



*See the possibilities*

## *User's Manual*

# ***SW-2000M-CXP-80***

*CMOS High Speed Monochrome  
CoaXPress<sup>®</sup> Line Scan Camera*

*CXP 1.1 and 1.0*

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## Warranty

12 months from date of delivery, 4 months for repairs covering the work and parts at the factory.

## Certifications

### CE compliance

As defined by the Electromagnetic compatibility requirements of Directive 2004/108/EC of the European Parliament and of the Council, JAI Oy, Finland, declares that SW-2000M-CXP-80 complies with the following provisions:

EN 61000-6-2 (2005), EMC immunity  
EN 61000-6-4 (2007), EMC emissions

### FCC

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

### Warning

Changes or modifications to this unit not expressly approved by the party responsible for FCC compliance could void the user's authority to operate the equipment.

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## 1 General

The JAI Sweep Series SW-2000M-CXP-80 is a CMOS line scan camera based on a custom-made 2048 pixel imager with large square pixels of 20  $\mu\text{m}$  for high responsivity. It operates at a rate of up to 80,000 scans per second.

The camera outputs digital data in 8-, 10-, or 12-bit formats, via one CoaXPress<sup>®</sup> (CXP) Link up to 3.125 Gbps. The camera is configured via CXP interface using GenICam<sup>™</sup> (a generic programming interface for machine vision cameras) or via a 10/100 Mbps Ethernet port using an industry standard RJ-45 connector.

The default lens mount is F-mount. Additional options will be added.

### 1.1 Camera nomenclature

The standard camera composition consists of:

SW-2000M-CXP-80 camera body with F-mount	x 1
Lens mount/sensor protection cap	x 1

In the model number of the camera, SW stands for "Sweep" Series, 2000 represents the resolution "2000 pixels", M stands for "monochrome", CXP stands for "CoaXPress<sup>®</sup>" interface, and 80 stands for "80 kHz" maximum scan rate.

## 2 Main features

- CMOS line scan camera
- Resolution: 2048 x 1
- Pixel size: 20  $\mu\text{m}$ , square
- Selectable Quantum Well size: 60k or 360k electrons
- Selectable clock rate for sensor
- Maximum scan rate: 80,000 lines per second
- CXP one link data interface
  - One connector
  - 8, 10, or 12 bits per pixel
  - Supported CXP operating frequencies: 1.25G, 2.5G and 3.125G
- DSNU correction as factory default
- Flat field correction (FFC)
- Test pattern generator for set-up and troubleshooting
- Default lens mount: F-mount
- DC input voltage via CXP cable
- Ethernet port for
  - Control and monitoring
  - Firmware updates
  - Download of files from camera (internal web server)
- Short ASCII commands for set-up via Ethernet using the Telnet protocol
  - Windows<sup>®</sup> user interface
- GenICam<sup>™</sup> compatible

### 3 Connectors and mounting

#### 3.1 Locations

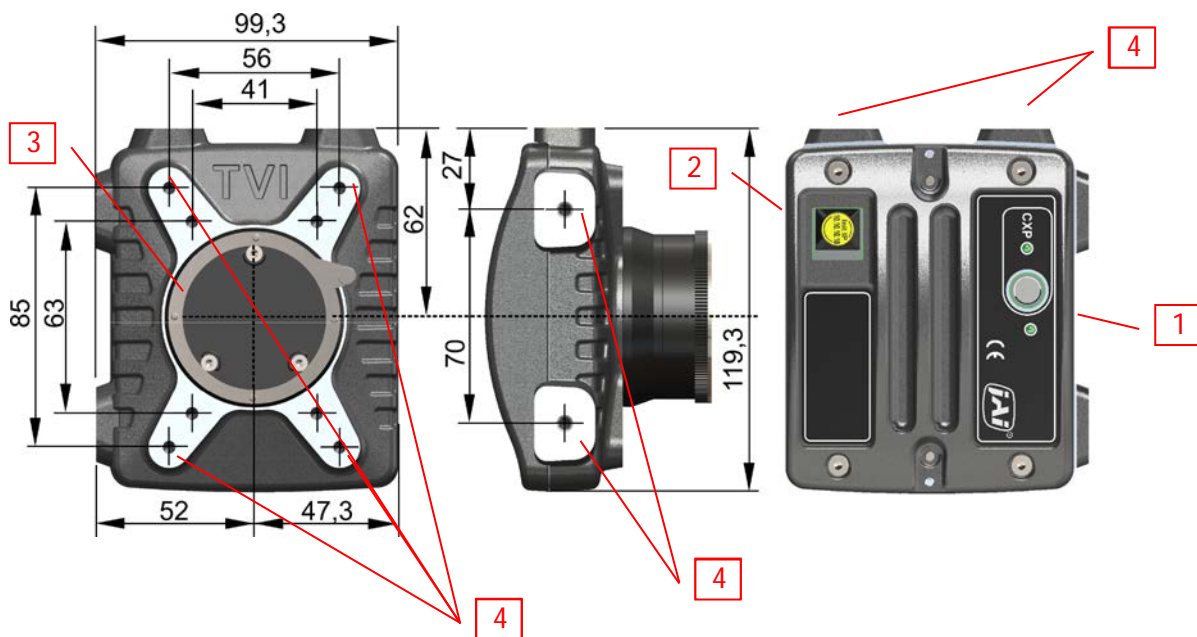


Fig. 1. Location of external features

- 1 CXP BNC connector
- 2 Ethernet connector
- 3 Lens mount: Nikon® F-Mount
- 4 Mounting holes: all 8 pcs. are M5 with depth of 8 mm

Note:

Both the CE and FCC approvals require that the camera chassis is grounded.

This will typically happen, when the camera is mounted using any of the mounting holes. Additionally, it can be secured by connecting a copper cable of 10 mm<sup>2</sup> or thicker to the electrical system ground.

### 3.2 Connector panel and indicators



Fig.2. Rear panel with the Ethernet connector cap on.

#### 1. CXP LED

A multi-color LED with the following functions:

- **Orange (steady)**  
CXP is booting up.
- ✳ **Red (flashing slowly)**  
Power ON. Not yet connected.
- ✳✳/✳✳ **Green/Orange (Flashing rapidly)**  
Connection detection in progress, PoCXP active.
- ✳✳ **Orange (Flashing rapidly)**  
Connection detection in progress, PoCXP not in use.
- **Green (steady)**  
Device connected, but no data is transferred.
- ✳✳ **Green (flashing rapidly)**  
Device connected. Data is being transferred.
- ✳✳ **Green/Orange (flashing slowly)**  
Connection test packets being sent.
- ✳✳✳ **Green/red/orange (flashing slowly)**  
Test mode for compliance.
- ✳ **Red (red pulse)**  
Error during data transfer.

## 2. Status LED

A multi-color LED with the following functions:

● **Green (steady)**

Normal operation.

✱ **Green (flashing slowly)**

Busy.

✱✱ **Green (flashing rapidly)**

Performing firmware update or waiting for a firmware update to start.

● **Orange (steady)**

Initializing.

✱✱ **Orange (flashing rapidly)**

MCU firmware update in progress.

**Do not disconnect the Ethernet cable.  
Do not switch off the power.**

● **Red**

Internal error

## 3. Ethernet Link LED

● **Green (steady)**

Connected to an active network device. This indicates the existence of a physical link only. It does not indicate a valid TCP/IP network configuration.

## 4. Ethernet Status LED

✱ **Yellow (flashing)**

Activity indicator. Blinks shortly during data transfer.



## 4 Input and output

### 4.1 CXP BNC connector

The CXP BNC connector connects to one, single, point-to-point, coaxial cable (75  $\Omega$ ) to output image data, communicate with the camera and to input power. Please refer to official standard ([www.coaxpress.com](http://www.coaxpress.com)) for more information on the cabling solutions. Each cable connects all the related grounds together: electrical zero of the internal electronics to the chassis of the camera and then via the shielding of the cable to the electrical zero of the other end, which is then often connected to system ground via its chassis.

### 4.2 CoaXPress<sup>®</sup> output modes

Bit depths of 8, 10, and 12 are supported. Camera operates internally with more than 12 bits. All blanks are electrically zeroes.

### 4.3 CXP revision

The camera supports either revision 1.0 or 1.1. Default setting is for rev. 1.1. The revision can be selected by writing to the CXP bootstrap register 0x4. The value 0x00010001 corresponds with CXP1.1, while value 0x00010000 is written to use CXP1.0 after next boot-up.

The CXP revision value can be changed via CXP bootstrap registers or via virtual register (set 4 0x0001000x). This is a non-volatile parameter.

## 5 Operation and functions

### 5.1 Introduction

#### 5.1.1 Image sensor

The SW-2000M-CXP-80 is built around a high performance CMOS line scan image sensor, which converts the light collected by each pixel into electrical charge. The amount of charge generated in each of the individual pixels is basically directly proportional to the amount of light they receive.

The sensor has two options to store the charge at each pixel. These are called Quantum Wells. The smaller well can hold about 60,000 electrons ( $60 \text{ ke}^-$ ), while the larger has capacity for 360  $\text{ke}^-$ . The larger well should be used whenever feasible as it provides the best image quality due to higher dynamic range and better signal-to-noise ratio (SNR), but also requires about six times the light for the same response.

SNR is limited by the shot noise of the light itself and thus it is beneficial to collect as many photons (light) as possible. The smaller well can be used to provide about six times as high response to light, but with the cost of lower SNR and dynamic range.

Due to internal timings and processing there is one inactive period of 1 to 3  $\mu\text{s}$  per each imaged line, when the received light is not used. Thus, the maximum time the light generated charge is integrated, is always slightly shorter than the line period.

Correlated Double Sampling (CDS) is used for sampling the charge voltage and the reset level to find the difference, which is then digitized into more than 12 bits and sent out of the sensor for processing. An analog gain factor of 2 can be applied to the above mentioned difference regardless of the well size. The selection is included in the SENSOR command syntax.

