

### 20.3.1 General

Even small amounts of dust on the infrared detector can result in major blemishes in the image. To remove any dust from the detector, follow the procedure below.

**Note**

- This section only applies to cameras where removing the lens exposes the infrared detector.
- In some cases the dust cannot be removed by following this procedure: the infrared detector must be cleaned mechanically. This mechanical cleaning must be carried out by an authorized service partner.

**CAUTION**

In Step 2 below, do not use pressurized air from pneumatic air circuits in a workshop, etc., as this air usually contains oil mist to lubricate pneumatic tools.

**20.3.2 Procedure**

Follow this procedure:

1. Remove the lens from the camera.
2. Use pressurized air from a compressed air canister to blow off the dust.

FLIR Systems was established in 1978 to pioneer the development of high-performance infrared imaging systems, and is the world leader in the design, manufacture, and marketing of thermal imaging systems for a wide variety of commercial, industrial, and government applications. Today, FLIR Systems embraces five major companies with outstanding achievements in infrared technology since 1958—the Swedish AGEMA Infrared Systems (formerly AGA Infrared Systems), the three United States companies Indigo Systems, FSI, and Inframetrics, and the French company Cedic.

Since 2007, FLIR Systems has acquired several companies with world-leading expertise in sensor technologies:

- Extech Instruments (2007)
- Ifara Tecnologías (2008)
- Salvador Imaging (2009)
- OmniTech Partners (2009)
- Directed Perception (2009)
- Raymarine (2010)
- ICx Technologies (2010)
- TackTick Marine Digital Instruments (2011)
- Aerius Photonics (2011)
- Lorex Technology (2012)
- Traficon (2012)
- MARSS (2013)
- DigitalOptics micro-optics business (2013)
- DVTEL (2015)

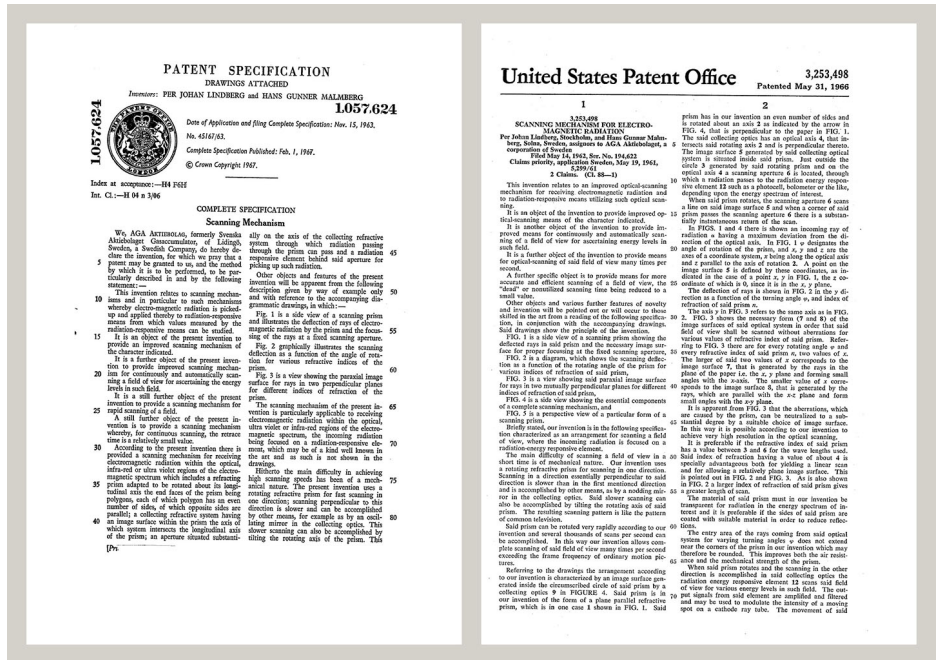


Figure 21.1 Patent documents from the early 1960s

FLIR Systems has three manufacturing plants in the United States (Portland, OR, Boston, MA, Santa Barbara, CA) and one in Sweden (Stockholm). Since 2007 there is also a manufacturing plant in Tallinn, Estonia. Direct sales offices in Belgium, Brazil, China, France, Germany, Great Britain, Hong Kong, Italy, Japan, Korea, Sweden, and the USA—together with a worldwide network of agents and distributors—support our international customer base.

FLIR Systems is at the forefront of innovation in the infrared camera industry. We anticipate market demand by constantly improving our existing cameras and developing new



ones. The company has set milestones in product design and development such as the introduction of the first battery-operated portable camera for industrial inspections, and the first uncooled infrared camera, to mention just two innovations.



**Figure 21.2** 1969: Thermovision Model 661. The camera weighed approximately 25 kg (55 lb.), the oscilloscope 20 kg (44 lb.), and the tripod 15 kg (33 lb.). The operator also needed a 220 VAC generator set, and a 10 L (2.6 US gallon) jar with liquid nitrogen. To the left of the oscilloscope the Polaroid attachment (6 kg/13 lb.) can be seen.



**Figure 21.3** 2015: FLIR One, an accessory to iPhone and Android mobile phones. Weight: 90 g (3.2 oz.).

FLIR Systems manufactures all vital mechanical and electronic components of the camera systems itself. From detector design and manufacturing, to lenses and system electronics, to final testing and calibration, all production steps are carried out and supervised by our own engineers. The in-depth expertise of these infrared specialists ensures the accuracy and reliability of all vital components that are assembled into your infrared camera.

### 21.1 More than just an infrared camera

At FLIR Systems we recognize that our job is to go beyond just producing the best infrared camera systems. We are committed to enabling all users of our infrared camera systems to work more productively by providing them with the most powerful camera–software combination. Especially tailored software for predictive maintenance, R & D, and process monitoring is developed in-house. Most software is available in a wide variety of languages.

We support all our infrared cameras with a wide variety of accessories to adapt your equipment to the most demanding infrared applications.

### 21.2 Sharing our knowledge

Although our cameras are designed to be very user-friendly, there is a lot more to thermography than just knowing how to handle a camera. Therefore, FLIR Systems has founded the Infrared Training Center (ITC), a separate business unit, that provides certified training courses. Attending one of the ITC courses will give you a truly hands-on learning experience.

The staff of the ITC are also there to provide you with any application support you may need in putting infrared theory into practice.

### 21.3 Supporting our customers

FLIR Systems operates a worldwide service network to keep your camera running at all times. If you discover a problem with your camera, local service centers have all the equipment and expertise to solve it within the shortest possible time. Therefore, there is

no need to send your camera to the other side of the world or to talk to someone who does not speak your language.

---

absorption (absorption factor)	The amount of radiation absorbed by an object relative to the received radiation. A number between 0 and 1.
atmosphere	The gases between the object being measured and the camera, normally air.
autoadjust	A function making a camera perform an internal image correction.
autopalette	The IR image is shown with an uneven spread of colors, displaying cold objects as well as hot ones at the same time.
blackbody	Totally non-reflective object. All its radiation is due to its own temperature.
blackbody radiator	An IR radiating equipment with blackbody properties used to calibrate IR cameras.
calculated atmospheric transmission	A transmission value computed from the temperature, the relative humidity of air and the distance to the object.
cavity radiator	A bottle shaped radiator with an absorbing inside, viewed through the bottleneck.
color temperature	The temperature for which the color of a blackbody matches a specific color.
conduction	The process that makes heat diffuse into a material.
continuous adjust	A function that adjusts the image. The function works all the time, continuously adjusting brightness and contrast according to the image content.
convection	Convection is a heat transfer mode where a fluid is brought into motion, either by gravity or another force, thereby transferring heat from one place to another.
dual isotherm	An isotherm with two color bands, instead of one.
emissivity (emissivity factor)	The amount of radiation coming from an object, compared to that of a blackbody. A number between 0 and 1.
emittance	Amount of energy emitted from an object per unit of time and area ( $W/m^2$ )
environment	Objects and gases that emit radiation towards the object being measured.
estimated atmospheric transmission	A transmission value, supplied by a user, replacing a calculated one
external optics	Extra lenses, filters, heat shields etc. that can be put between the camera and the object being measured.
filter	A material transparent only to some of the infrared wavelengths.
FOV	Field of view: The horizontal angle that can be viewed through an IR lens.
FPA	Focal plane array: A type of IR detector.
graybody	An object that emits a fixed fraction of the amount of energy of a blackbody for each wavelength.
IFOV	Instantaneous field of view: A measure of the geometrical resolution of an IR camera.

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image correction (internal or external)	A way of compensating for sensitivity differences in various parts of live images and also of stabilizing the camera.
infrared	Non-visible radiation, having a wavelength from about 2–13 $\mu\text{m}$ .
IR	infrared
isotherm	A function highlighting those parts of an image that fall above, below or between one or more temperature intervals.
isothermal cavity	A bottle-shaped radiator with a uniform temperature viewed through the bottleneck.
Laser LocatIR	An electrically powered light source on the camera that emits laser radiation in a thin, concentrated beam to point at certain parts of the object in front of the camera.
laser pointer	An electrically powered light source on the camera that emits laser radiation in a thin, concentrated beam to point at certain parts of the object in front of the camera.
level	The center value of the temperature scale, usually expressed as a signal value.
manual adjust	A way to adjust the image by manually changing certain parameters.
NETD	Noise equivalent temperature difference. A measure of the image noise level of an IR camera.
noise	Undesired small disturbance in the infrared image
object parameters	A set of values describing the circumstances under which the measurement of an object was made, and the object itself (such as emissivity, reflected apparent temperature, distance etc.)
object signal	A non-calibrated value related to the amount of radiation received by the camera from the object.
palette	The set of colors used to display an IR image.
pixel	Stands for <i>picture element</i> . One single spot in an image.
radiance	Amount of energy emitted from an object per unit of time, area and angle ( $\text{W}/\text{m}^2/\text{sr}$ )
radiant power	Amount of energy emitted from an object per unit of time (W)
radiation	The process by which electromagnetic energy, is emitted by an object or a gas.
radiator	A piece of IR radiating equipment.
range	The current overall temperature measurement limitation of an IR camera. Cameras can have several ranges. Expressed as two blackbody temperatures that limit the current calibration.
reference temperature	A temperature which the ordinary measured values can be compared with.
reflection	The amount of radiation reflected by an object relative to the received radiation. A number between 0 and 1.
relative humidity	Relative humidity represents the ratio between the current water vapour mass in the air and the maximum it may contain in saturation conditions.
saturation color	The areas that contain temperatures outside the present level/span settings are colored with the saturation colors. The saturation colors contain an 'overflow' color and an 'underflow' color. There is also a third red saturation color that marks everything saturated by the detector indicating that the range should probably be changed.

