JAI®

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User's Manual

SW-2000M-CL-65

CMOS High Speed Monochrome Camera Link® Line Scan Camera

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Notice

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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-CL-65 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.

SW-2000M-CL-65

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1 General

The JAI® Sweep Series SW-2000M-CL-65 is a CMOS line scan camera based on a custom-made 2048 pixel imager with large square pixels of 20 μm for high responsivity. It operates at a rate of up to 65,000 scans per second.

The camera outputs digital data in 8-, 10-, or 12-bit formats, one, two, or three pixel values at a time via one Camera Link® (v2.0) connector. The camera is configured by software through the serial communication port of the Camera Link interface 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-CL-65 camera body with F-mount	x 1
3-pin power cable, 5 m, open-end	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", **CL** stands for "Camera Link®" interface, and **65** stands for "65 kHz" maximum scan rate.

2 Main features

- CMOS line scan camera
- Resolution: 2048 x 1
- Pixel size: 20 μm, square
- Selectable Quantum Well size: 60k or 360k electrons
- Selectable clock rate for sensor and data output
- Maximum scan rate: 65,000 lines per second
- Camera Link® Base Configuration data interface
    - One connector
    - 8, 10, or 12 bits per pixel
    - Single, dual, and triple data formats
- 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 range from +12 V to +24 V
- Ethernet port for
    - Control and monitoring
    - Firmware updates
    - Download of files from camera (internal web server)
- Short ASCII commands for set-up via Camera Link or Ethernet using the Telnet protocol
    - Windows® user interface
- GenICam™ compatible (JAI SDK, etc.)
    -

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3 Connectors and mounting

3.1 Main unit
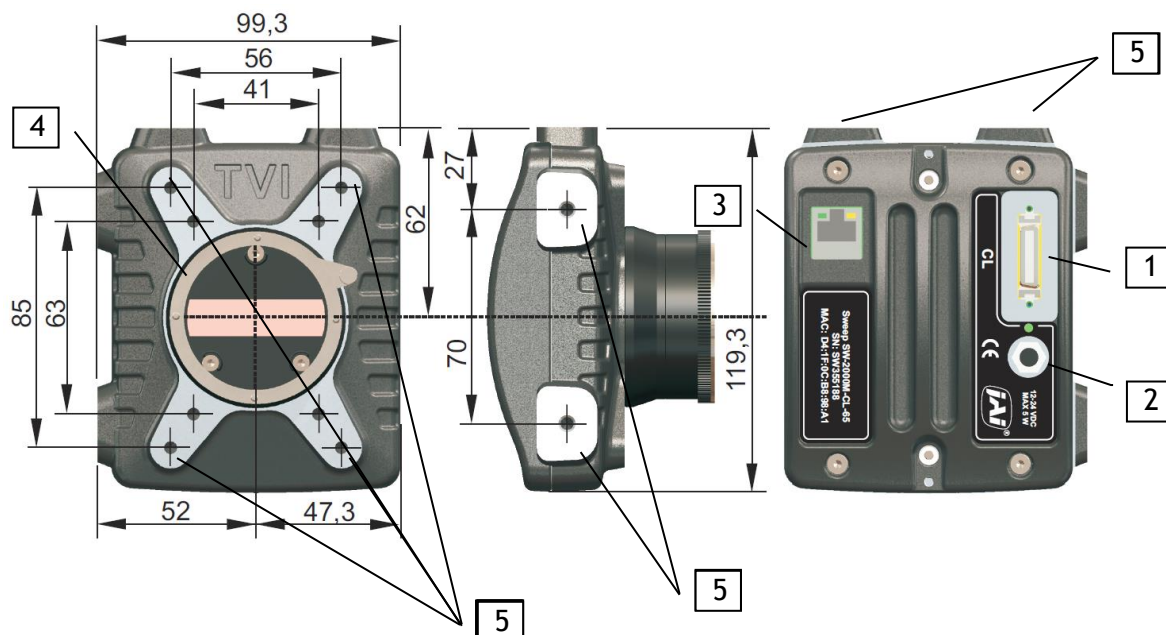
Fig. 1.   Location of external features

1   Camera Link Base Configuration connector [1]
2   M8 connector for supply voltage (+12 to +24 V DC)
3   Ethernet connector
4   Lens mount: Nikon® F-Mount
5   Mounting holes: all 8 pcs. are M5 with depth of 8 mm

Note 1: *Please do not excessively tighten the Camera Link connector screws by using tools.*
           This may damage the receptacle on the camera side. It is sufficient to tighten by hand.