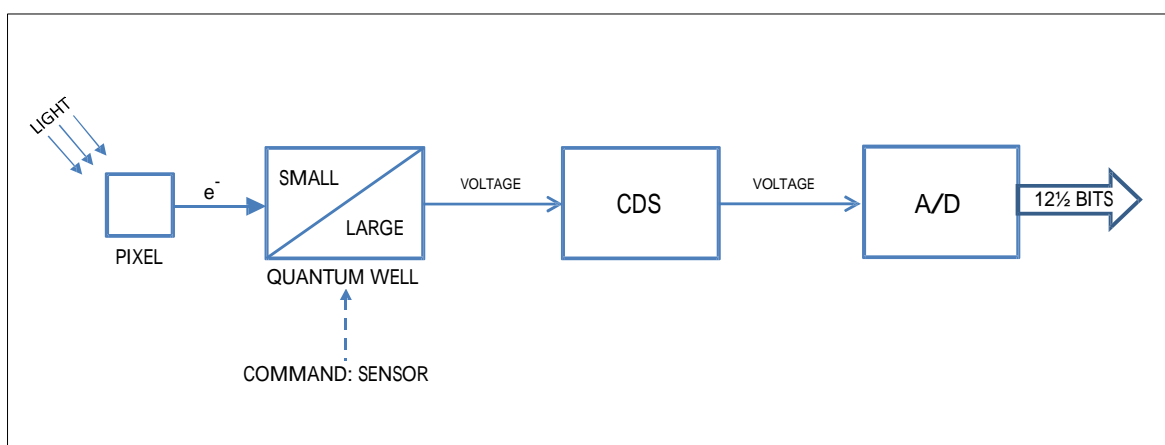


Fig. 3. Sensor block diagram

### 5.1.2 Line image processing

The output data from the imager is buffered for further processing to be then finally sent out of the camera via the CoaXPress<sup>®</sup> interface. The processing chain is controlled by user accessible commands. The DSNU corrector is calibrated individually for each camera at the factory and always in use with fixed settings.

The scan rate and the integration of light within each line period can be controlled either by the CXP trigger, internal timers, or a combination of these.

Serial communication channels are used to control and monitor the camera. Both the standard CXP communication link as well as the Ethernet connection can be used for the same purpose and even at the same time. Some functions are only supported via Ethernet.

### 5.2 Operating Modes

The camera can be configured to offer several operating modes that are fundamentally different from each other. The operating mode is configured upon start-up and can only be changed by issuing a new mode selection command and rebooting the camera.

### 5.3 DSNU Corrector

DSNU (Dark Signal Non-uniformity) describes the pixel-specific differences of response in dark, while PRNU (Photo Response Non-uniformity) respectively describes the pixel-specific differences of response to equal amounts of light falling onto all the pixels. Both are basic sensor- and pixel-specific imperfections, which can be characterized and minimized. DSNU is corrected already during production. Users may use the FFC function to further adapt the camera into existing lighting conditions, if necessary.

### 5.4 Digital offset and gain stages

This block first shifts the digital pixel value up or down and then applies a digital gain. The result is limited to stay between zero and the maximum digital value. Gain values lower than the default 1x may cause the maximum output value to be lower than the maximum of the range in use.

The offset block is a direct subtraction or addition. It does not define the target value for dark response and has no feedback loop. That is why the gain block, which is simply a digital multiplier, will also change the offset level, thus possibly causing a need to readjust the offset value.

5.5 Test Pattern Generator

The SW-2000M-CXP-80 can send out five, defined test patterns instead of the real imaged lines for purposes like interfacing and problem analysis. The patterns replace the image data and can thus be used also to test the following blocks. Original, full patterns are available after switching off the FFC, ROI and binning. Test data is also affected by the readout direction selection.

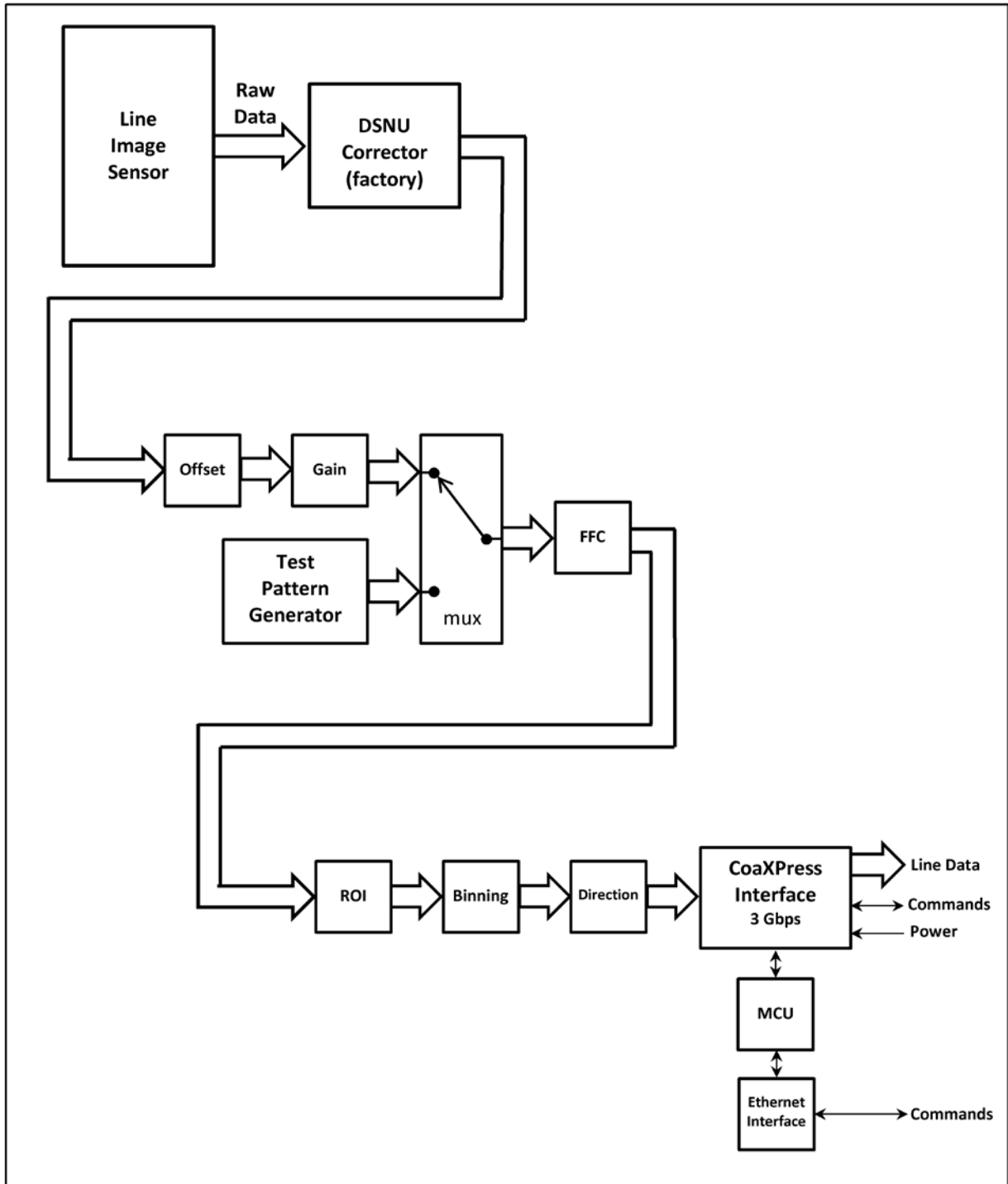


Fig. 4. Image processing block diagram

### 5.6 Flat Field Corrector, FFC

Factory calibrated DSNU corrector minimizes pixel-specific differences in darkness. There is no use correcting the PRNU as a factory setting as it is less than the noise. Real applications only rarely can provide equal amounts of light for all pixels. This is caused mainly by effects like uneven distribution of light (light profile) or properties of lenses like vignetting. Pixels at the center region tend to get more light, while the intensity decreases towards both ends of the line image sensor.

The compensation method called Shading Correction results in a flat, equal response to light under the same conditions in which the calibration routine was run. It is generally thought of as a coarse correction to regionally scale or gain the pixel responses without paying attention to any pixel-specific differences. Also, generally, a method called Flat Field Correction (FFC) is used for operations where a similar correction is done more precisely and for each pixel individually. The correction typically uses a 2-point linear method, where both the dark and bright level pixel responses are equalized making it possible to have uniform response on all light levels within the operating range of the camera. This would in fact be a complete, single routine to perform DSNU, PRNU and Shading Corrections all at the same time, but the corrections are separated in this implementation. DSNU correction is preset at the factory. Shading correction is replaced by FFC, which operates assuming a fixed dark reference level and includes the PRNU correction.

The FFC unit of SW-2000M-CXP-80 scales the pixel values by factors that are calculated by imaging a calibration target in order to produce a uniform (flat) response under the same conditions as where the calibration routine was run. A constant value (same as DSNU target value) is used as the dark reference. Bright references are taken by averaging the lines that were imaged from the calibration target.

### 5.7 Regions of interest, ROI

This block can be used to select up to four sections of pixels to be used as one combined line of pixels. The purpose is to reduce the amount of data and to remove unnecessary regions.

### 5.8 Binning

Neighboring pixels can be digitally added or averaged as pairs. The resulting larger pixels are then sent out as one. The resolution as well as the number of pixels will be half. The goal is to have larger pixel area either to increase the response or to reduce noise.

### 5.9 Reversed readout direction

This function enables reading of the pixel values in correct order in cases where it is not practical to install the camera to follow the intended imaging direction.

## SW-2000M-CXP-80

### 5.10 CoaXPress® interface

CoaXPress® (CXP) is a communication standard for imaging applications. It provides high speed image data, communications and control, triggering and power input all over a single coaxial cable as one CXP link. The transmission is point to point and up to distances exceeding 100 meters. The so called Uplink for communications and control runs always at the constant rate of 20 Mbps.

#### 5.10.1 Selection of the revision (CXP 1.0 or 1.1)

The camera operates according to revision 1.1 as default, but supports also rev. 1.0. The revision is selected by writing to the bootstrap register defined in the standard itself. The new selection is automatically saved and taken into use at next boot up. The host should check the setting during initialization and change it, if necessary.

#### 5.10.2 Link modes

The camera always boots up at link speed of 3.125G to negotiate with the host on transmission properties. The host is typically a frame grabber board and acts as the master here. It can try any of the standard speeds or read the preferred link mode that the camera has been set to show. The host then sets the camera to the mode it wants to use.

The preferred link mode of the camera can be preset to be one of the three options listed in the table below. The command 'cxp config' is available only via the Ethernet connection as a telnet command - not via GenICam™. The given values are immediately saved, but will not become effective until the next boot up. If the new mode is slower, please make sure that the line rate value saved by the CS SAVE command is not too high.