---

span	The interval of the temperature scale, usually expressed as a signal value.
spectral (radiant) emittance	Amount of energy emitted from an object per unit of time, area and wavelength ( $W/m^2/\mu m$ )
temperature difference, or difference of temperature.	A value which is the result of a subtraction between two temperature values.
temperature range	The current overall temperature measurement limitation of an IR camera. Cameras can have several ranges. Expressed as two blackbody temperatures that limit the current calibration.
temperature scale	The way in which an IR image currently is displayed. Expressed as two temperature values limiting the colors.
thermogram	infrared image
transmission (or transmittance) factor	Gases and materials can be more or less transparent. Transmission is the amount of IR radiation passing through them. A number between 0 and 1.
transparent isotherm	An isotherm showing a linear spread of colors, instead of covering the highlighted parts of the image.
visual	Refers to the video mode of a IR camera, as opposed to the normal, thermographic mode. When a camera is in video mode it captures ordinary video images, while thermographic images are captured when the camera is in IR mode.

## 23.1 Introduction

An infrared camera measures and images the emitted infrared radiation from an object. The fact that radiation is a function of object surface temperature makes it possible for the camera to calculate and display this temperature.

However, the radiation measured by the camera does not only depend on the temperature of the object but is also a function of the emissivity. Radiation also originates from the surroundings and is reflected in the object. The radiation from the object and the reflected radiation will also be influenced by the absorption of the atmosphere.

To measure temperature accurately, it is therefore necessary to compensate for the effects of a number of different radiation sources. This is done on-line automatically by the camera. The following object parameters must, however, be supplied for the camera:

- The emissivity of the object
- The reflected apparent temperature
- The distance between the object and the camera
- The relative humidity
- Temperature of the atmosphere

## 23.2 Emissivity

The most important object parameter to set correctly is the emissivity which, in short, is a measure of how much radiation is emitted from the object, compared to that from a perfect blackbody of the same temperature.

Normally, object materials and surface treatments exhibit emissivity ranging from approximately 0.1 to 0.95. A highly polished (mirror) surface falls below 0.1, while an oxidized or painted surface has a higher emissivity. Oil-based paint, regardless of color in the visible spectrum, has an emissivity over 0.9 in the infrared. Human skin exhibits an emissivity 0.97 to 0.98.

Non-oxidized metals represent an extreme case of perfect opacity and high reflexivity, which does not vary greatly with wavelength. Consequently, the emissivity of metals is low – only increasing with temperature. For non-metals, emissivity tends to be high, and decreases with temperature.

### 23.2.1 Finding the emissivity of a sample

#### 23.2.1.1 Step 1: Determining reflected apparent temperature

Use one of the following two methods to determine reflected apparent temperature:

### 23.2.1.1.1 Method 1: Direct method

Follow this procedure:

1. Look for possible reflection sources, considering that the incident angle = reflection angle ( $a = b$ ).

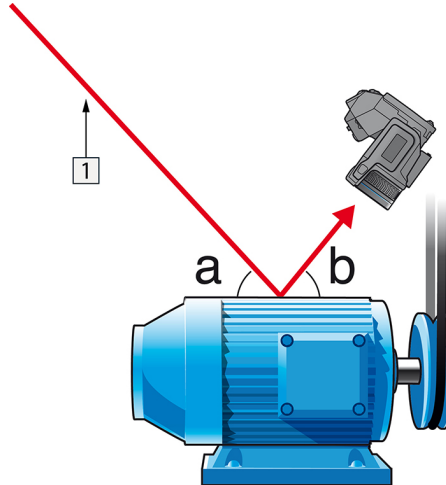


Figure 23.1 1 = Reflection source

2. If the reflection source is a spot source, modify the source by obstructing it using a piece of cardboard.

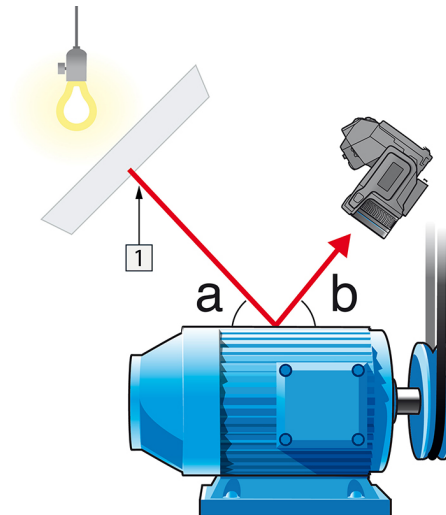


Figure 23.2 1 = Reflection source

3. Measure the radiation intensity (= apparent temperature) from the reflecting source using the following settings:

- Emissivity: 1.0
- $D_{obj}$ : 0

You can measure the radiation intensity using one of the following two methods:

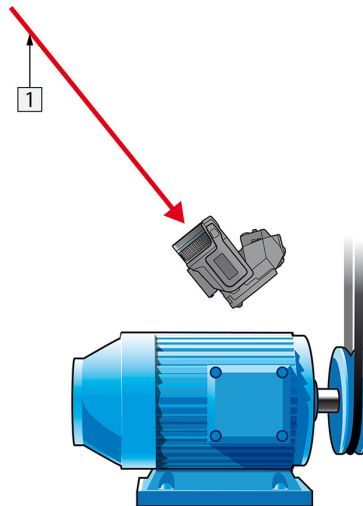


Figure 23.3 1 = Reflection source

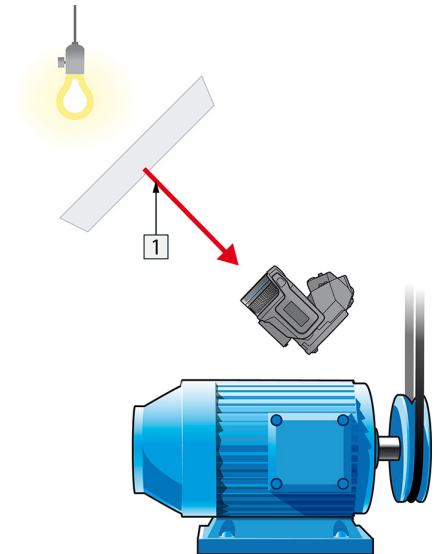


Figure 23.4 1 = Reflection source

Using a thermocouple to measure reflected apparent temperature is not recommended for two important reasons:

- A thermocouple does not measure radiation intensity
- A thermocouple requires a very good thermal contact to the surface, usually by gluing and covering the sensor by a thermal isolator.

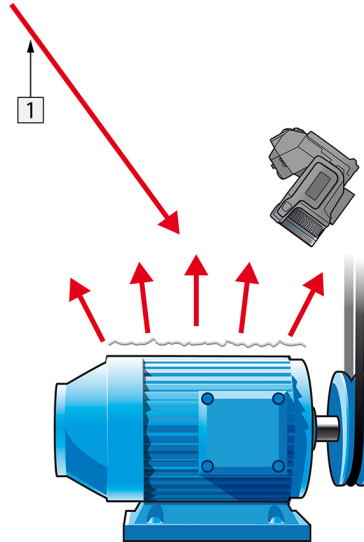
#### 23.2.1.1.2 Method 2: Reflector method

Follow this procedure:

1. Crumble up a large piece of aluminum foil.
2. Uncrumble the aluminum foil and attach it to a piece of cardboard of the same size.
3. Put the piece of cardboard in front of the object you want to measure. Make sure that the side with aluminum foil points to the camera.
4. Set the emissivity to 1.0.



5. Measure the apparent temperature of the aluminum foil and write it down.



**Figure 23.5** Measuring the apparent temperature of the aluminum foil.

#### 23.2.1.2 Step 2: Determining the emissivity

Follow this procedure:

1. Select a place to put the sample.
2. Determine and set reflected apparent temperature according to the previous procedure.
3. Put a piece of electrical tape with known high emissivity on the sample.
4. Heat the sample at least 20 K above room temperature. Heating must be reasonably even.
5. Focus and auto-adjust the camera, and freeze the image.
6. Adjust *Level* and *Span* for best image brightness and contrast.
7. Set emissivity to that of the tape (usually 0.97).
8. Measure the temperature of the tape using one of the following measurement functions:
  - *Isotherm* (helps you to determine both the temperature and how evenly you have heated the sample)
  - *Spot* (simpler)
  - *Box Avg* (good for surfaces with varying emissivity).
9. Write down the temperature.
10. Move your measurement function to the sample surface.
11. Change the emissivity setting until you read the same temperature as your previous measurement.
12. Write down the emissivity.

#### Note

- Avoid forced convection
- Look for a thermally stable surrounding that will not generate spot reflections
- Use high quality tape that you know is not transparent, and has a high emissivity you are certain of
- This method assumes that the temperature of your tape and the sample surface are the same. If they are not, your emissivity measurement will be wrong.

### 23.3 Reflected apparent temperature

This parameter is used to compensate for the radiation reflected in the object. If the emissivity is low and the object temperature relatively far from that of the reflected it will be important to set and compensate for the reflected apparent temperature correctly.

#### 23.4 Distance

The distance is the distance between the object and the front lens of the camera. This parameter is used to compensate for the following two facts:

- That radiation from the target is absorbed by the atmosphere between the object and the camera.
- That radiation from the atmosphere itself is detected by the camera.

#### 23.5 Relative humidity

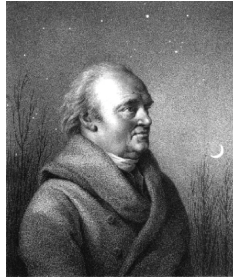
The camera can also compensate for the fact that the transmittance is also dependent on the relative humidity of the atmosphere. To do this set the relative humidity to the correct value. For short distances and normal humidity the relative humidity can normally be left at a default value of 50%.