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^2 or thicker to the electrical system ground.

3.2 Connector panel and indicators

Fig.2. Connector panel

1. Status indicator

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.

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2. 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.

3. Ethernet Status LED

✹ **Yellow (flashing)**
Activity indicator. Blinks shortly during data transfer.

4   Input and output

4.1   M8 connector for power supply

Camera side connector is an industry standard 3-pin M8 male connector. Use any compatible 3-pin M8 female connector on the cable side.

The internal electronics are electrically floating. The camera should be grounded from its chassis. The power cable does not need to be shielded. All three pins should be connected to the cable, but only the plus and minus power input wires should be connected at the other end to the power supply. The third wire (CHGND) should be insulated and not connected.
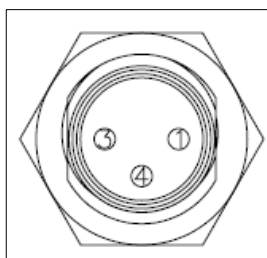
Fig. 3.   Power supply connector (viewed looking into the camera)

Pin No.	Signal	Remarks
1	plus	positive power supply: +12 Vdc to +24 Vdc
3	minus	negative power supply: 0 Vdc
4	CHGND	Chassis ground

4.2 Camera Link® connector
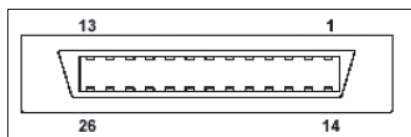
Fig. 4. Camera Link connector (viewed looking into the camera)

The connector and respective signalling comply with Base Configuration of AIA Camera Link standard v2.0. Thumb screw attached cables are recommended. Some latch type cables may not be mechanically compliant.

Pin No	In/Out	Name	Note
1,14		Shield	GND
2(-),15(+)	O	TxOUT0	
3(-),16(+)	O	TxOUT1	Data out
4(-),17(+)	O	TxOUT2	
5(-),18(+)	O	TxClk	Clock for CL
6(-),19(+)	O	TxOUT3	Data out
7(+),20(-)	I	SerTC (RxD)	LVDS Serial Control
8(-),21(+)	O	SerTFG (TxD)	
9(-),22(+)	I	CC1 (Trigger)	Trigger, line rate
10(+),23(-)	I	CC2 (reserved)	integration control
11,24		N.C.	
12,25		N.C.	
13,26		Shield	GND

4.3 Camera Link® output modes

All these modes are presented in the standard according to the names shown on the first line. This table shows the use of these configurations to implement various data output modes.

Bit depths of 8, 10, and 12 are supported, where MSB is labeled as M11 and LSB as M0. Camera operates internally with more than 12 bits. All blanks are zeroes.

Dual and Triple modes send data from multiple pixels in parallel to enable higher scan rates and/or longer cable lengths. Camera Link is nominally limited to 10 meters and 85 MHz (not the same time). Data from two or three consecutive pixels is sent out at once, where the index n-1 refers to the previous pixel and n-2 respectively to the pixel before that. If the pixels are numbered from 1 to 2048, then the transmission in 8-bit Triple mode starts with a 24-bit package, where port A shows the 8-bit value for pixel #3, Port B equals pixel #2 and Port C contains data from the first pixel. Respectively, the Dual modes effectively send the data out as odd and even numbered pixels, two in parallel.