Command	Link mode	Max. line rate. Use of ROI and BINNING may raise the limits. The selected Operating Mode (see 7.1.1) is the absolute limit.
cxp config 1 1	one link, 1.25G	55/44/36 kHz for 8/10/12 bits
cxp config 2 1	one link, 2.5G	80/80/73 kHz
cxp config 3 1	one link, 3.125G	80/80/80 kHz

The host can then change the frequency of the image data link during the operation, if the camera supports the new mode. The camera must follow the selections made by the host.

#### 5.10.3 ECT test modes

The camera includes a special operating mode for the Electrical Compliance Tests (ECT) of the standard. The camera will then output test mode data with the selected link speed. The new values are automatically saved and taken into use at next boot up.

## 5.11 Ethernet interface

The 10/100 Mbps Ethernet port interface is provided as an alternative way to communicate with the camera. Connection to Ethernet offers usual networking possibilities like remote access and connecting multiple cameras together for control and monitoring. The standard GenICam™ programming interface via the CoaXPress® connection is allowed to be in use at the same time. This of course requires caution, if both channels are used for changing camera settings.

Firmware updates are loaded only via this interface. Standard web browsers can be used to establish connections to the internal web server, which includes a few basic functions like downloading of some documents and supporting updates.

This port can not be used for any actual image acquisition. Single lines (average of 32) can be slowly read out and displayed as graphs by using the JAI Ethernet Tool software.

## 5.12 Firmware updates

It is possible to update or change the camera firmware without opening the housing. New code is loaded in via the Ethernet port and with help of web browser user interface. There are two kinds of firmware updates: MCU and FPGA. The MCU (microcontroller unit) updates affect the user interface and high level features of the camera, while the FPGA (field-programmable gate array) updates provide enhancements for low level or hardware related functions.

The MCU update is first initiated by the command FIRMWARE UPDATE and then completed with help of the user interface that opens up by accessing the main page of the camera web server. The FPGA update is done by directly accessing the respective update page.

*Caution: Ensure that the camera receives proper power during the complete firmware update process. A power break can potentially leave the camera in a state, where it can not start again.*

### 5.12.1 MCU firmware update

1. Make sure you have the correct file (.hex) for the camera model and the existing configuration available.
2. Make sure you have a working communication via the Ethernet port.
3. Make sure you have a compatible web browser and can access the main page at <http://10.10.10.10>.
4. Check and make a note of the existing configuration (telnet command: VER).
5. Save any settings that you want to keep. The camera will reboot during the process.
6. Initiate the camera by telnet command FIRMWARE UPDATE. You may still cancel the operation after this. Send command CONFIRM when asked, if you want to go ahead.
7. The CXP LED will turn orange and the status LED will start flashing rapidly. This indicates that the camera is waiting for the new code.
8. Access <http://10.10.10.10> or refresh the page, if you already were there. The user interface will let you browse for the new file (.hex) and upload it to the camera.



Fig. 5. User interface for MCU update.



9. You can still cancel the update here, in which case the camera will reboot once automatically. After a few short flashes, both LEDs turn into steady orange color. Wait until the status LED becomes green and steady again. Close all communication sessions to the camera and establish new ones as needed.
10. If you instead clicked on the upload button, the rapid flashing of the status LED will continue with alternating orange and green colors until the upload is complete. **Do not interrupt the upload.**
11. The camera will then automatically reboot. The LED will first go off, then turn orange and finally green.
12. Close old communication sessions to the camera and establish new ones as needed.
13. Verify by command VER that the MCU version number has changed as intended.

### 5.12.2 FPGA firmware update

1. Make sure you have the correct file (.rbf) for the camera model and the existing configuration available.
2. Make sure you have a working communication via the Ethernet port.
3. Make sure you have a compatible web browser and can access the main page at <http://10.10.10.10>.
4. Check and make a note of the existing configuration (telnet command: VER).
5. Save any settings that you want to keep. The camera must be rebooted during the process.
6. Access <http://10.10.10.10/FPGAupdate.html>.
7. Browse and open the file (.rbf). You may cancel the operation now by closing the web page. Click on Upload to proceed. **Do not interrupt the upload.**
8. Both LEDs will now turn off. The Ethernet status LED will blink during the upload.
9. Wait for the user interface page to change. This may take minutes. Then click on the 'HOME' button. The LEDs remain off.
10. The camera must next be rebooted. You may power cycle the camera or send the REBOOT command followed by CONFIRM. No other commands should be sent before this.
11. Close all communication sessions to the camera and establish new ones as needed.
12. Verify by command VER that the Logic version has changed as intended.

## 6 Command line interface

The command line interface provides an easy, interactive way to control the camera. All commands can be given through the Ethernet interface using the Telnet protocol.

### 6.1 Connecting via Telnet

To connect the camera using Telnet:

- Consult your IT department to check if you can plug the camera to your local area network with the default IP address 10.10.10.10. You may change the address by using the NET IP command. Alternatively, you may configure your network card to build a direct connection to the camera.
- Connect the camera to a local area network using a twisted-pair cable. A shielded cable of category 5 or higher is recommended.
- Open a Telnet client on the computer. Two options are available from JAI. Please refer to chapter 9 of this document. Also free or commercial Telnet clients can be downloaded from various internet sites. The following Telnet clients are examples of clients tested with the Sweep cameras:
  - [Foxterm](#)
  - [PuTTY](#)
- Open a Telnet connection to the IP address of the camera.

### 6.2 Entering the commands

The commands are typed in the client console window like in any command line interface. A carriage return (ENTER) terminates the command line and transmits it to the command interpreter in the camera for parsing and execution.

If the communication is coded into a software application then each line must have a carriage return character (ASCII: 0x0D) at the end. Also, a line feed character (0x0A) may be sent after the carriage return, but it is not needed.

Please note that the response time of some commands is considerably longer. Commands like VER, STATUS, CS LOAD, CS LOAD2 and CS FACTORY RESET take almost 10 seconds to complete.

### 6.3 Command Format

The following notation is used for describing the command syntax:

- **BOLDFACE** indicates the fixed command word that must be typed as it is
- | A vertical line delimits alternative forms of a command
- {braces} are used to group the alternative forms delimited by the vertical line |
- <wedge brackets> are used to delimit the names of values
- [square brackets] indicate an optional part that can be omitted
- All parameters (numbers, options) must be separated by one or more spaces.
- All commands are case insensitive; **VER**, **Ver** and **ver** are all equal

Example: **LINE IT** {<time>|<value>%}

A command described using this syntax has two alternative forms. The first form takes a time as its only parameter, while the second form takes the percentage as an optional integration time. The following commands are valid examples of this:

LINE IT 12 (according to form: LINE IT <time>)  
LINE IT 100% (according to form: LINE IT <value>%; the optional <time> is omitted)

When the command parameter is a physical quantity, the unit itself must not be given. For example, the integration time is set to 12  $\mu$ s but the microsecond unit is implied by the camera. It must not be typed by the user.

## 7 Description of commands

The commands can be divided into four groups:

### Group A: General settings

**MODE** for selecting operating mode after boot-up.

**NET** for network settings for the Ethernet communication. The NET settings are saved automatically.

**CS SAVE**, **CS LOAD**, **CS SAVE2**, **CS LOAD2** and **CS FACTORY RESET** for saving, loading or restoring the settings of group B and C.

### Group B: Commands affecting exposure

**SENSOR** for setting sensor responsivity.

**LINE RATE** and **LINE PERIOD** for setting the scan rate.

**LINE IT** for selecting the actual light integration time.

**LINE CTRL** for selecting the trigger source.

**GAIN** for setting the camera gain.

**OFFSET** for setting the line offset value.

**FFC** for Flat Field Correction.

### Group C: Commands affecting image output format

**CXP FORMAT** for setting the pixel depth.

**READOUT** for selecting normal or reverse readout direction.

**ROI** for selecting Regions Of Interest.

**BINNING** for combining adjacent pixels.

**ACQ** for start and stop of acquisition.

### Group D: Utilities

**HELP** or **'?'** for list of all commands.

**VER** for displaying firmware versions and camera identifiers.

**STATUS** to display camera information and settings.

**TEST** for selecting test patterns.

**REBOOT** for restarting the camera.

**FIRMWARE UPDATE** to change the MCU code.

The four groups will be described in detail in the following sections. Most commands display help on how to use it if a space and a question mark is added after the command, and current status of the function if the command is entered as such with no parameters.

The general principle with all the group B and C commands is that users may experiment with the settings without losing the latest, saved and working setup (exception: CS FACTORY RESET). New settings are in use, but not permanently saved, until the user decides to save them. It is always possible to return to the latest saved settings either by sending the CS LOAD, CS LOAD2 or REBOOT command or power cycling the camera.

<p>NOTE: The CS FACTORY RESET command also saves the new values to the first memory location like the command CS SAVE.</p>
--

## 7.1 Group A: General settings

### 7.1.1 MODE - select camera operating mode

The command MODE selects the operating mode that will be entered when the camera is rebooted. The names of the modes refer to the maximum line rate of each mode. If the maximum required line rate is known, this command can be used to select the most suitable option. Changing to a lower speed option may set the camera to operate internally at a slower clock rate, which will lead to lower internal temperatures and slightly increased operating temperature range.

MODE	internal clock	max. line rate
SPEED40kL	60 MHz	40 kHz
SPEED70kL	100 MHz	70 kHz, factory default
SPEED80kL	100 MHz	80 kHz

Command	Description
MODE ?	Returns the MODE setting syntax and a list of available modes to select from.
MODE	Returns the present setting of MODE.
MODE <file name>	Sets a new operating mode. Reboot required.

### 7.1.2 NET - network settings

The Ethernet control interface settings can be changed using the NET group of commands.

**Caution:** Setting incorrect network properties can cause the camera to be unreachable through the network. If this happens, please use GenICam™ via an SDK interface to reset or correct the network settings.

Command	Description
NET ?	Returns the NET settings syntax for manual/DHCP, IP address, Gateway and Subnet Mask.
NET	Returns the present setting of manual/DHCP, IP Address, Subnet Mask and Gateway together with the settings after the next reboot of the camera.  Default settings: The IP setup mode is STATIC. IP Address .... 10.10.10.10 Subnet mask ... 255.255.255.0 Gateway ..... 10.10.10.1

### 7.1.2.1 NET IP - set the IP address

The command NET IP sets the IP address of the camera. Default is 10.10.10.10.