#### 23.6 Other parameters

In addition, some cameras and analysis programs from FLIR Systems allow you to compensate for the following parameters:

- Atmospheric temperature – *i.e.* the temperature of the atmosphere between the camera and the target
- External optics temperature – *i.e.* the temperature of any external lenses or windows used in front of the camera
- External optics transmittance – *i.e.* the transmission of any external lenses or windows used in front of the camera

Before the year 1800, the existence of the infrared portion of the electromagnetic spectrum wasn't even suspected. The original significance of the infrared spectrum, or simply 'the infrared' as it is often called, as a form of heat radiation is perhaps less obvious today than it was at the time of its discovery by Herschel in 1800.



**Figure 24.1** Sir William Herschel (1738–1822)

The discovery was made accidentally during the search for a new optical material. Sir William Herschel – Royal Astronomer to King George III of England, and already famous for his discovery of the planet Uranus – was searching for an optical filter material to reduce the brightness of the sun's image in telescopes during solar observations. While testing different samples of colored glass which gave similar reductions in brightness he was intrigued to find that some of the samples passed very little of the sun's heat, while others passed so much heat that he risked eye damage after only a few seconds' observation.

Herschel was soon convinced of the necessity of setting up a systematic experiment, with the objective of finding a single material that would give the desired reduction in brightness as well as the maximum reduction in heat. He began the experiment by actually repeating Newton's prism experiment, but looking for the heating effect rather than the visual distribution of intensity in the spectrum. He first blackened the bulb of a sensitive mercury-in-glass thermometer with ink, and with this as his radiation detector he proceeded to test the heating effect of the various colors of the spectrum formed on the top of a table by passing sunlight through a glass prism. Other thermometers, placed outside the sun's rays, served as controls.

As the blackened thermometer was moved slowly along the colors of the spectrum, the temperature readings showed a steady increase from the violet end to the red end. This was not entirely unexpected, since the Italian researcher, Landriani, in a similar experiment in 1777 had observed much the same effect. It was Herschel, however, who was the first to recognize that there must be a point where the heating effect reaches a maximum, and that measurements confined to the visible portion of the spectrum failed to locate this point.



**Figure 24.2** Marsilio Landriani (1746–1815)

Moving the thermometer into the dark region beyond the red end of the spectrum, Herschel confirmed that the heating continued to increase. The maximum point, when he found it, lay well beyond the red end – in what is known today as the 'infrared wavelengths'.

When Herschel revealed his discovery, he referred to this new portion of the electromagnetic spectrum as the 'thermometrical spectrum'. The radiation itself he sometimes referred to as 'dark heat', or simply 'the invisible rays'. Ironically, and contrary to popular opinion, it wasn't Herschel who originated the term 'infrared'. The word only began to appear in print around 75 years later, and it is still unclear who should receive credit as the originator.

Herschel's use of glass in the prism of his original experiment led to some early controversies with his contemporaries about the actual existence of the infrared wavelengths. Different investigators, in attempting to confirm his work, used various types of glass indiscriminately, having different transparencies in the infrared. Through his later experiments, Herschel was aware of the limited transparency of glass to the newly-discovered thermal radiation, and he was forced to conclude that optics for the infrared would probably be doomed to the use of reflective elements exclusively (i.e. plane and curved mirrors). Fortunately, this proved to be true only until 1830, when the Italian investigator, Melloni, made his great discovery that naturally occurring rock salt (NaCl) – which was available in large enough natural crystals to be made into lenses and prisms – is remarkably transparent to the infrared. The result was that rock salt became the principal infrared optical material, and remained so for the next hundred years, until the art of synthetic crystal growing was mastered in the 1930's.



**Figure 24.3** Macedonio Melloni (1798–1854)

Thermometers, as radiation detectors, remained unchallenged until 1829, the year Nobili invented the thermocouple. (Herschel's own thermometer could be read to 0.2 °C (0.036 °F), and later models were able to be read to 0.05 °C (0.09 °F)). Then a breakthrough occurred; Melloni connected a number of thermocouples in series to form the first thermopile. The new device was at least 40 times as sensitive as the best thermometer of the day for detecting heat radiation – capable of detecting the heat from a person standing three meters away.

The first so-called 'heat-picture' became possible in 1840, the result of work by Sir John Herschel, son of the discoverer of the infrared and a famous astronomer in his own right. Based upon the differential evaporation of a thin film of oil when exposed to a heat pattern focused upon it, the thermal image could be seen by reflected light where the interference effects of the oil film made the image visible to the eye. Sir John also managed to obtain a primitive record of the thermal image on paper, which he called a 'thermograph'.



**Figure 24.4** Samuel P. Langley (1834–1906)

The improvement of infrared-detector sensitivity progressed slowly. Another major breakthrough, made by Langley in 1880, was the invention of the bolometer. This consisted of a thin blackened strip of platinum connected in one arm of a Wheatstone bridge circuit upon which the infrared radiation was focused and to which a sensitive galvanometer responded. This instrument is said to have been able to detect the heat from a cow at a distance of 400 meters.

An English scientist, Sir James Dewar, first introduced the use of liquefied gases as cooling agents (such as liquid nitrogen with a temperature of  $-196\text{ }^{\circ}\text{C}$  ( $-320.8\text{ }^{\circ}\text{F}$ )) in low temperature research. In 1892 he invented a unique vacuum insulating container in which it is possible to store liquefied gases for entire days. The common 'thermos bottle', used for storing hot and cold drinks, is based upon his invention.

Between the years 1900 and 1920, the inventors of the world 'discovered' the infrared. Many patents were issued for devices to detect personnel, artillery, aircraft, ships – and even icebergs. The first operating systems, in the modern sense, began to be developed during the 1914–18 war, when both sides had research programs devoted to the military exploitation of the infrared. These programs included experimental systems for enemy intrusion/detection, remote temperature sensing, secure communications, and 'flying torpedo' guidance. An infrared search system tested during this period was able to detect an approaching airplane at a distance of 1.5 km (0.94 miles), or a person more than 300 meters (984 ft.) away.

The most sensitive systems up to this time were all based upon variations of the bolometer idea, but the period between the two wars saw the development of two revolutionary new infrared detectors: the image converter and the photon detector. At first, the image converter received the greatest attention by the military, because it enabled an observer for the first time in history to literally 'see in the dark'. However, the sensitivity of the image converter was limited to the near infrared wavelengths, and the most interesting military targets (i.e. enemy soldiers) had to be illuminated by infrared search beams. Since this involved the risk of giving away the observer's position to a similarly-equipped enemy observer, it is understandable that military interest in the image converter eventually faded.

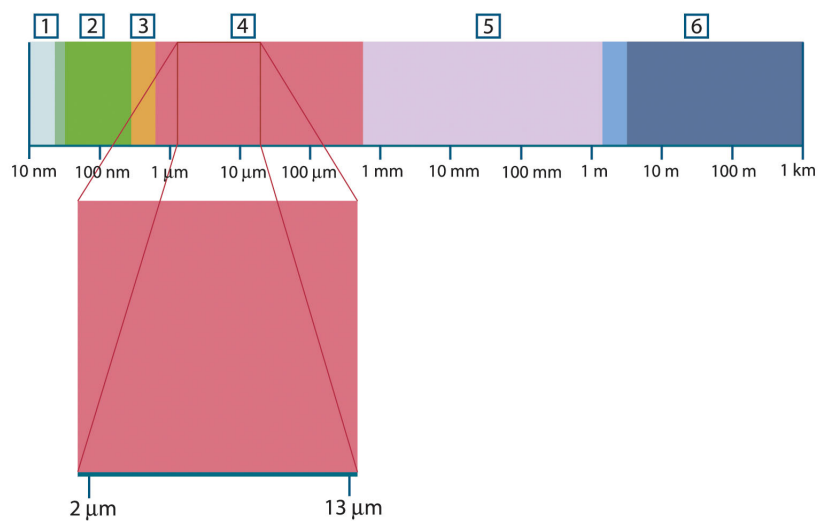
The tactical military disadvantages of so-called 'active' (i.e. search beam-equipped) thermal imaging systems provided impetus following the 1939–45 war for extensive secret military infrared-research programs into the possibilities of developing 'passive' (no search beam) systems around the extremely sensitive photon detector. During this period, military secrecy regulations completely prevented disclosure of the status of infrared-imaging technology. This secrecy only began to be lifted in the middle of the 1950's, and from that time adequate thermal-imaging devices finally began to be available to civilian science and industry.

### 25.1 Introduction

The subjects of infrared radiation and the related technique of thermography are still new to many who will use an infrared camera. In this section the theory behind thermography will be given.

### 25.2 The electromagnetic spectrum

The electromagnetic spectrum is divided arbitrarily into a number of wavelength regions, called *bands*, distinguished by the methods used to produce and detect the radiation. There is no fundamental difference between radiation in the different bands of the electromagnetic spectrum. They are all governed by the same laws and the only differences are those due to differences in wavelength.



**Figure 25.1** The electromagnetic spectrum. 1: X-ray; 2: UV; 3: Visible; 4: IR; 5: Microwaves; 6: Radiowaves.

Thermography makes use of the infrared spectral band. At the short-wavelength end the boundary lies at the limit of visual perception, in the deep red. At the long-wavelength end it merges with the microwave radio wavelengths, in the millimeter range.

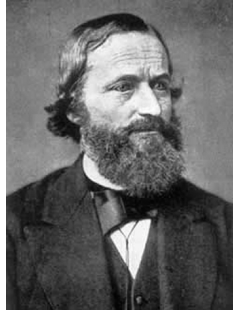
The infrared band is often further subdivided into four smaller bands, the boundaries of which are also arbitrarily chosen. They include: the *near infrared* (0.75–3  $\mu\text{m}$ ), the *middle infrared* (3–6  $\mu\text{m}$ ), the *far infrared* (6–15  $\mu\text{m}$ ) and the *extreme infrared* (15–100  $\mu\text{m}$ ). Although the wavelengths are given in  $\mu\text{m}$  (micrometers), other units are often still used to measure wavelength in this spectral region, e.g. nanometer (nm) and Ångström (Å).

The relationships between the different wavelength measurements is:

$$10\,000 \text{ \AA} = 1\,000 \text{ nm} = 1 \mu = 1 \mu\text{m}$$

### 25.3 Blackbody radiation

A blackbody is defined as an object which absorbs all radiation that impinges on it at any wavelength. The apparent misnomer *black* relating to an object emitting radiation is explained by Kirchhoff's Law (after *Gustav Robert Kirchhoff*, 1824–1887), which states that a body capable of absorbing all radiation at any wavelength is equally capable in the emission of radiation.