CL v2.0 specification		8-bit x 1	10-bit x 1	12-bit x 1	8-bit x 2	10-bit x 2	12-bit x 2	8-bit x 3
CL MODE		SINGLE 8	SINGLE 10	SINGLE 12	DUAL 8	DUAL 10	DUAL 12	TRIPLE 8
Port	**Bit**				*2 x 8-bit*	*2 x 10-bit*	*2 x 12-bit*	*3 x 8-bit*
A	0	M4	M2	M0	M4	M2	M0	M4
	1	M5	M3	M1	M5	M3	M1	M5
	2	M6	M4	M2	M6	M4	M2	M6
	3	M7	M5	M3	M7	M5	M3	M7
	4	M8	M6	M4	M8	M6	M4	M8
	5	M9	M7	M5	M9	M7	M5	M9
	6	M10	M8	M6	M10	M8	M6	M10
	7	M11	M9	M7	M11	M9	M7	M11
B	0		M10	M8	M4(n-1)	M10	M8	M4(n-1)
	1		M11	M9	M5(n-1)	M11	M9	M5(n-1)
	2			M10	M6(n-1)		M10	M6(n-1)
	3			M11	M7(n-1)		M11	M7(n-1)
	4				M8(n-1)	M10(n-1)	M8(n-1)	M8(n-1)
	5				M9(n-1)	M11(n-1)	M9(n-1)	M9(n-1)
	6				M10(n-1)		M10(n-1)	M10(n-1)
	7				M11(n-1)		M11(n-1)	M11(n-1)
C	0					M2(n-1)	M0(n-1)	M4(n-2)
	1					M3(n-1)	M1(n-1)	M5(n-2)
	2					M4(n-1)	M2(n-1)	M6(n-2)
	3					M5(n-1)	M3(n-1)	M7(n-2)
	4					M6(n-1)	M4(n-1)	M8(n-2)
	5					M7(n-1)	M5(n-1)	M9(n-2)
	6					M8(n-1)	M6(n-1)	M10(n-2)
	7					M9(n-1)	M7(n-1)	M11(n-2)

5 Operation and functions

5.1 Introduction

5.1.1 Image sensor

The SW-2000M-CL-65 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 ke⁻), while the larger has capacity for 360 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 2 µs 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.
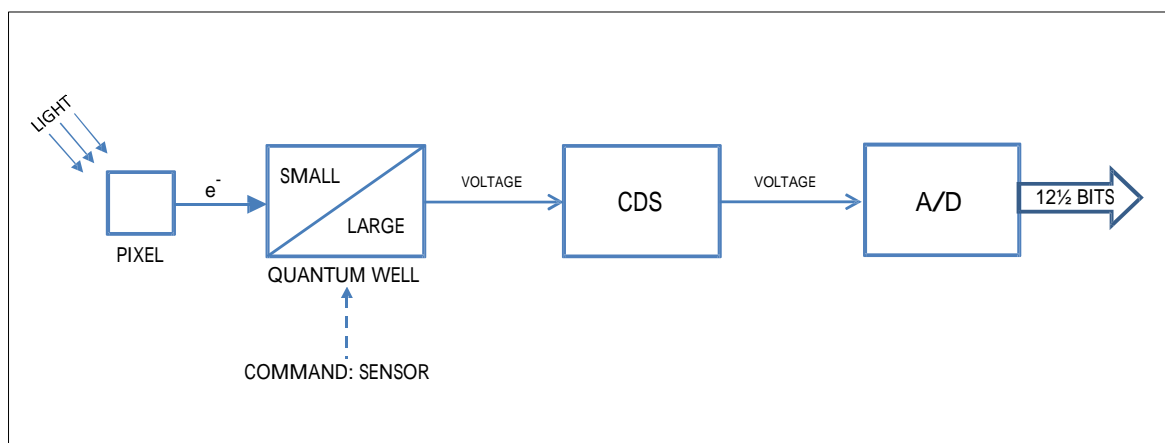

Fig.5.   Sensor block diagram

Please note that these cameras have not been designed for low light conditions, but for high image quality, which always requires reasonable amount of light to be available.

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 Camera Link 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 Camera Link input signals CC1 and CC2, internal timers, or a combination of these.

Serial communication channels are used to control and monitor the camera. Both the standard Camera Link serial channel 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 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.