Command	Description
NET IP ?	Returns the NET IP setting syntax.
NET IP	Please use command NET for settings information.
NET IP <xxx.xxx.xxx.xxx>	Sets the camera to use a static IP address xxx.xxx.xxx.xxx.
NET IP AUTO	Sets the camera to obtain a dynamic IP address using DHCP.

*Caution: It is recommended to use a static IP address. If a dynamic address is selected, there is no straightforward way to determine the address assigned by the DHCP server. You may use GenICam™ via an SDK interface to search for the address.*

### 7.1.2.2 NET MASK - set the IP subnet mask

This command sets the IP subnet mask of the camera. The command has no effect in case of using dynamic IP addressing.

Command	Description
NET MASK ?	Returns the syntax for setting NET MASK.
NET MASK	Please use command NET for settings information.
NET MASK <xxx.xxx.xxx.xxx>	Sets the camera to use an IP subnet mask.

### 7.1.2.3 NET GATEWAY - set the IP default gateway

The command NET GATEWAY sets the IP default gateway (default router) of the camera. The command has no effect in case of using dynamic IP addressing.

Command	Description
NET GATEWAY ?	Returns the NET GATEWAY syntax.
NET GATEWAY	Please use command NET for settings information.
NET GATEWAY <xxx.xxx.xxx.xxx>	Sets the address of the default gateway.

### 7.1.2.4 NET FACTORY RESET - resetting the net settings

The command NET FACTORY RESET sets the net to the factory default values.

Command	Description
NET FACTORY RESET	Resets the network settings to factory default values: The IP setup mode is STATIC. IP Address .... 10.10.10.10 Subnet mask ... 255.255.255.0 Gateway ..... 10.10.10.1

### 7.1.2.5 NET NAME - set a name for the camera

This command gives a name for the camera. The name is listed with the VER command, if a name was given. The name is not visible to the network.

Command	Description
NET NAME ?	Returns the NET NAME syntax.
NET NAME	Returns the camera name.
NET NAME <name>	Sets the name for the camera.
NET NAME DELETE	Removes the name.

### 7.1.2.6 NET CLOSE - close the current session

This command closes the current session immediately.

Command	Description
NET CLOSE	Ends the current Telnet session. Alternative commands are NET QUIT and BYE.

## 7.1.3 Saving and restoring the capture settings

This group of commands is used for saving and reloading image capture related settings as one set. Two storage locations are available for writing and reading. The third storage location is for the factory settings, which can only be loaded.

Note:  
The ON/OFF status of FFC is included in both sets.  
The correction data itself is the same with both sets.  
There is only one, common storage place for this data.

Command	Description
CS ?	List of available Capture Settings group commands.
CS	Returns the present Capture Settings.
CS SAVE	Saves the present Capture Settings to the first memory location. Loaded during reboot and power-up.
CS LOAD	Loads the stored Capture Settings from the first memory location.
CS SAVE2	Saves the present Capture Settings to the second memory location.
CS LOAD2	Loads the stored Capture Settings from the second memory location.
CS FACTORY RESET	Restores the Capture Settings to the factory values and saves them to the first memory location.



### 7.1.3.1 CS - show image capture settings

The command CS shows existing settings for this group of commands:

- SENSOR
- LINE RATE, LINE PERIOD
- LINE CTRL
- LINE IT
- GAIN
- OFFSET
- CXP FORMAT
- READOUT
- ROI
- BINNING
- FFC

### 7.1.3.2 CS SAVE - save settings (1<sup>st</sup> set)

This command stores all the above-mentioned settings to the first location in non-volatile memory. The settings are loaded at power-up and during reboot of the camera.

### 7.1.3.3 CS LOAD - load settings (1<sup>st</sup> set)

This command restores all the above-mentioned settings from the first memory location of the non-volatile memory.

### 7.1.3.4 CS SAVE2 - save settings (2<sup>nd</sup> set)

This command stores all the above-mentioned settings to the second location in non-volatile memory.

### 7.1.3.5 CS LOAD2 - load settings (2<sup>nd</sup> set)

This command restores all the above-mentioned settings from the second memory location of the non-volatile memory.

### 7.1.3.6 CS FACTORY RESET - restore settings to factory default

This command restores the factory values for all the above-mentioned settings from the camera non-volatile memory and saves them like the command 'CS SAVE'.

Factory defaults:

Command	Factory default
SENSOR	RESPONSIVE 1
LINE RATE	10 kHz
LINE PERIOD	100.0 $\mu$ s
LINE CTRL	internal
LINE IT	100 %, (98.50 $\mu$ s)
GAIN	1.000
OFFSET	0
CXP FORMAT	MONO 8
READOUT	NORMAL
ROI	OFF
BINNING	OFF
FFC	OFF

## 7.2 Group B: Commands affecting exposure

### 7.2.1 SENSOR - selects the sensor mode and analog gain

The sensor has two possibilities to collect the light generated charge. The default setting uses the smaller well size for higher responsivity. The larger well size is used for a wider dynamic range and a better signal to noise ratio, which results in more valid bits. The difference of the responsivity between the two well sizes is approximately a factor of 6. Additionally, an analog gain factor of 2 can be selected with both modes.

Command	Description
SENSOR ?	Returns the SENSOR setting syntax.
SENSOR	Returns the present setting of SENSOR.
DYNAMIC 1	Sets the sensor into the high dynamic range operating mode. Larger Quantum Well is in use.
SENSOR DYNAMIC 2	Analog gain of 2x added.
SENSOR RESPONSIVE 1	Sets the sensor into the high responsivity operating mode. Smaller Quantum Well is in use. Default setting.
SENSOR RESPONSIVE 2	Analog gain of 2x added.

### 7.2.2 LINE PERIOD and LINE RATE

These commands are used to set the scan rate for the internal timing generator, which is selected by the LINE CTRL INT command. A new setting will be effective even though the camera is in external timing mode. The LINE RATE is the inverse of the LINE PERIOD and if one of them is changed then the other will be changed as well.

The LINE PERIOD command specifies the line interval in microseconds. The valid range is from 12.5 to 100000.0. The line period can be changed with the resolution of 0.1  $\mu$ s. However, internal rounding can take place. In this case, the resulting rounded line period length is returned as the response to the command. The response has a resolution of 0.01  $\mu$ s.

The LINE RATE command is used for specifying the scan rate as lines per second. The valid range is from 10 to 80,000. The line rate can be specified in steps of 0.1 Hz. However, internal rounding can take place. In this case, the resulting rounded line rate is returned as the response to the command.

Command	Description
LINE PERIOD ?	Returns the command syntax and the available range.
LINE PERIOD	Returns the present line period .
LINE PERIOD <line period>	Sets the line period as microseconds ( $\mu$ s) in steps of 0.1. Default: 100.0.
LINE RATE ?	Returns the command syntax and the available range.
LINE RATE	Returns the present line rate. A value 8888.0 Hz indicates that the CXP Link speed was changed and is too slow to support the line rate in use or the rate loaded from memory.
LINE RATE <line_rate>	Sets the line rate as lines per second in steps of 0.1 Hz. Default: 10000.0.

Please note:

The settings made by commands MODE, CXP CONFIG, CXP FORMAT, BINNING and ROI may affect the available range of values.

If the status inquiry 'LINE RATE' returns the value 8888.0 Hz, the camera has automatically dropped the line rate to a safe value due to a too slow CXP Link speed that has been set after the faster line rate was already once accepted. This can happen also when loading the factory settings or the user settings from the first (CS LOAD) or the second location (CS LOAD2).

### 7.2.3 LINE CTRL - Exposure Control

The camera has three exposure control modes: internal, mixed, and Pulse Width Control (PWC), which uses only one input signal to control both the line rate as well as the effective time to integrate light.

The time when the exposure of one line ends and the exposure of the next line starts (change of line) initiates a procedure that is common to all the modes. That includes stopping the integration of light - or actually the collecting of the light generated electrons to the selected Quantum Wells (one per pixel), sampling the respective charge voltages, and starting the conversions into digital values to represent the amount of light that each pixel collected.

At the same time, the new line period starts and the camera starts to process the data that in fact originates from the line period that occurred two periods earlier. There is a constant delay from the end of each scan to the time where the first pixel value comes out of the camera. The user always gets exactly one line of data for each request of a new line, but due to the internal delay, it cannot always be the next line after the request. No lines though are lost in the process.

It is possible to limit the amount of time that light is effectively collected (integration time) within each scan period by using an electronic shutter function. The integration time always ends at the same time as the line. The start of the integration time should thus be selected to match the intended duration.

Only two signals or events are needed for these operations. First one is the new line request and the second one is the signal or event to start the integration. The source for these events can either come from the CXP trigger, or from internal timers, or as a combination of these two.

The CXP trigger is generated by the host internally or based on its input signals. It is forwarded to the camera as a transmission packet. In order to provide the camera a real time trigger, the trigger packet transmission over the coaxial cable has the highest priority. The time delay value between the trigger event and the trigger packet being sent is coded into the packet itself. The camera uses these values to recreate the trigger event with low jitter and a fixed latency.

Command	Description
LINE CTRL ?	Returns the command syntax.
LINE CTRL	Returns the present line control setting.
LINE CTRL INT	Line rate and integration time are controlled by the camera. Default setting.
LINE CTRL MIX	Line rate is controlled externally by the CXP trigger. Integration time is controlled internally by the camera.
LINE CTRL PWC	Line rate and integration time are controlled externally by the CXP trigger.

Command	Line period control	Integration time	Related commands
LINE CTRL INT	internal	internal	LINE RATE or LINE PERIOD, and LINE IT
LINE CTRL MIX	external	internal	LINE IT
LINE CTRL PWC	external	external	none

7.2.3.1 Internal exposure control (command: LINE CTRL INT)

The scan rate is defined either by the LINE RATE or the LINE PERIOD command, which are inverse of each other. The LINE IT command (LINE Integration Time) sets the length of the exposure time during each scan. The Line IT must be shorter than the Line Period. The actual integration takes place in the first part of the line period. If the Line Integration time is commanded to be longer than the Line Period then the integration time will stop at the same time as the line period ends.

The Internal exposure mode cannot be synchronized to an external event. If external synchronization is needed then the MIX or the PWC mode should be used.

7.2.3.2 Mixed mode exposure control (command: LINE CTRL MIX)

The line period is now the time between two consecutive rising edges of the CXP-trigger signal.

The integration time is controlled internally by the command 'LINE IT <time>'. The command 'LINE IT <value>%' is not available in this mode.