**Figure 25.2** Gustav Robert Kirchhoff (1824–1887)

The construction of a blackbody source is, in principle, very simple. The radiation characteristics of an aperture in an isotherm cavity made of an opaque absorbing material represents almost exactly the properties of a blackbody. A practical application of the principle to the construction of a perfect absorber of radiation consists of a box that is light tight except for an aperture in one of the sides. Any radiation which then enters the hole is scattered and absorbed by repeated reflections so only an infinitesimal fraction can possibly escape. The blackness which is obtained at the aperture is nearly equal to a blackbody and almost perfect for all wavelengths.

By providing such an isothermal cavity with a suitable heater it becomes what is termed a *cavity radiator*. An isothermal cavity heated to a uniform temperature generates blackbody radiation, the characteristics of which are determined solely by the temperature of the cavity. Such cavity radiators are commonly used as sources of radiation in temperature reference standards in the laboratory for calibrating thermographic instruments, such as a FLIR Systems camera for example.

If the temperature of blackbody radiation increases to more than 525°C (977°F), the source begins to be visible so that it appears to the eye no longer black. This is the incipient red heat temperature of the radiator, which then becomes orange or yellow as the temperature increases further. In fact, the definition of the so-called *color temperature* of an object is the temperature to which a blackbody would have to be heated to have the same appearance.

Now consider three expressions that describe the radiation emitted from a blackbody.

### 25.3.1 Planck's law



**Figure 25.3** Max Planck (1858–1947)

*Max Planck* (1858–1947) was able to describe the spectral distribution of the radiation from a blackbody by means of the following formula:

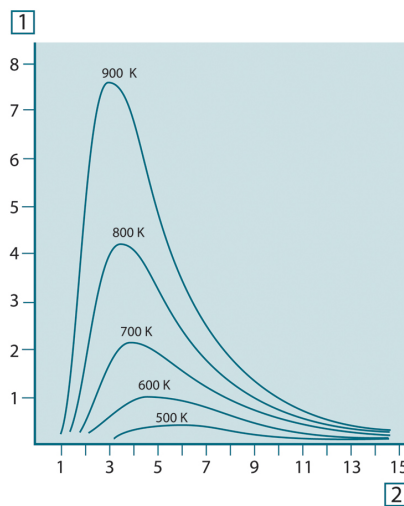
$$W_{\lambda b} = \frac{2\pi hc^2}{\lambda^5 \left( e^{\frac{hc}{\lambda kT}} - 1 \right)} \times 10^{-6} [\text{Watt} / \text{m}^2, \mu\text{m}]$$

where:

$W_{\lambda b}$	Blackbody spectral radiant emittance at wavelength $\lambda$ .
$c$	Velocity of light = $3 \times 10^8$ m/s
$h$	Planck's constant = $6.6 \times 10^{-34}$ Joule sec.
$k$	Boltzmann's constant = $1.4 \times 10^{-23}$ Joule/K.
$T$	Absolute temperature (K) of a blackbody.
$\lambda$	Wavelength ( $\mu\text{m}$ ).

**Note** The factor  $10^{-6}$  is used since spectral emittance in the curves is expressed in  $\text{Watt/m}^2, \mu\text{m}$ .

Planck's formula, when plotted graphically for various temperatures, produces a family of curves. Following any particular Planck curve, the spectral emittance is zero at  $\lambda = 0$ , then increases rapidly to a maximum at a wavelength  $\lambda_{\text{max}}$  and after passing it approaches zero again at very long wavelengths. The higher the temperature, the shorter the wavelength at which maximum occurs.



**Figure 25.4** Blackbody spectral radiant emittance according to Planck's law, plotted for various absolute temperatures. 1: Spectral radiant emittance ( $\text{W/cm}^2 \times 10^3(\mu\text{m})$ ); 2: Wavelength ( $\mu\text{m}$ )

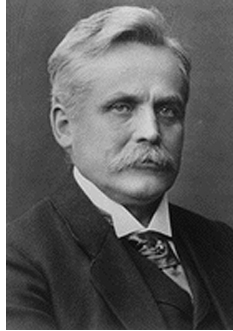
### 25.3.2 Wien's displacement law

By differentiating Planck's formula with respect to  $\lambda$ , and finding the maximum, we have:

$$\lambda_{\text{max}} = \frac{2898}{T} [\mu\text{m}]$$

This is Wien's formula (after *Wilhelm Wien*, 1864–1928), which expresses mathematically the common observation that colors vary from red to orange or yellow as the temperature of a thermal radiator increases. The wavelength of the color is the same as the wavelength calculated for  $\lambda_{\text{max}}$ . A good approximation of the value of  $\lambda_{\text{max}}$  for a given blackbody temperature is obtained by applying the rule-of-thumb  $3\,000/T \mu\text{m}$ . Thus, a very hot star such as Sirius (11 000 K), emitting bluish-white light, radiates with the peak of spectral radiant emittance occurring within the invisible ultraviolet spectrum, at wavelength  $0.27 \mu\text{m}$ .

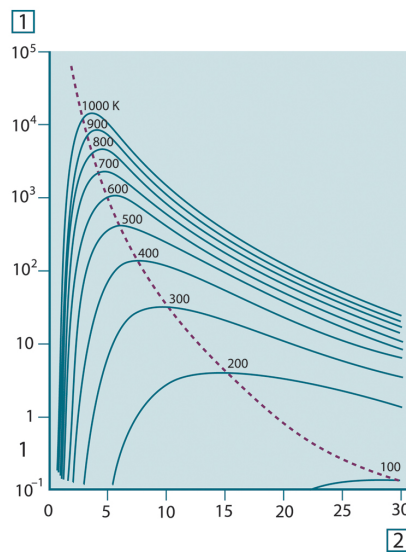




**Figure 25.5** Wilhelm Wien (1864–1928)

The sun (approx. 6 000 K) emits yellow light, peaking at about 0.5  $\mu\text{m}$  in the middle of the visible light spectrum.

At room temperature (300 K) the peak of radiant emittance lies at 9.7  $\mu\text{m}$ , in the far infrared, while at the temperature of liquid nitrogen (77 K) the maximum of the almost insignificant amount of radiant emittance occurs at 38  $\mu\text{m}$ , in the extreme infrared wavelengths.



**Figure 25.6** Planckian curves plotted on semi-log scales from 100 K to 1000 K. The dotted line represents the locus of maximum radiant emittance at each temperature as described by Wien's displacement law. 1: Spectral radiant emittance ( $\text{W/cm}^2 (\mu\text{m})$ ); 2: Wavelength ( $\mu\text{m}$ ).

### 25.3.3 Stefan-Boltzmann's law

By integrating Planck's formula from  $\lambda = 0$  to  $\lambda = \infty$ , we obtain the total radiant emittance ( $W_b$ ) of a blackbody:

$$W_b = \sigma T^4 \text{ [Watt/m}^2\text{]}$$

This is the Stefan-Boltzmann formula (after *Josef Stefan*, 1835–1893, and *Ludwig Boltzmann*, 1844–1906), which states that the total emissive power of a blackbody is proportional to the fourth power of its absolute temperature. Graphically,  $W_b$  represents the area below the Planck curve for a particular temperature. It can be shown that the radiant emittance in the interval  $\lambda = 0$  to  $\lambda_{\text{max}}$  is only 25% of the total, which represents about the amount of the sun's radiation which lies inside the visible light spectrum.



**Figure 25.7** Josef Stefan (1835–1893), and Ludwig Boltzmann (1844–1906)

Using the Stefan-Boltzmann formula to calculate the power radiated by the human body, at a temperature of 300 K and an external surface area of approx. 2 m<sup>2</sup>, we obtain 1 kW. This power loss could not be sustained if it were not for the compensating absorption of radiation from surrounding surfaces, at room temperatures which do not vary too drastically from the temperature of the body – or, of course, the addition of clothing.

### 25.3.4 Non-blackbody emitters

So far, only blackbody radiators and blackbody radiation have been discussed. However, real objects almost never comply with these laws over an extended wavelength region – although they may approach the blackbody behavior in certain spectral intervals. For example, a certain type of white paint may appear perfectly *white* in the visible light spectrum, but becomes distinctly *gray* at about 2 μm, and beyond 3 μm it is almost *black*.

There are three processes which can occur that prevent a real object from acting like a blackbody: a fraction of the incident radiation  $\alpha$  may be absorbed, a fraction  $\rho$  may be reflected, and a fraction  $\tau$  may be transmitted. Since all of these factors are more or less wavelength dependent, the subscript  $\lambda$  is used to imply the spectral dependence of their definitions. Thus:

- The spectral absorptance  $\alpha_\lambda$  = the ratio of the spectral radiant power absorbed by an object to that incident upon it.
- The spectral reflectance  $\rho_\lambda$  = the ratio of the spectral radiant power reflected by an object to that incident upon it.
- The spectral transmittance  $\tau_\lambda$  = the ratio of the spectral radiant power transmitted through an object to that incident upon it.

The sum of these three factors must always add up to the whole at any wavelength, so we have the relation:

$$\alpha_\lambda + \rho_\lambda + \tau_\lambda = 1$$

For opaque materials  $\tau_\lambda = 0$  and the relation simplifies to:

$$\varepsilon_\lambda + \rho_\lambda = 1$$

Another factor, called the emissivity, is required to describe the fraction  $\varepsilon$  of the radiant emittance of a blackbody produced by an object at a specific temperature. Thus, we have the definition:

The spectral emissivity  $\varepsilon_\lambda$  = the ratio of the spectral radiant power from an object to that from a blackbody at the same temperature and wavelength.

Expressed mathematically, this can be written as the ratio of the spectral emittance of the object to that of a blackbody as follows:

$$\varepsilon_\lambda = \frac{W_{\lambda o}}{W_{\lambda b}}$$

Generally speaking, there are three types of radiation source, distinguished by the ways in which the spectral emittance of each varies with wavelength.