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.
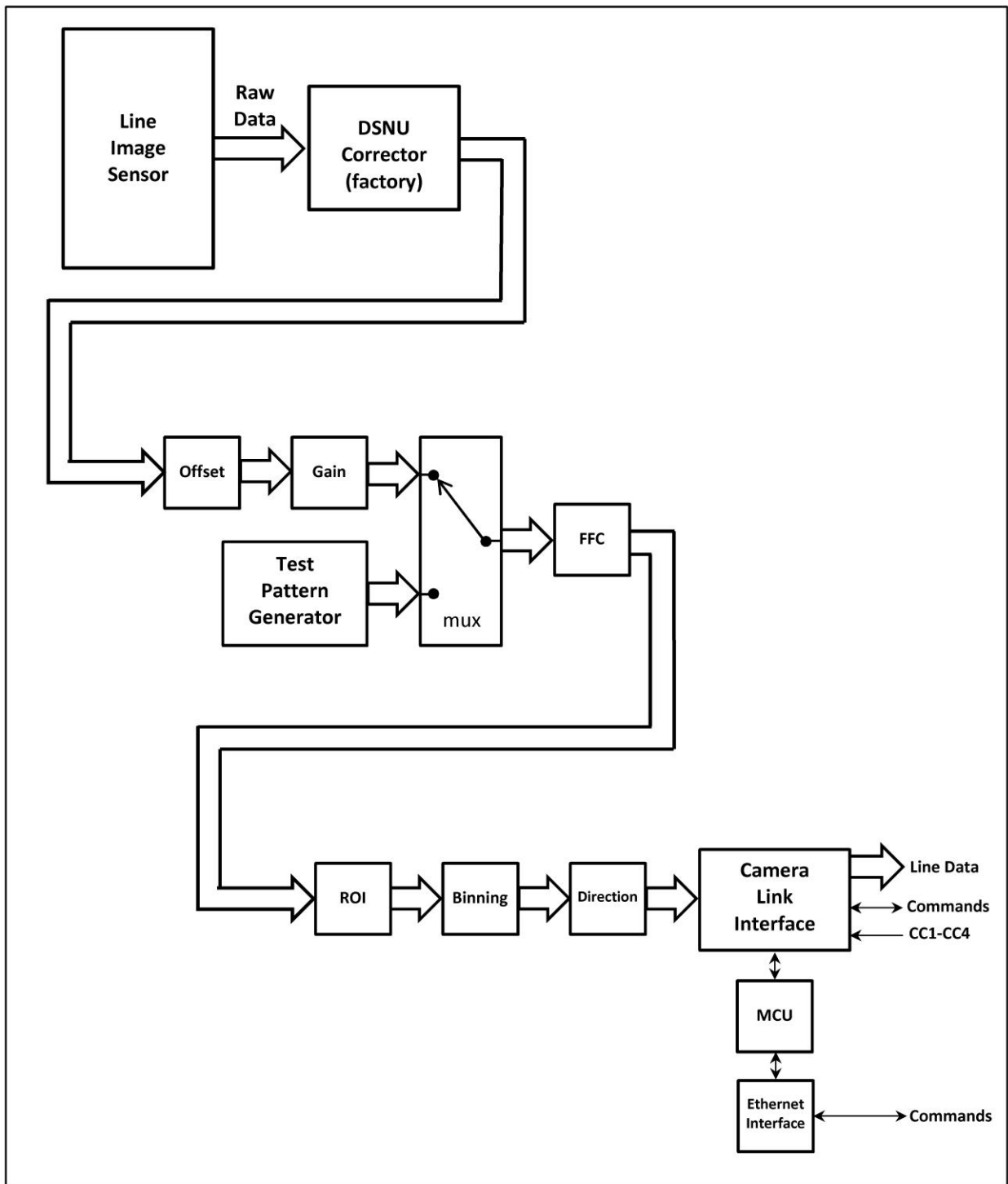
Fig.6. Image processing block diagram.

5.5 Test Pattern Generator

The SW-2000M-CL-65 can send out five, 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.

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 (profile of light) 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 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.

5.10 Camera Link® interface

One Camera Link connector is available to connect standard Base Configuration interface devices (frame grabber boards, etc.) to receive image data, to control the scan rate and exposure of the camera, as well as to communicate via the Camera Link serial channel.

Output modes include possibilities to transfer two or three pixel values at the same time to increase throughput or to decrease the pixel clock frequency. The clock rate can be adjusted between 20 to 85 MHz in steps of 5 MHz. Lower frequencies may allow use of longer cables.

5.11 Ethernet interface

The Ethernet interface is provided as an alternative way to communicate with the camera. The 10/100 Mbps port provides very fast data transfer rates compared to standard Camera Link speeds, which are all less than 1 Mbps.

Connection to Ethernet offers usual networking possibilities like remote access and connecting multiple cameras together for control and monitoring. Standard Camera Link serial communication 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 (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 green LED near the power connector should now start flashing rapidly. This is the indication 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.

> Sweep Firmware Update v 2.2
>
> Camera serial number: SW447001
>
> Please specify a Sweep hex file to upload.
>
> Browse… No file selected.
>
> Upload
>
> Alternatively, restart the camera without updating.
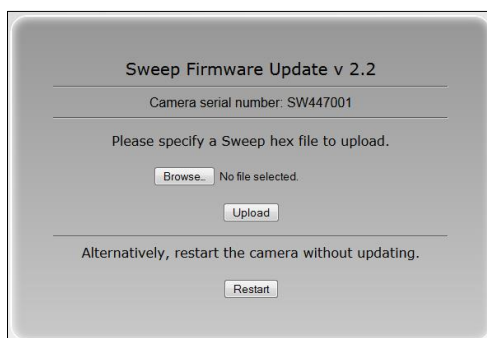>
> Restart

Fig.7.   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 either through the Ethernet interface using the Telnet protocol, or through the Camera Link serial port using plain ASCII communication. The command line usage instructions are common to both Telnet and serial bus command line interfaces.