This mode is useful in situations, where the integration time needs to stay constant regardless of variations in the line frequency. Each scan would then be triggered from some external source, while the actual integration time of light would be programmed in advance as an absolute value. The maximum integration time is always about 2 μs shorter than the line interval. If the integration time is too long, it will be limited to the maximum, in which case it will vary according to the line trigger input (CXP trigger) frequency. The camera monitors this frequency. The approximate value can be read out by the command LINE RATE.

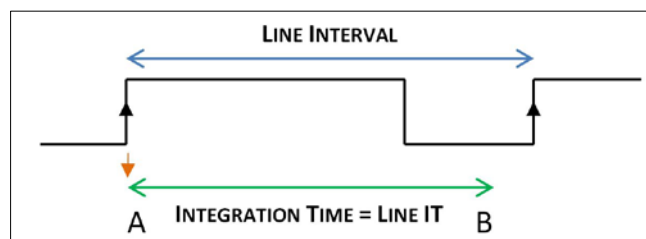


Fig. 6. Line timings in mixed control mode.

### 7.2.3.3 PWC mode exposure control (command: LINE CTRL PWC)

Both the line period and the integration time are controlled externally by the CXP trigger. The time between two falling edges defines the line period. Integration starts at the rising edge and stops at the end of the line period. Thus, effectively the exposure time is equal to the HIGH period, while the length of one period equals the line rate.

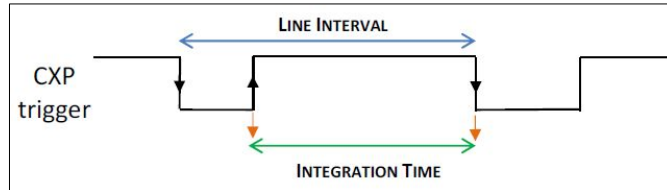


Fig. 7. Line timings in PWC control mode.

### 7.2.4 LINE IT - integration time

This command is used to control the integration time (effective exposure time) for each line. The timing can be specified either as an absolute time in microseconds, or as percentage of the line period. The integration time given as percentage of the line interval is recalculated automatically when the line rate changes. The integration time set in absolute units remains constant, unless the line rate setting forces the camera to shorten it.

Command	Description
LINE IT ?	Returns the command syntax and the available range.
LINE IT	Returns the present Line Integration setting.
LINE IT <time>	Sets the integration time to <time> in microseconds, where <time> is a numerical value between 2.00 - 99998.50 with 0, 1 or 2 decimal places.
LINE IT <value>%	Sets the integration time to <value> per cent of the maximum integration time, where <value> is a numerical value between 0.10 % to 100.00 % (default) with 0, 1 or 2 decimal places. Not available in the LINE CTRL MIX mode.

### 7.2.5 GAIN - digital signal gain

The gain control can be used to scale the camera response up or down. In addition to the digital gain control the sensor responsivity can be selected to be either Dynamic or Responsive giving a factor of 6 in responsivity due to the difference in quantum well size. An analog gain of 2 can be added to both options. Please refer to the SENSOR command.

It is recommended to use the SENSOR command first as far as possible and only then use the digital gain to fine tune the response. Use of values lower than 1 may cause the maximum output value to stay lower than the maximum value of the selected output range.

All changes in GAIN apply directly both to the signal and the dark level as well. If the dark level needs to be maintained, it is necessary to modify the OFFSET value respectively. A coarse estimate for the new OFFSET value can be calculated as follows and regardless of the bit depth in use:

<b>OFFSET <math>\approx</math> 50 / GAIN - 50</b>
---

Command	Description
GAIN ?	Returns the command syntax.
GAIN	Returns the present Gain setting.
GAIN <value>	Sets the Gain to <value>, where <value> is any number between 0.1 and 32 with up to three decimals. The default setting is 1.000

### 7.2.6 OFFSET - output offset

The value given by this command is directly added to or subtracted from all the pixel values prior to applying the GAIN.

Command	Description
OFFSET ?	Returns the command syntax and the available range.
OFFSET	Returns the present Offset setting.
OFFSET <offset>	Changes the signal level prior to the GAIN stage. Offset is always given as a 12-bit number. Offset changes in any 10 bit scale need to be multiplied by a factor of 4 to get the correct value for this command. Respectively, 8 bit offsets must be multiplied by 16. Default value is zero.

<offset> is a positive or negative integer within a range of -1023 to 1023. This equals  $\pm 25\%$  of the full scale. The offset is always entered as a 12-bit number, which means that if you have set the camera for one of the 8-bit output modes, you should multiply the intended offset shift by 16 to get the offset for this command.

Please keep in mind that this command changes the digital output signal level just before the gain factor is applied. A positive number raises the output levels, while negative numbers drop the levels. The lower limit of the adjusted level is zero. Lower output values can be used for a Contrast Expansion, where the darkest response of an application is brought closer to zero.



### 7.2.7 FFC - flat field correction

The function of the Flat Field Correction (FFC) is to compensate for differences in the optical input. This can be shading due to lower transmission at the lens sides or similar optical corrections. The Flat Field Correction should be done when the input light distribution is as uniform as possible in order to avoid the possibility of the FFC correction adding errors to the compensation when activated.

The procedure is then to establish a scene illumination as uniform as possible and to use the intended optics and adjustments for the application. A uniform test target is needed. It is recommended to calibrate the correction slightly off focal. This can be achieved either by changing the viewing distance (recommended option) or by turning the lens a little off the best focus.

The calibration routine first switches the correction off. The correction itself is a 2-point linear calculation to compensate for all the pixel-specific differences both at the lowest response levels (darkness) as well as at the bright levels, which exist when the routine is run. Two reference lines are used. Both are an average of 32 lines. The dark reference was calibrated already at the factory (DSNU). The bright reference is taken during the calibration. The peak value of the bright reference is used as the target value for all the pixels.

The correction unit is loaded with the new factors and the correction is turned on. The correction factors are saved and loaded along with the commands CS SAVE, CS SAVE2, CS LOAD and CS LOAD2, but because there is only one common memory location available, they actually all operate with the same data.

Command	Description
FFC ?	Returns the command syntax
FFC	Shows whether the correction is ON or OFF.
FFC RUN	Calibrates the correction to reach the same response at all the pixels and turns the correction on.
FFC ON	Activates the function. If FFC was never run, no correction data is available and no changes will be made to the line image.
FFC OFF	Switches the function OFF. Default setting.

## 7.3 Group C: Commands affecting image output format

### 7.3.1 CXP FORMAT

Command	Description
CXP FORMAT ?	Returns the CXP FORMAT command syntax.
CXP FORMAT	Returns the present CXP FORMAT setting.
CXP FORMAT MONO 8	8 bits per pixel. Default setting
CXP FORMAT MONO 10	10 bits per pixel.
CXP FORMAT MONO 12	12 bits per pixel.

### 7.3.2 READOUT - pixel readout direction

Sets the pixel readout to normal or reverse direction.

Command	Description
READOUT ?	Returns the READOUT command syntax.
READOUT	Returns the present READOUT setting.
READOUT NORMAL	Sets the READOUT direction to normal starting with first pixel. Default.
READOUT REVERSE	Sets the READOUT direction to reverse starting with last pixel.

### 7.3.3 ROI - regions of interest

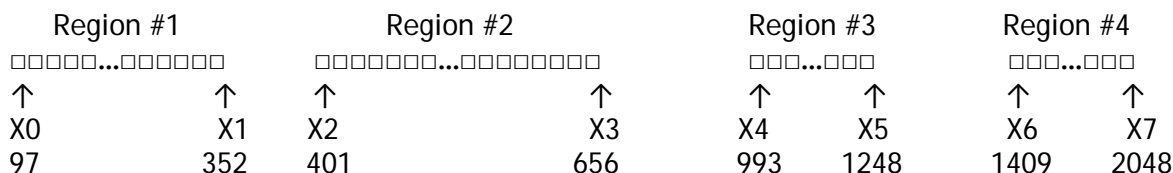
This command can be used to select only specific sections of each line to be sent out. Up to four regions can be defined. The selected parts of the line will be combined together to make one, shorter line. This increases the limit of the maximum line rate, the absolute maximum still being set by the selected MODE. There are no empty pixels or spaces in between the regions in the output data.

Furthermore, both binning and reversed readout order can be applied after this. Please note that all pixel number indices still and always refer to the real, physical pixel numbers of the sensor itself. First pixel is labelled as '1' and thus the last pixel is number 2048.

For simplicity and first trials it is recommended to divide the full range of pixels into 8 sections of 256 pixels each and then select individual or groups of sections by using the respective start and end pixel indices.

Alternatively, the selections can be optimised by following these detailed rules. The start pixel index must always be odd and smaller than the respective end pixel index at each region and the regions must not overlap. All indices must be within range of 1 to 2048. **Minimum width** of each ROI is **128 pixels or 256 pixels**, if binning is in use. Each region may have **individual widths**, but they all must be **divisible by 64**. Additionally, **GenICam™ use requires that the index of each end pixel must be divisible by 16**. Changes to selections are made by defining the complete set again.

Examples:



Command	Description
ROI ?	Returns the syntax.
ROI	Returns the present settings.
ROI X0-X1	Sets the ROI to start at pixel X0 and end at pixel X1.
ROI X0-X1, X2-X3	Sets region #1 to start at pixel X0 and end at pixel X1 and region #2 to start at pixel X2 and end at pixel X3.
ROI X0-X1, X2-X3, X4-X5	Sets region #1 to start at pixel X0 and end at pixel X1 and region #2 to start at pixel X2 and end at pixel X3 and region #3 to start at pixel X4 and end at pixel X5.
ROI X0-X1, X2-X3, X4-X5, X6-X7	Sets region #1 to start at pixel X0 and end at pixel X1 and region #2 to start at pixel X2 and end at pixel X3 and region #3 to start at pixel X4 and end at pixel X5 and region #4 to start at pixel X6 and end at pixel X7.
ROI ON	Activates ROI. If no regions are specified then all 2048 pixels will be sent out. Returns the same regions into use, unless new regions have been defined.
ROI OFF	Deactivates ROI. Default setting.

### 7.3.4 BINNING - pairing of pixels

Binning mode combines adjacent pixels as pairs either to double the response by summing the two original values or to decrease noise by taking the average of the two values. ROI operation may be in use prior to this. Binning decreases the number of output values by a factor of two. This increases the limit of the maximum line rate, the absolute maximum still being set by the selected MODE.