- A blackbody, for which  $\varepsilon_\lambda = \varepsilon = 1$
- A graybody, for which  $\varepsilon_\lambda = \varepsilon = \text{constant less than } 1$

- A selective radiator, for which  $\varepsilon$  varies with wavelength

According to Kirchhoff's law, for any material the spectral emissivity and spectral absorptance of a body are equal at any specified temperature and wavelength. That is:

$$\varepsilon_\lambda = \alpha_\lambda$$

From this we obtain, for an opaque material (since  $\alpha_\lambda + \rho_\lambda = 1$ ):

$$\varepsilon_\lambda + \rho_\lambda = 1$$

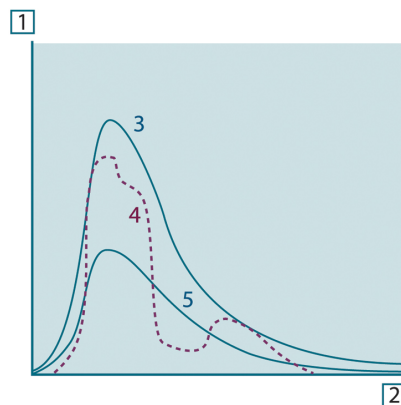
For highly polished materials  $\varepsilon_\lambda$  approaches zero, so that for a perfectly reflecting material (*i.e.* a perfect mirror) we have:

$$\rho_\lambda = 1$$

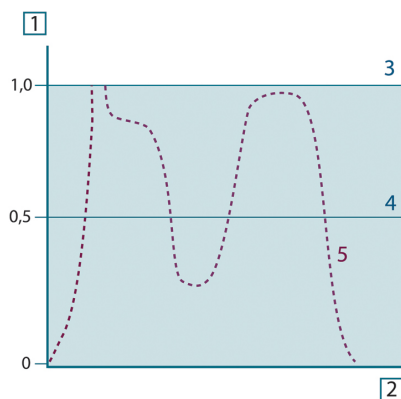
For a graybody radiator, the Stefan-Boltzmann formula becomes:

$$W = \varepsilon \sigma T^4 \text{ [Watt/m}^2\text{]}$$

This states that the total emissive power of a graybody is the same as a blackbody at the same temperature reduced in proportion to the value of  $\varepsilon$  from the graybody.



**Figure 25.8** Spectral radiant emittance of three types of radiators. 1: Spectral radiant emittance; 2: Wavelength; 3: Blackbody; 4: Selective radiator; 5: Graybody.



**Figure 25.9** Spectral emissivity of three types of radiators. 1: Spectral emissivity; 2: Wavelength; 3: Blackbody; 4: Graybody; 5: Selective radiator.

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#### 25.4 Infrared semi-transparent materials

Consider now a non-metallic, semi-transparent body – let us say, in the form of a thick flat plate of plastic material. When the plate is heated, radiation generated within its volume must work its way toward the surfaces through the material in which it is partially absorbed. Moreover, when it arrives at the surface, some of it is reflected back into the interior. The back-reflected radiation is again partially absorbed, but some of it arrives at the other surface, through which most of it escapes; part of it is reflected back again. Although the progressive reflections become weaker and weaker they must all be added up when the total emittance of the plate is sought. When the resulting geometrical series is summed, the effective emissivity of a semi-transparent plate is obtained as:

$$\varepsilon_{\lambda} = \frac{(1 - \rho_{\lambda})(1 - \tau_{\lambda})}{1 - \rho_{\lambda}\tau_{\lambda}}$$

When the plate becomes opaque this formula is reduced to the single formula:

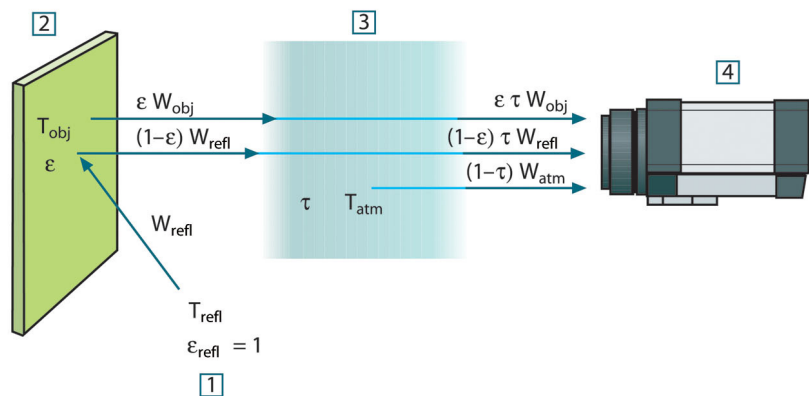
$$\varepsilon_{\lambda} = 1 - \rho_{\lambda}$$

This last relation is a particularly convenient one, because it is often easier to measure reflectance than to measure emissivity directly.

As already mentioned, when viewing an object, the camera receives radiation not only from the object itself. It also collects radiation from the surroundings reflected via the object surface. Both these radiation contributions become attenuated to some extent by the atmosphere in the measurement path. To this comes a third radiation contribution from the atmosphere itself.

This description of the measurement situation, as illustrated in the figure below, is so far a fairly true description of the real conditions. What has been neglected could for instance be sun light scattering in the atmosphere or stray radiation from intense radiation sources outside the field of view. Such disturbances are difficult to quantify, however, in most cases they are fortunately small enough to be neglected. In case they are not negligible, the measurement configuration is likely to be such that the risk for disturbance is obvious, at least to a trained operator. It is then his responsibility to modify the measurement situation to avoid the disturbance e.g. by changing the viewing direction, shielding off intense radiation sources etc.

Accepting the description above, we can use the figure below to derive a formula for the calculation of the object temperature from the calibrated camera output.



**Figure 26.1** A schematic representation of the general thermographic measurement situation. 1: Surroundings; 2: Object; 3: Atmosphere; 4: Camera

Assume that the received radiation power  $W$  from a blackbody source of temperature  $T_{source}$  on short distance generates a camera output signal  $U_{source}$  that is proportional to the power input (power linear camera). We can then write (Equation 1):

$$U_{source} = CW(T_{source})$$

or, with simplified notation:

$$U_{source} = CW_{source}$$

where  $C$  is a constant.

Should the source be a graybody with emittance  $\epsilon$ , the received radiation would consequently be  $\epsilon W_{source}$ .

We are now ready to write the three collected radiation power terms:

1. *Emission from the object* =  $\epsilon \tau W_{obj}$ , where  $\epsilon$  is the emittance of the object and  $\tau$  is the transmittance of the atmosphere. The object temperature is  $T_{obj}$ .

2. *Reflected emission from ambient sources* =  $(1 - \varepsilon)\tau W_{\text{refl}}$ , where  $(1 - \varepsilon)$  is the reflectance of the object. The ambient sources have the temperature  $T_{\text{refl}}$ .

It has here been assumed that the temperature  $T_{\text{refl}}$  is the same for all emitting surfaces within the hemisphere seen from a point on the object surface. This is of course sometimes a simplification of the true situation. It is, however, a necessary simplification in order to derive a workable formula, and  $T_{\text{refl}}$  can – at least theoretically – be given a value that represents an efficient temperature of a complex surrounding.

Note also that we have assumed that the emittance for the surroundings = 1. This is correct in accordance with Kirchhoff's law: All radiation impinging on the surrounding surfaces will eventually be absorbed by the same surfaces. Thus the emittance = 1. (Note though that the latest discussion requires the complete sphere around the object to be considered.)

3. *Emission from the atmosphere* =  $(1 - \tau)\tau W_{\text{atm}}$ , where  $(1 - \tau)$  is the emittance of the atmosphere. The temperature of the atmosphere is  $T_{\text{atm}}$ .

The total received radiation power can now be written (Equation 2):

$$W_{\text{tot}} = \varepsilon\tau W_{\text{obj}} + (1 - \varepsilon)\tau W_{\text{refl}} + (1 - \tau)W_{\text{atm}}$$

We multiply each term by the constant C of Equation 1 and replace the CW products by the corresponding U according to the same equation, and get (Equation 3):

$$U_{\text{tot}} = \varepsilon\tau U_{\text{obj}} + (1 - \varepsilon)\tau U_{\text{refl}} + (1 - \tau)U_{\text{atm}}$$

Solve Equation 3 for  $U_{\text{obj}}$  (Equation 4):

$$U_{\text{obj}} = \frac{1}{\varepsilon\tau}U_{\text{tot}} - \frac{1 - \varepsilon}{\varepsilon}U_{\text{refl}} - \frac{1 - \tau}{\varepsilon\tau}U_{\text{atm}}$$

This is the general measurement formula used in all the FLIR Systems thermographic equipment. The variables of the formula are:

**Table 26.1** Voltages

$U_{\text{obj}}$	Calculated camera output voltage for a blackbody of temperature $T_{\text{obj}}$ i.e. a voltage that can be directly converted into true requested object temperature.
$U_{\text{tot}}$	Measured camera output voltage for the actual case.
$U_{\text{refl}}$	Theoretical camera output voltage for a blackbody of temperature $T_{\text{refl}}$ according to the calibration.
$U_{\text{atm}}$	Theoretical camera output voltage for a blackbody of temperature $T_{\text{atm}}$ according to the calibration.

The operator has to supply a number of parameter values for the calculation:

- the object emittance  $\varepsilon$ ,
- the relative humidity,
- $T_{\text{atm}}$
- object distance ( $D_{\text{obj}}$ )
- the (effective) temperature of the object surroundings, or the reflected ambient temperature  $T_{\text{refl}}$ , and
- the temperature of the atmosphere  $T_{\text{atm}}$

This task could sometimes be a heavy burden for the operator since there are normally no easy ways to find accurate values of emittance and atmospheric transmittance for the actual case. The two temperatures are normally less of a problem provided the surroundings do not contain large and intense radiation sources.

A natural question in this connection is: How important is it to know the right values of these parameters? It could though be of interest to get a feeling for this problem already here by looking into some different measurement cases and compare the relative

magnitudes of the three radiation terms. This will give indications about when it is important to use correct values of which parameters.