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 Connecting via Camera Link® Serial Bus

To connect the camera using the Camera Link Serial Bus:
- Open a serial port. This may be a COM port of your PC or a terminal supplied by the frame grabber board.
- Select the port settings: 9600 bps, 8 data bits, no parity, 1 stop bit
- Open a serial connection.

6.3 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.

6.4 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 µs 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.
CL SERIAL set the baud rate for Camera Link communications.
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 selecting the quantum well size and analog gain.
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

CL MODE for setting the Camera Link output format.
CL RATE for setting the pixel clock frequency.
READOUT for selecting normal or reverse readout direction.
ROI for selecting Regions Of Interest.
BINNING for combining adjacent pixels.

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.

NOTE:	The CS FACTORY RESET command also saves the new values to the first memory location like the command CS SAVE.

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	50 MHz	40 kHz
SPEED55kL	80 MHz	55 kHz, factory default
SPEED65kL	80 MHz	65 kHz

Model SW-2000M-CL-80 includes the same modes plus two faster modes.

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 the Camera Link 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. The address can be queried through the Camera Link serial interface.

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 CL SERIAL – sets the baud rate

The baud rate of the serial communications channel via the Camera Link cable has the default value of 9600 bps after each power-up or restart, but can be set for higher speed. Please note that as the new value takes effect immediately, the response to this command will not be received correctly, if the command was given via Camera Link. In that case it is recommended to save the settings first and then to reload them after connecting again with the new speed.

Command	Description
CL SERIAL ?	Returns the command syntax and the available rates.
CL SERIAL	Returns the present CL SERIAL settings.
CL SERIAL <rate>	Sets the Camera Link serial communications channel to one of the accepted baud rates of 9600 (default), 19200, 38400, 57600 and 115200.

Other settings are 8 bits, no parity bit and one stop bit, commonly referred as 9600,8,N,1.

7.1.4   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.

7.1.4.1 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
- CL MODE
- CL RATE
- READOUT
- ROI
- BINNING
- FFC

7.1.4.2 CS SAVE – save settings (1st 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.

7.1.4.3 CS LOAD – load settings (1st set)

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

7.1.4.4 CS SAVE2 – save settings (2nd set)

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

7.1.4.5 CS LOAD2 – load settings (2nd set)

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

7.1.4.6 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 µs
LINE CTRL	internal
LINE IT	100 %, (97.90 µs)
GAIN	1.000
OFFSET	0
CL MODE	DUAL 8
CL RATE	85 MHz
READOUT	NORMAL
ROI	OFF
BINNING	OFF
FFC	OFF

7.2   Group B: Commands affecting exposure

7.2.1   **SENSOR**   – selects the quantum well size 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.
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 15.3 to 100000.0. The line period can be changed with the resolution of 0.1 µs. 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 µs.

The LINE RATE command is used for specifying the scan rate as lines per second. The valid range is from 10 to 65,000. 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 (µs) 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.
LINE RATE <line_rate>	Sets the line rate as lines per second in steps of 0.1 Hz. Default: 10000.0.

Please note that settings made by commands CL MODE, CL RATE, BINNING, ROI and MODE may affect the available range of values.

7.2.3 LINE CTRL - Exposure Control

The camera has four exposure control modes: internal, external, and mixed, which is a combined mode of the first two, as well as a 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 directly from the one or two input signals of the camera, or from internal timers, or as a combination of these two.

Command	Description
LINE CTRL ?	Returns the command syntax.
LINE CTRL	Returns the present line control setting.
LINE CTRL EXT	Line rate and integration time are controlled externally by two input signals, CC1 and CC2.
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 CC1 input signal. Integration time is controlled internally by the camera.
LINE CTRL PWC	Line rate and integration time are controlled externally by the CC1 input signal.