The two output values are added together in the summing mode and the output is limited to the maximum digital value of the original pixel values. The averaging mode sums the two values with no maximum limit and then takes the most significant bits into use to represent the new, combined pixel (lowest bit is removed).

The index of the first pixel of each pair must be odd.

Command	Description
BINNING ?	Returns the BINNING command syntax.
BINNING	Returns the present BINNING setting.
BINNING AVG	Activates BINNING in the averaging mode.
BINNING SUM	Activates BINNING in the summing mode.
BINNING OFF	Deactivates BINNING mode. Default setting.

### 7.3.5 ACQ - start and stop of acquisition

CoaXPress® links stay active after connections have been established, but actual image data is being transferred only when the acquisition is enabled.

Command	Description
ACQ ?	Returns the command syntax.
ACQ	Shows the status.
ACQ START	Enable image transfer.
ACQ STOP	Disable image transfer.

GenICam™ compatible software uses these functions directly as needed. The acquisition should be stopped (ACQ STOP) before any of the following telnet commands:

- ROI
- BINNING
- READOUT
- CXP FORMAT
- TEST
- LINE CTRL
- CS LOAD1, CS LOAD2
- CS FACTORY RESET

The acquisition is always disabled after power-up, restart and loading of factory settings. The status can not be saved. The commands CS LOAD and CS LOAD2 do not change the status.

## 7.4 Group D: Utilities

### 7.4.1 HELP or '?' - list of commands

### 7.4.2 VER - camera information

This command displays version information of various components of the camera. The command also returns camera model number, MAC address and serial number.

Command	Description
VER	Display version information and identifiers of the camera.

### 7.4.3 STATUS - camera information and settings

This command includes the VER command and additionally shows all camera settings.

Command	Description
STATUS	Display all identifiers and user settings.





### 7.4.4 TEST - test patterns

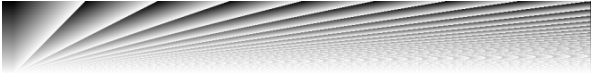
The image data can be replaced by artificially generated, known test patterns to help interfacing the camera, trouble shooting, and locating faults. Five patterns are available. They all depend on the selected bit depth. Horizontal patterns ramp either up or up-down within each line with steps that equal the selected camera output bit depth. All lines are then equal. Vertical patterns perform the same, but in line to line direction. All values within each line are then equal.

The last pattern, P5, is a combination of these two directions to enable tracking in both domains with a single test pattern. It starts exactly like the horizontal pattern P1, but when advancing to next lines it leaves the darkest pixel values out one by each line. This effectively also shortens the length of the horizontal sequences causing the position of the horizontal ramps to move from line to line. The last line of one sequence then finally only contains the maximum values making it to look like one completely white line.

The lowest value is actually always the same as what the vertically changing pattern P3 would have, if it had been started at the same time as P5. Thinking of the visual look of the pattern P3, the correct look of this pattern (P5) can be better understood: the base level or the darkest part of the pattern varies just like the vertically ramping P3 would vary. And while the base level gets brighter the horizontal pattern also gets tighter as the lengths of those horizontal ramps decrease making the respective image look like a pattern of higher frequencies.

Please note that the selection is not saved nor loaded along with the other settings. Power cycling, rebooting and loading of factory settings will switch the test mode off.

Command	Description
TEST OFF	No test pattern. Image data originates from the sensor (default).
TEST P1	Sawtooth: horizontal rising ramps from 0 to maximum. All lines are equal. In case of 8-bit output, the line graph includes 8 such periods, when advancing across the 2K pixels. The respective image should thus look like this:  
TEST P2	Triangles: horizontal ramps from 0 to maximum followed by falling ramps from maximum to zero. All lines are equal. In case of 8-bit output, the line graph includes 4 such periods, when advancing across the 2K pixels. The respective image should thus look like this:  
TEST P3	Vertical sawtooth: rising ramps from 0 to maximum in line to line direction. Each line has only one value for all the pixels. In case of 8-bit output, the ramp from black to white takes 256 lines in the respective image:  
TEST P4	Vertical triangles: rising ramps from 0 to maximum followed by falling ramps from maximum to zero in line to line direction. Each line has only one value for all the pixels. In case of using an 8-bit output mode, the cycle repeats itself every 512 lines. The respective image should look like this:  

TEST P5	<p>A combination of rising ramps in both directions. Horizontally the length of the sequence varies at the same phase as the lowest value of the pattern changes from line to line.</p> <p>Vertically the lowest value of each line-specific pattern varies from line to line as rising ramps from zero to maximum, similarly to how the pattern P3 behaves on its own.</p> <p>The resulting image is shown below (8-bit). The first line is identical to any line of P1. Then, instead of always starting from zero, the lowest value will rise by one per line thus also making the sequence shorter. This will continue making the pattern look like having higher frequencies all the way until finally a completely white line is produced. The sequence will then start over from the beginning.</p> 
TEST	Returns information on the current status of test modes

Note: all ramps increase or decrease by one level per pixel or line, where the step follows the selected output bit depth of 8, 10 or 12 bits. When the direction of any ramp changes, the last value of previous ramp is repeated once as the first value of the next ramp to keep the lengths of the sequences equal, when feasible.

#### 7.4.5 REBOOT - restart the camera

The command REBOOT resets the camera and starts it from the beginning as if the power had been cycled.

Command	Description
REBOOT	Restart the camera. Same initializations as during power-up. Close existing Telnet sessions and start new ones as needed.

#### 7.4.6 FIRMWARE UPDATE - initiate the MCU update

This command starts the loading of new firmware for the MCU. Please refer to chapter 5.12 for detailed instructions. Also the FPGA update process is described there.

Command	Description
FIRMWARE UPDATE	Initiates the microcontroller firmware update after confirmation.

## 8 Summary of commands

A - General settings.				
	Command Function	Command Format	Parameter	Remarks
1	Camera operating mode	MODE	<file name>	fundamental settings, reboot required
2	Network settings	NET		
3	set IP address	NET IP <address> NET IP AUTO	xxx.xxx.xxx.xxx	static, DHCP off dynamic, DHCP on
4	set subnet mask	NET MASK <mask>	xxx.xxx.xxx.xxx	only with static address
5	set default router	NET GATEWAY <address>	xxx.xxx.xxx.xxx	only with static address
6	reset net settings	NET FACTORY RESET		
7	camera name	NET NAME <name>	new name	
8	remove the camera name for network	NET NAME DELETE		
9	close session	NET CLOSE, NET QUIT or BYE		
10	Save capture settings	CS SAVE CS SAVE2		affected commands: SENSOR LINE RATE LINE PERIOD LINE CTRL LINE IT GAIN OFFSET CXP FORMAT READOUT ROI BINNING FFC
11	Load capture settings	CS LOAD CS LOAD2		
12	Restore factory settings for image capture and save	CS FACTORY RESET		



B - Commands affecting exposure.				
	Command Function	Command Format	Parameter	Remarks
1	Sensor operating mode and analog gain	SENSOR	DYNAMIC 1 DYNAMIC 2 RESPONSIVE 1 RESPONSIVE 2	Larger capacity, lower noise. Smaller capacity, higher responsivity. Followed by analog gain of 1x or 2x.
2	Line interval	LINE PERIOD <time>	Line interval in $\mu$ s, from 12.5 to 100 000	Minimum depends on MODE, ROI, binning, bit depth, and link speed.
3	Line rate (note 1)	LINE RATE <rate>	Lines per second, from 10 to 80,000	Maximum depends on MODE, ROI, binning, bit depth, and link speed.
4	Timing source	LINE CTRL <mode>	INT = internal MIX = external line timing, internal integration time PWC = Pulse Width Control	Recommended minimum line rate under external control: 10 Hz.
5	Integration time as microseconds	LINE IT <time>	2.00 to 99,998.60 $\mu$ s	Maximum depends on line rate.
6	Integration time as percentage	LINE IT <time>%	0.10 % to 100.00 %	
7	Gain	GAIN <gain>	0.100 to 32.000	no analog gain
8	Offset	OFFSET<offset>	-1023 to 1023	entered as 12 bits
9	Calibrate the Flat Field Correction	FFC RUN		define and apply
10	activate correction	FFC ON		
11	deactivate	FFC OFF		

Note 1.

If the status inquiry 'LINE RATE' returns the value 8888.0 Hz, the camera has automatically dropped the line rate to a safe value due to a too slow CXP Link speed that has been set after the faster line rate was already once accepted (in use or saved).

C - Commands affecting image output format.				
	Command Function	Command Format	Parameter	Remarks
1	CXP pixel format	CXP FORMAT <mode>	MONO 8 MONO 10 MONO 12	8 bits per pixel 10 bits per pixel 12 bits per pixel
2	Readout direction	READOUT	Normal or Reverse	
3	Set the regions of interest	ROI <regions>	Pixel numbers, 1 to 4 regions.	Check the list of requirements below.
4	Activate ROI	ROI ON		
5	Deactivate ROI	ROI OFF		
6	Pixel binning	BINNING <mode>	AVG, SUM or OFF	
7	Start acquisition	ACQ START		
8	Stop acquisition	ACQ STOP		Use before any of the other commands of this table.

**Requirements for ROI.**

For simplicity and first trials it is recommended to divide the full range of pixels into 8 sections of 256 pixels each and then select individual or groups of sections. The following list shows the detailed rules to optimise the regions depending on operating mode.

1. Pixel indices are from 1 to 2048 (also with binning).
2. Start index of each region must be odd.
3. Width of each ROI must be divisible by 64.
4. Width of each ROI must be at least 128 pixels.
5. Width of each ROI must be at least 256 pixels, if binning is in use.
6. Regions must not overlap.
7. All regions must be set at once and in ascending order of pixel indices.
8. GenICam™ use additionally requires that each end pixel index is divisible by 16.

D - Utilities.				
	Command Function	Command Format	Parameter	Remarks
1	Help	HELP or '?'		list of commands
2	Help on any specific command	add a '?'		examples: GAIN ? LINE RATE ?
3	Query of existing setting	<command> with no parameters		examples: GAIN LINE RATE
4	Camera identifiers and version numbers	VER		Model, SN, MAC. Versions: MCU, HW, sensor, logic.
5	Camera information and settings	STATUS		
6	Selection of test patterns	TEST <pattern> TEST OFF	From P1 to P5	not saved
7	Re-booting the camera	REBOOT		close Telnet sessions
8	Firmware update	FIRMWARE UPDATE		<a href="http://10.10.10.10">http://10.10.10.10</a>

## 9 Software tools for camera communications

The camera can communicate either via GenICam™ SDK or the Ethernet (10/100) port. Both communications can be used at the same time. The reply is sent to only the channel from where the command was received.