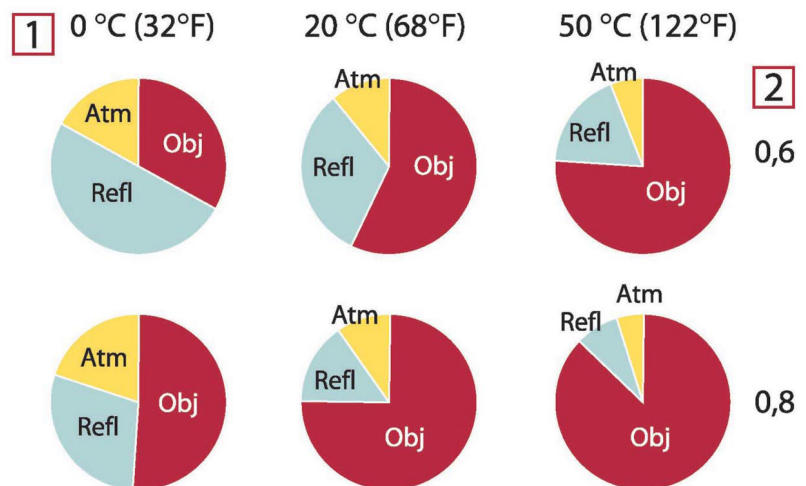
The figures below illustrates the relative magnitudes of the three radiation contributions for three different object temperatures, two emittances, and two spectral ranges: SW and LW. Remaining parameters have the following fixed values:

- $\tau = 0.88$
- $T_{refl} = +20^{\circ}\text{C} (+68^{\circ}\text{F})$
- $T_{atm} = +20^{\circ}\text{C} (+68^{\circ}\text{F})$

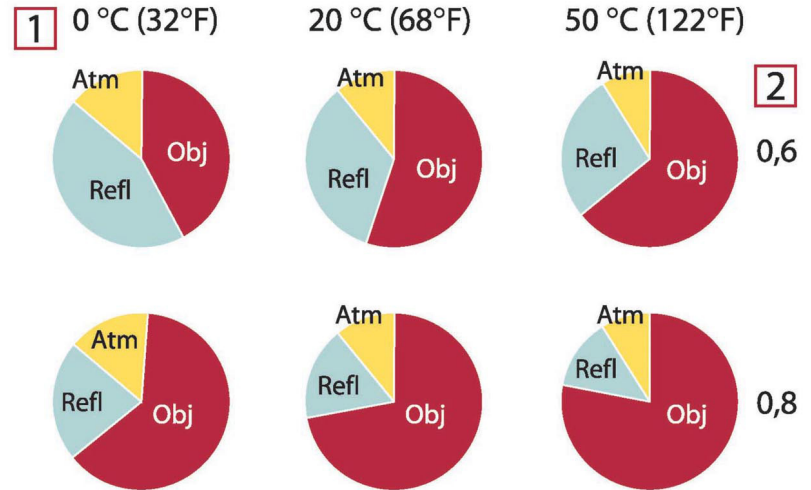
It is obvious that measurement of low object temperatures are more critical than measuring high temperatures since the ‘disturbing’ radiation sources are relatively much stronger in the first case. Should also the object emittance be low, the situation would be still more difficult.

We have finally to answer a question about the importance of being allowed to use the calibration curve above the highest calibration point, what we call extrapolation. Imagine that we in a certain case measure  $U_{tot} = 4.5$  volts. The highest calibration point for the camera was in the order of 4.1 volts, a value unknown to the operator. Thus, even if the object happened to be a blackbody, i.e.  $U_{obj} = U_{tot}$ , we are actually performing extrapolation of the calibration curve when converting 4.5 volts into temperature.

Let us now assume that the object is not black, it has an emittance of 0.75, and the transmittance is 0.92. We also assume that the two second terms of Equation 4 amount to 0.5 volts together. Computation of  $U_{obj}$  by means of Equation 4 then results in  $U_{obj} = 4.5 / 0.75 / 0.92 - 0.5 = 6.0$ . This is a rather extreme extrapolation, particularly when considering that the video amplifier might limit the output to 5 volts! Note, though, that the application of the calibration curve is a theoretical procedure where no electronic or other limitations exist. We trust that if there had been no signal limitations in the camera, and if it had been calibrated far beyond 5 volts, the resulting curve would have been very much the same as our real curve extrapolated beyond 4.1 volts, provided the calibration algorithm is based on radiation physics, like the FLIR Systems algorithm. Of course there must be a limit to such extrapolations.



**Figure 26.2** Relative magnitudes of radiation sources under varying measurement conditions (SW camera). 1: Object temperature; 2: Emittance; Obj: Object radiation; Refl: Reflected radiation; Atm: atmosphere radiation. Fixed parameters:  $\tau = 0.88$ ;  $T_{refl} = 20^{\circ}\text{C} (+68^{\circ}\text{F})$ ;  $T_{atm} = 20^{\circ}\text{C} (+68^{\circ}\text{F})$ .



**Figure 26.3** Relative magnitudes of radiation sources under varying measurement conditions (LW camera). 1: Object temperature; 2: Emittance; Obj: Object radiation; Refl: Reflected radiation; Atm: atmosphere radiation. Fixed parameters:  $\tau = 0.88$ ;  $T_{\text{refl}} = 20^\circ\text{C}$  (+68°F);  $T_{\text{atm}} = 20^\circ\text{C}$  (+68°F).



This section presents a compilation of emissivity data from the infrared literature and measurements made by FLIR Systems.

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**Note** The emissivity values in the table below are recorded using a shortwave (SW) camera. The values should be regarded as recommendations only and used with caution.

### 27.2 Tables

**Table 27.1** T: Total spectrum; SW: 2–5  $\mu\text{m}$ ; LW: 8–14  $\mu\text{m}$ , LLW: 6.5–20  $\mu\text{m}$ ; 1: Material; 2: Specification; 3: Temperature in  $^{\circ}\text{C}$ ; 4: Spectrum; 5: Emissivity; 6: Reference

1	2	3	4	5	6
3M type 35	Vinyl electrical tape (several colors)	< 80	LW	$\approx 0.96$	13
3M type 88	Black vinyl electrical tape	< 105	LW	$\approx 0.96$	13
3M type 88	Black vinyl electrical tape	< 105	MW	< 0.96	13
3M type Super 33+	Black vinyl electrical tape	< 80	LW	$\approx 0.96$	13
Aluminum	anodized sheet	100	T	0.55	2
Aluminum	anodized, black, dull	70	SW	0.67	9
Aluminum	anodized, black, dull	70	LW	0.95	9
Aluminum	anodized, light gray, dull	70	SW	0.61	9

## Emissivity tables

**Table 27.1** T: Total spectrum; SW: 2–5  $\mu\text{m}$ ; LW: 8–14  $\mu\text{m}$ , LLW: 6.5–20  $\mu\text{m}$ ; 1: Material; 2: Specification; 3: Temperature in  $^{\circ}\text{C}$ ; 4: Spectrum; 5: Emissivity; 6: Reference (continued)

1	2	3	4	5	6
Aluminum	anodized, light gray, dull	70	LW	0.97	9
Aluminum	as received, plate	100	T	0.09	4
Aluminum	as received, sheet	100	T	0.09	2
Aluminum	cast, blast cleaned	70	SW	0.47	9
Aluminum	cast, blast cleaned	70	LW	0.46	9
Aluminum	dipped in $\text{HNO}_3$ , plate	100	T	0.05	4
Aluminum	foil	27	10 $\mu\text{m}$	0.04	3
Aluminum	foil	27	3 $\mu\text{m}$	0.09	3
Aluminum	oxidized, strongly	50–500	T	0.2–0.3	1
Aluminum	polished	50–100	T	0.04–0.06	1
Aluminum	polished plate	100	T	0.05	4
Aluminum	polished, sheet	100	T	0.05	2
Aluminum	rough surface	20–50	T	0.06–0.07	1
Aluminum	roughened	27	10 $\mu\text{m}$	0.18	3
Aluminum	roughened	27	3 $\mu\text{m}$	0.28	3
Aluminum	sheet, 4 samples differently scratched	70	SW	0.05–0.08	9
Aluminum	sheet, 4 samples differently scratched	70	LW	0.03–0.06	9
Aluminum	vacuum deposited	20	T	0.04	2
Aluminum	weathered, heavily	17	SW	0.83–0.94	5
Aluminum bronze		20	T	0.60	1
Aluminum hydroxide	powder		T	0.28	1
Aluminum oxide	activated, powder		T	0.46	1
Aluminum oxide	pure, powder (alumina)		T	0.16	1
Asbestos	board	20	T	0.96	1
Asbestos	fabric		T	0.78	1
Asbestos	floor tile	35	SW	0.94	7
Asbestos	paper	40–400	T	0.93–0.95	1
Asbestos	powder		T	0.40–0.60	1
Asbestos	slate	20	T	0.96	1
Asphalt paving		4	LLW	0.967	8
Brass	dull, tarnished	20–350	T	0.22	1
Brass	oxidized	100	T	0.61	2
Brass	oxidized	70	SW	0.04–0.09	9
Brass	oxidized	70	LW	0.03–0.07	9
Brass	oxidized at 600 $^{\circ}\text{C}$	200–600	T	0.59–0.61	1

**Table 27.1** T: Total spectrum; SW: 2–5 µm; LW: 8–14 µm, LLW: 6.5–20 µm; 1: Material; 2: Specification; 3: Temperature in °C; 4: Spectrum; 5: Emissivity; 6: Reference (continued)