CoaXPress® interface supports GenICam™ for use with compatible user software like the JAI SDK, which can be downloaded from the JAI web site.

Ethernet port supports multiple Telnet sessions at the same time. Standard terminal programs can be used for control at command level. Default IP address is 10.10.10.10. Telnet Port is number 23.

JAI provides a control tool as Windows® software and a web browser access.

## 9.1 JAI Sweep Ethernet Tool

The Sweep Ethernet Tool is a telnet terminal program with possibility to run scripts and to display single line graphs (average of 32 lines).

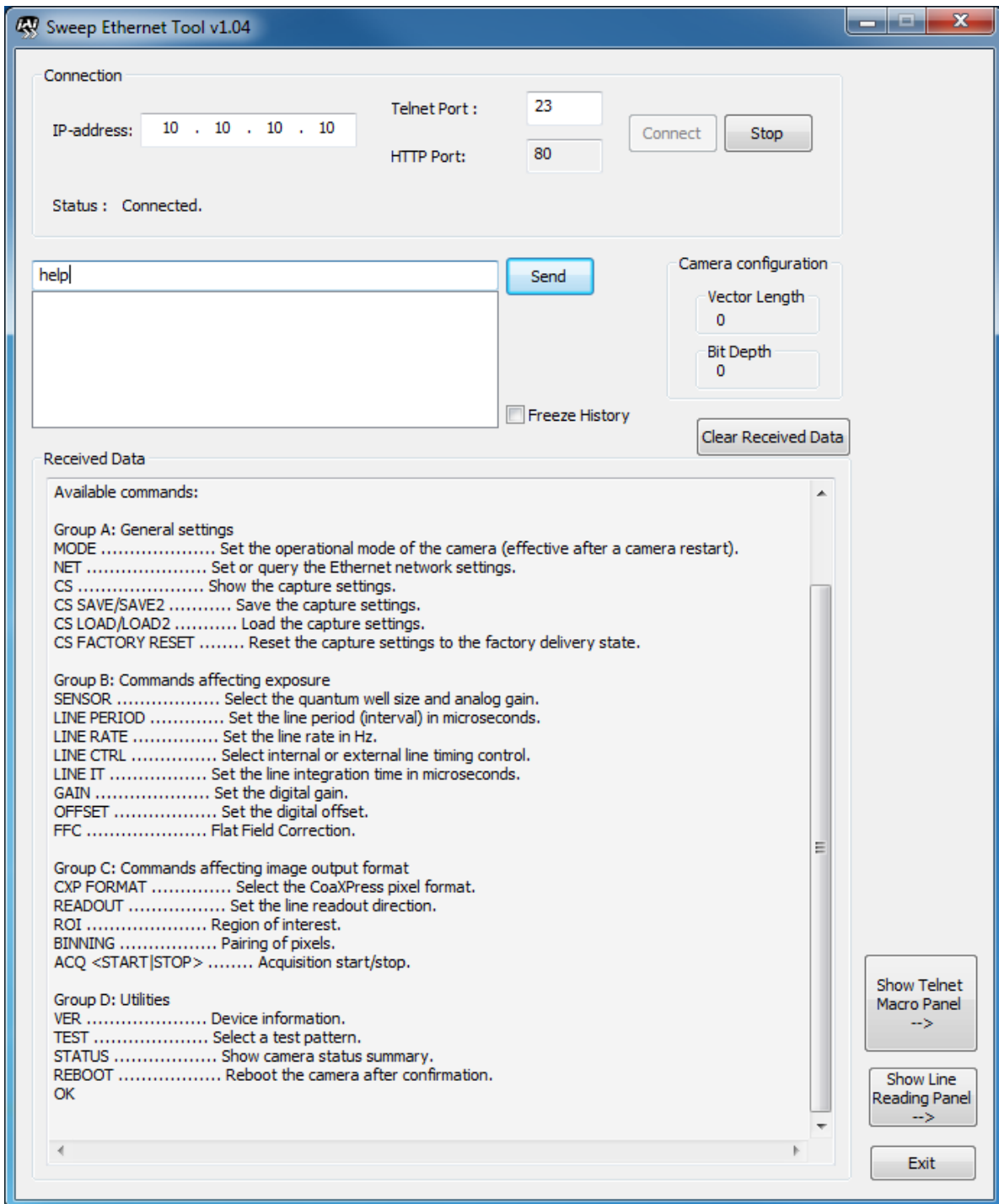


Fig. 8. Front page after initialization and the help command.

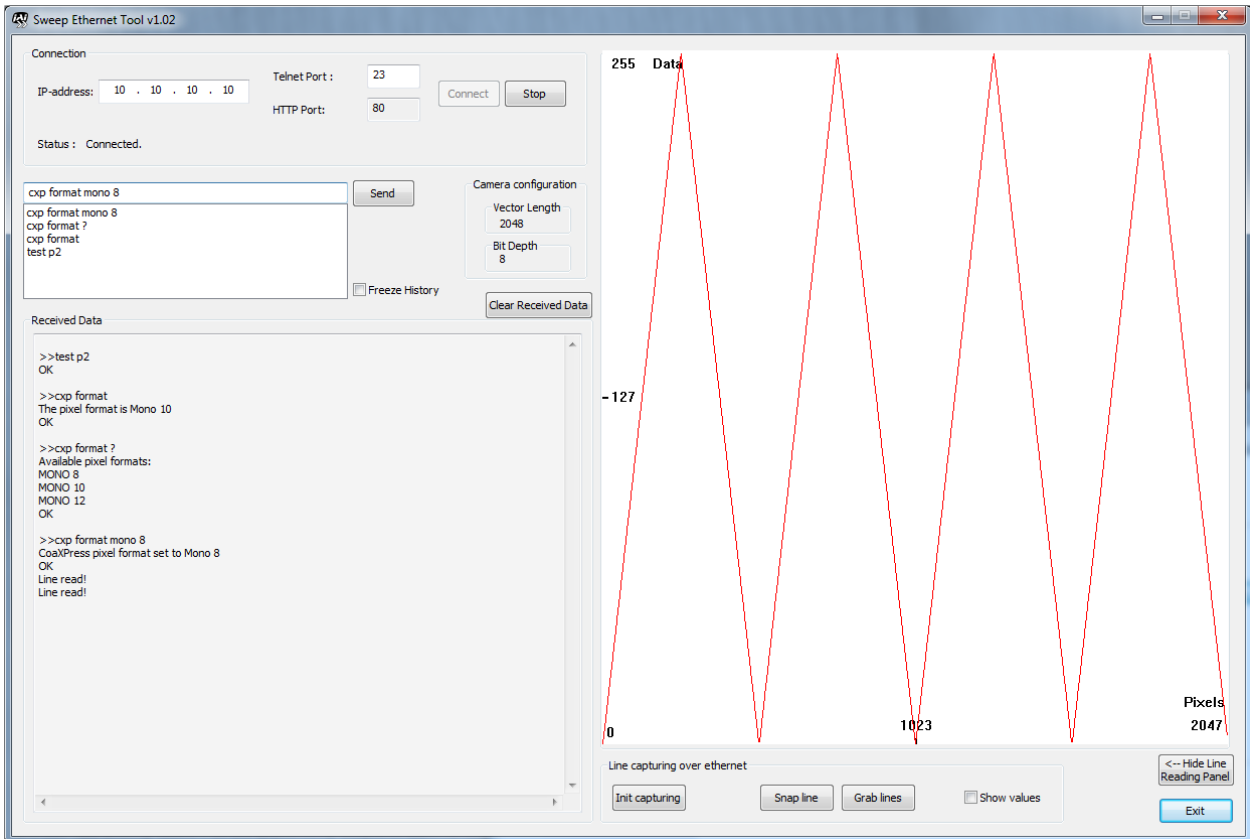


Fig. 9. Line graph display with no frame grabber. Test pattern 2.

## 9.2 Internal web server

The internal Web server can be accessed by standard web browsers at <http://10.10.10.10/>.

It offers some documents for download and is used while updating camera firmware.

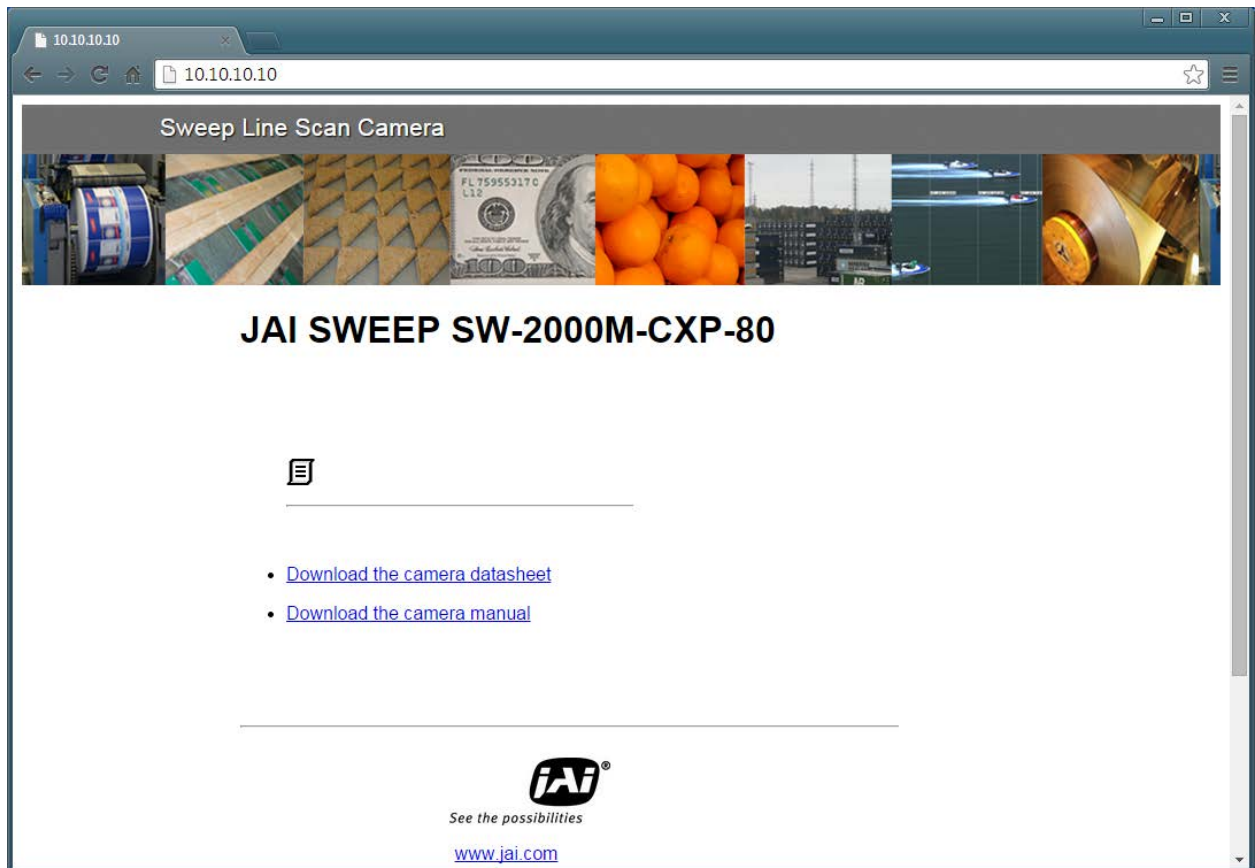


Fig. 10. Home page.

10 External dimensions

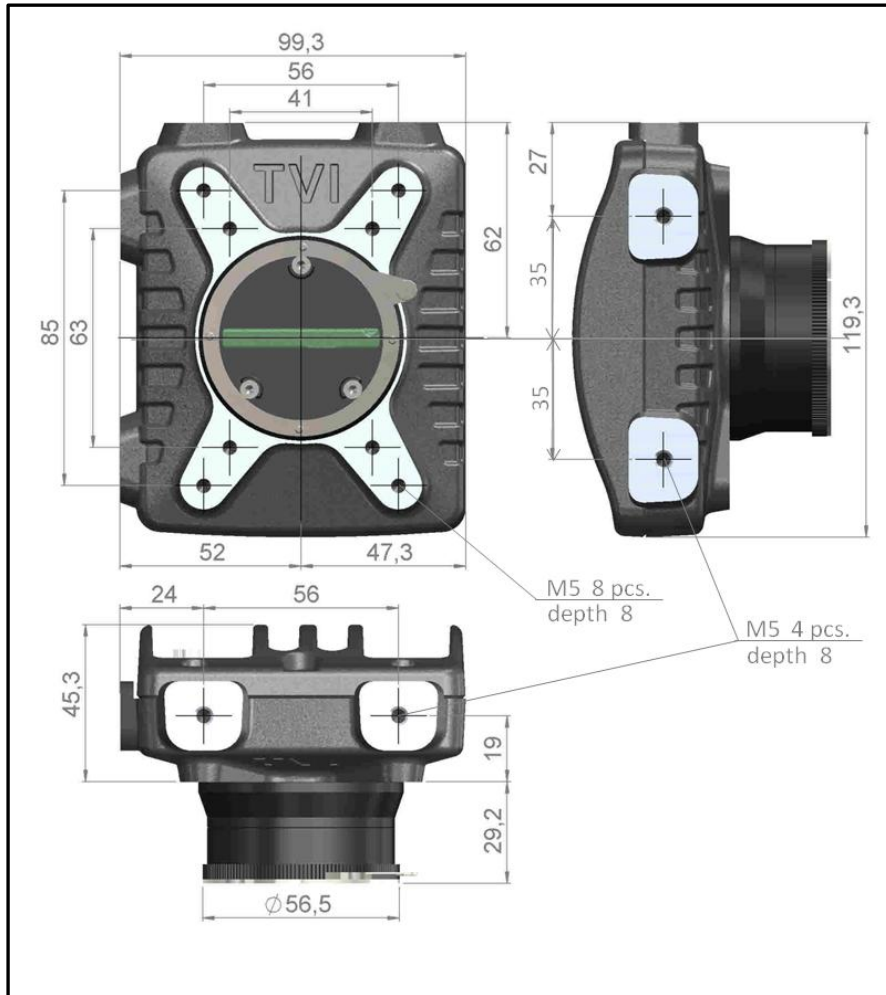


Fig. 11. External dimensions in mm.



## 11 Specifications

### 11.1 Operating range

Parameter	Min	Typical	Max	Unit	Notes
Number of pixels	2048	-	2048	-	CMOS (custom), line scan
Pixel size	20.0	-	20.0	μm	square
Fill factor	100	-	100	%	
Length of the imager	40.96	-	40.96	mm	
Line scan period in the internal mode	12.5	-	100k	μs	line rate: 10 Hz to 80 kHz
Electronic shutter in the internal mode	2	-	99,998	μs	integration time
Line scan period in the INT and PWC modes	12.5	-	100k	μs	line rate: 10 Hz to 80 kHz
Internal A/D conversions		12½		bit	
Analog gain	1x	-	12x	-	only discrete values of 1x, 2x, 6x or 12x (SENSOR command)
Digital gain	0.1x	-	32x	-	
Flange back distance		46.5		mm	Nikon® F-mount
Lens protrusion	-	-	27	mm	from flange of Nikon® F-mount
Position of optical axis		±0.1	±0.2	mm	
Power consumption	4	-	5	W	
Temperature, operating storage	+5 -10	- -	+50 +60	°C	
Humidity, operating and storage	5	-	80	%	relative, non-condensing
Vibration			3	G	IEC 60068-2-6
Shock			25	G	IEC 60068-2-27
Dimensions (with no lens mount)		119.3 99.3 45.3		mm	width height depth
Weight		550 620		g	w/o lens mount with F-mount

11.2 Common properties

Property	Notes
Operation modes	Internal (internal line rate, internal shutter) Mixed (external line rate, internal shutter) Pulse Width Control, PWC (one CXP trigger for line rate and shutter)
Data interface	CoaXPress <sup>®</sup> , revision 1.0 or 1.1 (default)
Output modes	8, 10 or 12 bits
Protective glass	1.0 mm BK7 with AR coating
Communication interface	CoaXPress <sup>®</sup> (incl. GenICam <sup>™</sup> ). 10/100 Mbps Ethernet.
Regulation	EN 61000-6-2 (2005), EMC immunity EN 61000-6-4 (2007), EMC emissions FCC Part 15, Subpart B

11.3 Performance per selected sensor mode

Parameter	Symbol	Responsive 1	Dynamic 1	Unit	Notes
Quantum efficiency	QE	60	60	%	
Quantum well size		60	360	ke <sup>-</sup>	
Conversion factor		6.4	1.1	DN/ke <sup>-</sup>	
Signal-to-noise ratio	SNR	240 : 1 48	580 : 1 55	dB	EMVA-1288
Dynamic range	DR	63	66	dB	
Temporal dark noise		2.9	1.9	DN	
Responsivity		480	80	DN/nJ/cm <sup>2</sup>	
Linearity error		0.5	0.7	%	5 % to 95 % of saturation

Notes:

- all specifications are subject to change without notice
- wavelength of light: 625 nm
- DN as 12 bit
- Gain: 1.0
- DR = 20 lg(4095/dark noise) dB
- $SNR \approx \sqrt{(Quantum\ well\ size)} : 1$   
= 20 lg(SNR) dB

### 11.4 Spectral response

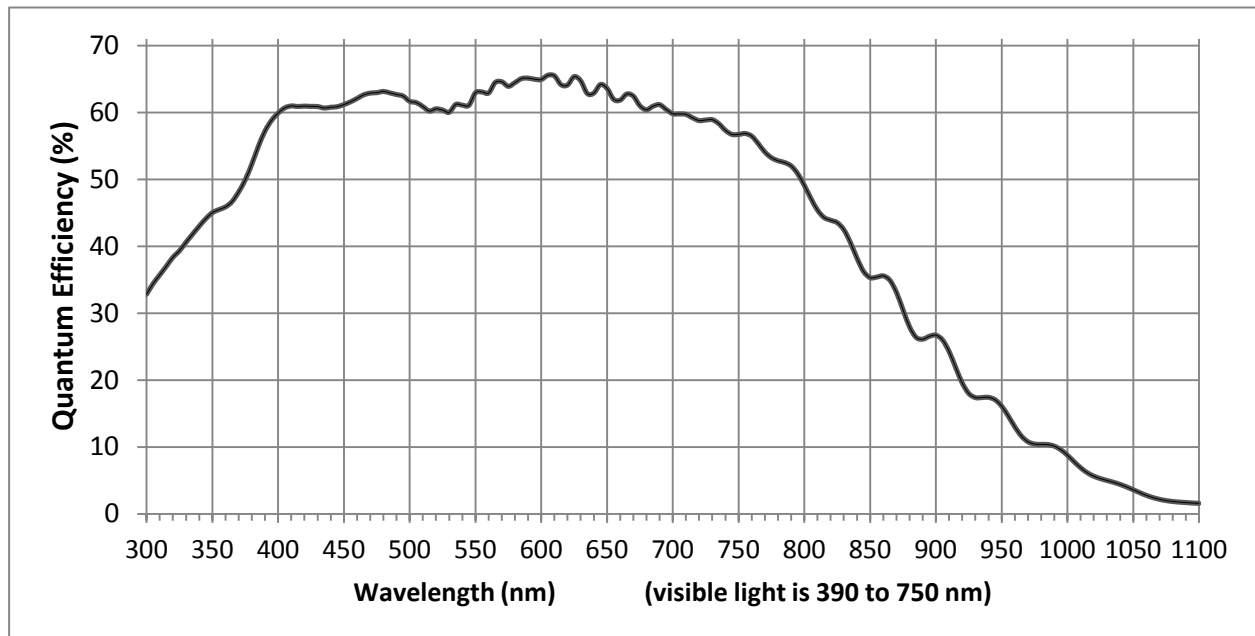


Fig. 12. Total spectral response without lens.

## 12 Change History

Date	Revision	Changes
March 13, 2015	1.3	First Release.

User's Record

Camera type: Sweep SW-2000M-CXP-80  
Revision: Release A, rev.1.3  
Serial No. ....  
Firmware version.      MCU: 1.071      (9 Mar 2015)  
                                 Logic: 20.017      (20 Feb 2015)

*Please contact your local JAI distributor for camera revision history.*

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User's mode settings.

User's modifications.

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