1	2	3	4	5	6
Brass	polished	200	T	0.03	1
Brass	polished, highly	100	T	0.03	2
Brass	rubbed with 80-grit emery	20	T	0.20	2
Brass	sheet, rolled	20	T	0.06	1
Brass	sheet, worked with emery	20	T	0.2	1
Brick	alumina	17	SW	0.68	5
Brick	common	17	SW	0.86–0.81	5
Brick	Dinas silica, glazed, rough	1100	T	0.85	1
Brick	Dinas silica, refractory	1000	T	0.66	1
Brick	Dinas silica, unglazed, rough	1000	T	0.80	1
Brick	firebrick	17	SW	0.68	5
Brick	fireclay	1000	T	0.75	1
Brick	fireclay	1200	T	0.59	1
Brick	fireclay	20	T	0.85	1
Brick	masonry	35	SW	0.94	7
Brick	masonry, plastered	20	T	0.94	1
Brick	red, common	20	T	0.93	2
Brick	red, rough	20	T	0.88–0.93	1
Brick	refractory, corundum	1000	T	0.46	1
Brick	refractory, magnesite	1000–1300	T	0.38	1
Brick	refractory, strongly radiating	500–1000	T	0.8–0.9	1
Brick	refractory, weakly radiating	500–1000	T	0.65–0.75	1
Brick	silica, 95% SiO <sub>2</sub>	1230	T	0.66	1
Brick	sillimanite, 33% SiO <sub>2</sub> , 64% Al <sub>2</sub> O <sub>3</sub>	1500	T	0.29	1
Brick	waterproof	17	SW	0.87	5
Bronze	phosphor bronze	70	SW	0.08	9
Bronze	phosphor bronze	70	LW	0.06	9
Bronze	polished	50	T	0.1	1
Bronze	porous, rough	50–150	T	0.55	1
Bronze	powder		T	0.76–0.80	1
Carbon	candle soot	20	T	0.95	2
Carbon	charcoal powder		T	0.96	1
Carbon	graphite powder		T	0.97	1
Carbon	graphite, filed surface	20	T	0.98	2
Carbon	lampblack	20–400	T	0.95–0.97	1

**Table 27.1** T: Total spectrum; SW: 2–5  $\mu\text{m}$ ; LW: 8–14  $\mu\text{m}$ , LLW: 6.5–20  $\mu\text{m}$ ; 1: Material; 2: Specification; 3: Temperature in  $^{\circ}\text{C}$ ; 4: Spectrum; 5: Emissivity; 6: Reference (continued)

1	2	3	4	5	6
Chipboard	untreated	20	SW	0.90	6
Chromium	polished	50	T	0.10	1
Chromium	polished	500–1000	T	0.28–0.38	1
Clay	fired	70	T	0.91	1
Cloth	black	20	T	0.98	1
Concrete		20	T	0.92	2
Concrete	dry	36	SW	0.95	7
Concrete	rough	17	SW	0.97	5
Concrete	walkway	5	LLW	0.974	8
Copper	commercial, burnished	20	T	0.07	1
Copper	electrolytic, carefully polished	80	T	0.018	1
Copper	electrolytic, polished	–34	T	0.006	4
Copper	molten	1100–1300	T	0.13–0.15	1
Copper	oxidized	50	T	0.6–0.7	1
Copper	oxidized to blackness		T	0.88	1
Copper	oxidized, black	27	T	0.78	4
Copper	oxidized, heavily	20	T	0.78	2
Copper	polished	50–100	T	0.02	1
Copper	polished	100	T	0.03	2
Copper	polished, commercial	27	T	0.03	4
Copper	polished, mechanical	22	T	0.015	4
Copper	pure, carefully prepared surface	22	T	0.008	4
Copper	scraped	27	T	0.07	4
Copper dioxide	powder		T	0.84	1
Copper oxide	red, powder		T	0.70	1
Ebonite			T	0.89	1
Emery	coarse	80	T	0.85	1
Enamel		20	T	0.9	1
Enamel	lacquer	20	T	0.85–0.95	1
Fiber board	hard, untreated	20	SW	0.85	6
Fiber board	masonite	70	SW	0.75	9
Fiber board	masonite	70	LW	0.88	9
Fiber board	particle board	70	SW	0.77	9
Fiber board	particle board	70	LW	0.89	9
Fiber board	porous, untreated	20	SW	0.85	6
Glass pane (float glass)	non-coated	20	LW	0.97	14
Gold	polished	130	T	0.018	1

**Table 27.1** T: Total spectrum; SW: 2–5  $\mu\text{m}$ ; LW: 8–14  $\mu\text{m}$ , LLW: 6.5–20  $\mu\text{m}$ ; 1: Material; 2: Specification; 3: Temperature in  $^{\circ}\text{C}$ ; 4: Spectrum; 5: Emissivity; 6: Reference (continued)

1	2	3	4	5	6
Gold	polished, carefully	200–600	T	0.02–0.03	1
Gold	polished, highly	100	T	0.02	2
Granite	polished	20	LLW	0.849	8
Granite	rough	21	LLW	0.879	8
Granite	rough, 4 different samples	70	SW	0.95–0.97	9
Granite	rough, 4 different samples	70	LW	0.77–0.87	9
Gypsum		20	T	0.8–0.9	1
Ice: See Water					
Iron and steel	cold rolled	70	SW	0.20	9
Iron and steel	cold rolled	70	LW	0.09	9
Iron and steel	covered with red rust	20	T	0.61–0.85	1
Iron and steel	electrolytic	100	T	0.05	4
Iron and steel	electrolytic	22	T	0.05	4
Iron and steel	electrolytic	260	T	0.07	4
Iron and steel	electrolytic, carefully polished	175–225	T	0.05–0.06	1
Iron and steel	freshly worked with emery	20	T	0.24	1
Iron and steel	ground sheet	950–1100	T	0.55–0.61	1
Iron and steel	heavily rusted sheet	20	T	0.69	2
Iron and steel	hot rolled	130	T	0.60	1
Iron and steel	hot rolled	20	T	0.77	1
Iron and steel	oxidized	100	T	0.74	4
Iron and steel	oxidized	100	T	0.74	1
Iron and steel	oxidized	1227	T	0.89	4
Iron and steel	oxidized	125–525	T	0.78–0.82	1
Iron and steel	oxidized	200	T	0.79	2
Iron and steel	oxidized	200–600	T	0.80	1
Iron and steel	oxidized strongly	50	T	0.88	1
Iron and steel	oxidized strongly	500	T	0.98	1
Iron and steel	polished	100	T	0.07	2
Iron and steel	polished	400–1000	T	0.14–0.38	1
Iron and steel	polished sheet	750–1050	T	0.52–0.56	1
Iron and steel	rolled sheet	50	T	0.56	1
Iron and steel	rolled, freshly	20	T	0.24	1
Iron and steel	rough, plane surface	50	T	0.95–0.98	1
Iron and steel	rusted red, sheet	22	T	0.69	4
Iron and steel	rusted, heavily	17	SW	0.96	5
Iron and steel	rusty, red	20	T	0.69	1
Iron and steel	shiny oxide layer, sheet,	20	T	0.82	1

**Table 27.1** T: Total spectrum; SW: 2–5  $\mu\text{m}$ ; LW: 8–14  $\mu\text{m}$ , LLW: 6.5–20  $\mu\text{m}$ ; 1: Material; 2: Specification; 3: Temperature in  $^{\circ}\text{C}$ ; 4: Spectrum; 5: Emissivity; 6: Reference (continued)

1	2	3	4	5	6
Iron and steel	shiny, etched	150	T	0.16	1
Iron and steel	wrought, carefully polished	40–250	T	0.28	1
Iron galvanized	heavily oxidized	70	SW	0.64	9
Iron galvanized	heavily oxidized	70	LW	0.85	9
Iron galvanized	sheet	92	T	0.07	4
Iron galvanized	sheet, burnished	30	T	0.23	1
Iron galvanized	sheet, oxidized	20	T	0.28	1
Iron tinned	sheet	24	T	0.064	4
Iron, cast	casting	50	T	0.81	1
Iron, cast	ingots	1000	T	0.95	1
Iron, cast	liquid	1300	T	0.28	1
Iron, cast	machined	800–1000	T	0.60–0.70	1
Iron, cast	oxidized	100	T	0.64	2
Iron, cast	oxidized	260	T	0.66	4
Iron, cast	oxidized	38	T	0.63	4
Iron, cast	oxidized	538	T	0.76	4
Iron, cast	oxidized at 600 $^{\circ}\text{C}$	200–600	T	0.64–0.78	1
Iron, cast	polished	200	T	0.21	1
Iron, cast	polished	38	T	0.21	4
Iron, cast	polished	40	T	0.21	2
Iron, cast	unworked	900–1100	T	0.87–0.95	1
Krylon Ultra-flat black 1602	Flat black	Room temperature up to 175	LW	$\approx 0.96$	12
Krylon Ultra-flat black 1602	Flat black	Room temperature up to 175	MW	$\approx 0.97$	12
Lacquer	3 colors sprayed on Aluminum	70	SW	0.50–0.53	9
Lacquer	3 colors sprayed on Aluminum	70	LW	0.92–0.94	9
Lacquer	Aluminum on rough surface	20	T	0.4	1
Lacquer	bakelite	80	T	0.83	1
Lacquer	black, dull	40–100	T	0.96–0.98	1
Lacquer	black, matte	100	T	0.97	2
Lacquer	black, shiny, sprayed on iron	20	T	0.87	1
Lacquer	heat-resistant	100	T	0.92	1
Lacquer	white	100	T	0.92	2
Lacquer	white	40–100	T	0.8–0.95	1
Lead	oxidized at 200 $^{\circ}\text{C}$	200	T	0.63	1
Lead	oxidized, gray	20	T	0.28	1
Lead	oxidized, gray	22	T	0.28	4
Lead	shiny	250	T	0.08	1

**Table 27.1** T: Total spectrum; SW: 2–5 µm; LW: 8–14 µm, LLW: 6.5–20 µm; 1: Material; 2: Specification; 3: Temperature in °C; 4: Spectrum; 5: Emissivity; 6: Reference (continued)

1	2	3	4	5	6
Lead	unoxidized, polished	100	T	0.05	4
Lead red		100	T	0.93	4
Lead red, powder		100	T	0.93	1
Leather	tanned		T	0.75–0.80	1
Lime			T	0.3–0.4	1
Magnesium		22	T	0.07	4
Magnesium		260	T	0.13	4
Magnesium		538	T	0.18	4
Magnesium	polished	20	T	0.07	2
Magnesium powder			T	0.86	1
Molybdenum		1500–2200	T	0.19–0.26	1
Molybdenum		600–1000	T	0.08–0.13	1
Molybdenum	filament	700–2500	T	0.1–0.3	1
Mortar		17	SW	0.87	5
Mortar	dry	36	SW	0.94	7
Nextel Velvet 811-21 Black	Flat black	–60–150	LW	> 0.97	10 and 11
Nichrome	rolled	700	T	0.25	1
Nichrome	sandblasted	700	T	0.70	1
Nichrome	wire, clean	50	T	0.65	1
Nichrome	wire, clean	500–1000	T	0.71–0.79	1
Nichrome	wire, oxidized	50–500	T	0.95–0.98	1
Nickel	bright matte	122	T	0.041	4
Nickel	commercially pure, polished	100	T	0.045	1
Nickel	commercially pure, polished	200–400	T	0.07–0.09	1
Nickel	electrolytic	22	T	0.04	4
Nickel	electrolytic	260	T	0.07	4
Nickel	electrolytic	38	T	0.06	4
Nickel	electrolytic	538	T	0.10	4
Nickel	electroplated on iron, polished	22	T	0.045	4
Nickel	electroplated on iron, unpolished	20	T	0.11–0.40	1
Nickel	electroplated on iron, unpolished	22	T	0.11	4
Nickel	electroplated, polished	20	T	0.05	2
Nickel	oxidized	1227	T	0.85	4
Nickel	oxidized	200	T	0.37	2
Nickel	oxidized	227	T	0.37	4
Nickel	oxidized at 600°C	200–600	T	0.37–0.48	1
Nickel	polished	122	T	0.045	4

**Table 27.1** T: Total spectrum; SW: 2–5  $\mu\text{m}$ ; LW: 8–14  $\mu\text{m}$ , LLW: 6.5–20  $\mu\text{m}$ ; 1: Material; 2: Specification; 3: Temperature in  $^{\circ}\text{C}$ ; 4: Spectrum; 5: Emissivity; 6: Reference (continued)

1	2	3	4	5	6
Nickel	wire	200–1000	T	0.1–0.2	1
Nickel oxide		1000–1250	T	0.75–0.86	1
Nickel oxide		500–650	T	0.52–0.59	1
Oil, lubricating	0.025 mm film	20	T	0.27	2
Oil, lubricating	0.050 mm film	20	T	0.46	2
Oil, lubricating	0.125 mm film	20	T	0.72	2
Oil, lubricating	film on Ni base: Ni base only	20	T	0.05	2
Oil, lubricating	thick coating	20	T	0.82	2
Paint	8 different colors and qualities	70	SW	0.88–0.96	9
Paint	8 different colors and qualities	70	LW	0.92–0.94	9
Paint	Aluminum, vari- ous ages	50–100	T	0.27–0.67	1
Paint	cadmium yellow		T	0.28–0.33	1
Paint	chrome green		T	0.65–0.70	1
Paint	cobalt blue		T	0.7–0.8	1
Paint	oil	17	SW	0.87	5
Paint	oil based, aver- age of 16 colors	100	T	0.94	2
Paint	oil, black flat	20	SW	0.94	6
Paint	oil, black gloss	20	SW	0.92	6
Paint	oil, gray flat	20	SW	0.97	6
Paint	oil, gray gloss	20	SW	0.96	6
Paint	oil, various colors	100	T	0.92–0.96	1
Paint	plastic, black	20	SW	0.95	6
Paint	plastic, white	20	SW	0.84	6
Paper	4 different colors	70	SW	0.68–0.74	9
Paper	4 different colors	70	LW	0.92–0.94	9
Paper	black		T	0.90	1
Paper	black, dull		T	0.94	1
Paper	black, dull	70	SW	0.86	9
Paper	black, dull	70	LW	0.89	9
Paper	blue, dark		T	0.84	1
Paper	coated with black lacquer		T	0.93	1
Paper	green		T	0.85	1
Paper	red		T	0.76	1
Paper	white	20	T	0.7–0.9	1
Paper	white bond	20	T	0.93	2
Paper	white, 3 different glosses	70	SW	0.76–0.78	9
Paper	white, 3 different glosses	70	LW	0.88–0.90	9



**Table 27.1** T: Total spectrum; SW: 2–5  $\mu\text{m}$ ; LW: 8–14  $\mu\text{m}$ , LLW: 6.5–20  $\mu\text{m}$ ; 1: Material; 2: Specification; 3: Temperature in  $^{\circ}\text{C}$ ; 4: Spectrum; 5: Emissivity; 6: Reference (continued)

1	2	3	4	5	6
Paper	yellow		T	0.72	1
Plaster		17	SW	0.86	5
Plaster	plasterboard, untreated	20	SW	0.90	6
Plaster	rough coat	20	T	0.91	2
Plastic	glass fibre laminate (printed circ. board)	70	SW	0.94	9
Plastic	glass fibre laminate (printed circ. board)	70	LW	0.91	9
Plastic	polyurethane isolation board	70	LW	0.55	9
Plastic	polyurethane isolation board	70	SW	0.29	9
Plastic	PVC, plastic floor, dull, structured	70	SW	0.94	9
Plastic	PVC, plastic floor, dull, structured	70	LW	0.93	9
Platinum		100	T	0.05	4
Platinum		1000–1500	T	0.14–0.18	1
Platinum		1094	T	0.18	4
Platinum		17	T	0.016	4
Platinum		22	T	0.03	4
Platinum		260	T	0.06	4
Platinum		538	T	0.10	4
Platinum	pure, polished	200–600	T	0.05–0.10	1
Platinum	ribbon	900–1100	T	0.12–0.17	1
Platinum	wire	1400	T	0.18	1
Platinum	wire	500–1000	T	0.10–0.16	1
Platinum	wire	50–200	T	0.06–0.07	1
Porcelain	glazed	20	T	0.92	1
Porcelain	white, shiny		T	0.70–0.75	1
Rubber	hard	20	T	0.95	1
Rubber	soft, gray, rough	20	T	0.95	1
Sand			T	0.60	1
Sand		20	T	0.90	2
Sandstone	polished	19	LLW	0.909	8
Sandstone	rough	19	LLW	0.935	8
Silver	polished	100	T	0.03	2
Silver	pure, polished	200–600	T	0.02–0.03	1
Skin	human	32	T	0.98	2
Slag	boiler	0–100	T	0.97–0.93	1
Slag	boiler	1400–1800	T	0.69–0.67	1
Slag	boiler	200–500	T	0.89–0.78	1
Slag	boiler	600–1200	T	0.76–0.70	1
Snow: See Water					

**Table 27.1** T: Total spectrum; SW: 2–5 µm; LW: 8–14 µm, LLW: 6.5–20 µm; 1: Material; 2: Specification; 3: Temperature in °C; 4: Spectrum; 5: Emissivity; 6: Reference (continued)

1	2	3	4	5	6
Soil	dry	20	T	0.92	2
Soil	saturated with water	20	T	0.95	2
Stainless steel	alloy, 8% Ni, 18% Cr	500	T	0.35	1
Stainless steel	rolled	700	T	0.45	1
Stainless steel	sandblasted	700	T	0.70	1
Stainless steel	sheet, polished	70	SW	0.18	9
Stainless steel	sheet, polished	70	LW	0.14	9
Stainless steel	sheet, untreated, somewhat scratched	70	SW	0.30	9
Stainless steel	sheet, untreated, somewhat scratched	70	LW	0.28	9
Stainless steel	type 18-8, buffed	20	T	0.16	2
Stainless steel	type 18-8, oxidized at 800°C	60	T	0.85	2
Stucco	rough, lime	10–90	T	0.91	1
Styrofoam	insulation	37	SW	0.60	7
Tar			T	0.79–0.84	1
Tar	paper	20	T	0.91–0.93	1
Tile	glazed	17	SW	0.94	5
Tin	burnished	20–50	T	0.04–0.06	1
Tin	tin-plated sheet iron	100	T	0.07	2
Titanium	oxidized at 540°C	1000	T	0.60	1
Titanium	oxidized at 540°C	200	T	0.40	1
Titanium	oxidized at 540°C	500	T	0.50	1
Titanium	polished	1000	T	0.36	1
Titanium	polished	200	T	0.15	1
Titanium	polished	500	T	0.20	1
Tungsten		1500–2200	T	0.24–0.31	1
Tungsten		200	T	0.05	1
Tungsten		600–1000	T	0.1–0.16	1
Tungsten	filament	3300	T	0.39	1
Varnish	flat	20	SW	0.93	6
Varnish	on oak parquet floor	70	SW	0.90	9
Varnish	on oak parquet floor	70	LW	0.90–0.93	9
Wallpaper	slight pattern, light gray	20	SW	0.85	6
Wallpaper	slight pattern, red	20	SW	0.90	6
Water	distilled	20	T	0.96	2
Water	frost crystals	–10	T	0.98	2
Water	ice, covered with heavy frost	0	T	0.98	1

**Table 27.1** T: Total spectrum; SW: 2–5  $\mu\text{m}$ ; LW: 8–14  $\mu\text{m}$ , LLW: 6.5–20  $\mu\text{m}$ ; 1: Material; 2: Specification; 3: Temperature in  $^{\circ}\text{C}$ ; 4: Spectrum; 5: Emissivity; 6: Reference (continued)

1	2	3	4	5	6
Water	ice, smooth	0	T	0.97	1
Water	ice, smooth	-10	T	0.96	2
Water	layer >0.1 mm thick	0–100	T	0.95–0.98	1
Water	snow		T	0.8	1
Water	snow	-10	T	0.85	2
Wood		17	SW	0.98	5
Wood		19	LLW	0.962	8
Wood	ground		T	0.5–0.7	1
Wood	pine, 4 different samples	70	SW	0.67–0.75	9
Wood	pine, 4 different samples	70	LW	0.81–0.89	9
Wood	planed	20	T	0.8–0.9	1
Wood	planed oak	20	T	0.90	2
Wood	planed oak	70	SW	0.77	9
Wood	planed oak	70	LW	0.88	9
Wood	plywood, smooth, dry	36	SW	0.82	7
Wood	plywood, untreated	20	SW	0.83	6
Wood	white, damp	20	T	0.7–0.8	1
Zinc	oxidized at 400 $^{\circ}\text{C}$	400	T	0.11	1
Zinc	oxidized surface	1000–1200	T	0.50–0.60	1
Zinc	polished	200–300	T	0.04–0.05	1
Zinc	sheet	50	T	0.20	1

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T505000.xml; en-US; 35155; 2016-04-21  
T505005.xml; en-US; 35155; 2016-04-21  
T505001.xml; en-US; 32554; 2016-01-20  
T505006.xml; en-US; 32555; 2016-01-20  
T505002.xml; en-US; 33518; 2016-02-18





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**Website**

<http://www.flir.com>

**Customer support**

<http://support.flir.com>

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