Command	Line period control	Integration time	Related commands
LINE CTRL EXT	external	external	LINE
LINE CTRL INT	internal	internal	LINE RATE or LINE PERIOD, LINE and LINE IT
LINE CTRL MIX	external	internal	LINE and LINE IT
LINE CTRL PWC	external	external	LINE

7.2.3.1 External exposure control (command: LINE CTRL EXT)

The line period and integration time are controlled externally by the CC1 and CC2 input signals at the Camera Link connector. Both signals are rising edge sensitive in this mode.

1) CC1. Line control. The time between two rising edges of CC1 defines the line period.
2) CC2. Integration control. There are three special cases of CC2:
   A) CC2 constantly low: the integration time is the minimum, which is a constant time in the range of 0.7 to 1.1 µs depending on the MODE.
   B) CC2 constantly high: the integration time is the maximum possible.
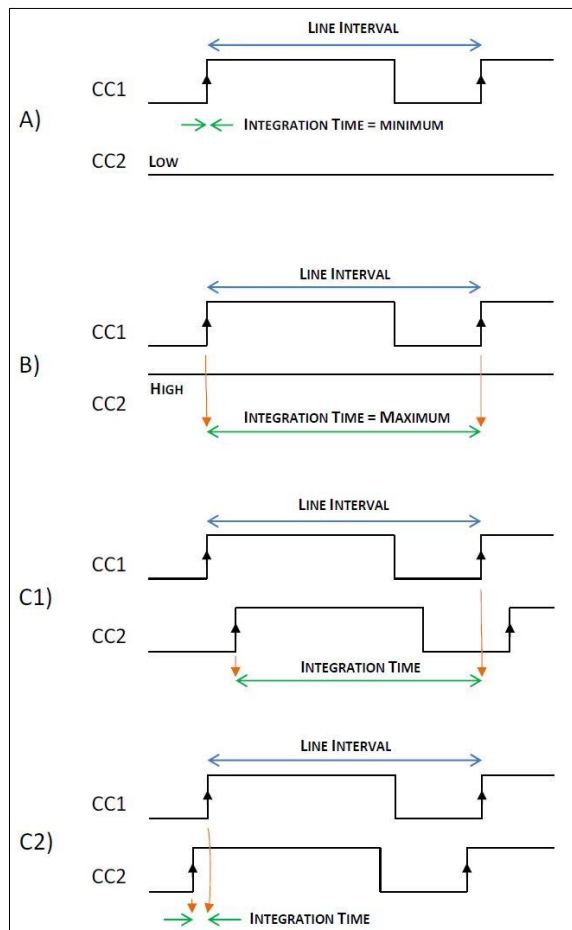   C) The integration time is from any rising edge of CC2 to the next rising edge of CC1 in all the other cases.

Fig.8.   Line timings in external control mode.

7.2.3.2 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 EXT, MIX or PWC mode should be used.

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

The line period is now the time between two consecutive rising edges of the CC1 input signal at the Camera Link connector.

The integration time is controlled internally by the command LINE IT. 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 absolute values. The maximum integration time is always be 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 (CC1) frequency. The camera monitors this frequency. Individual, exact values can be read out by the command LINE.
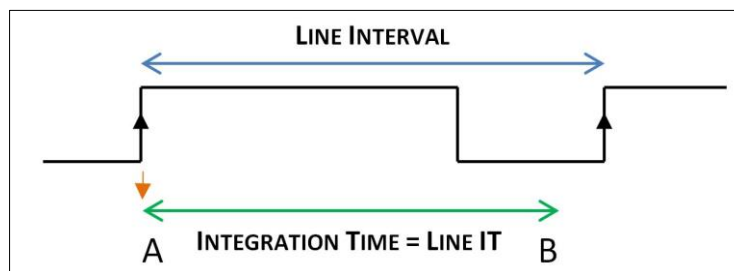

Fig.9.   Line timings in mixed control mode.

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7.2.3.4 PWC mode exposure control (command: LINE CTRL PWC)

The line period and integration time are controlled externally by the CC1 input signal at the Camera Link connector. 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 of the CC1, while the length of one CC1 period equals the line rate.
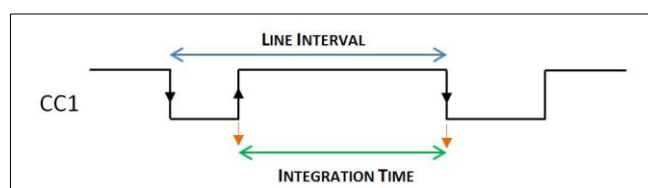

Fig.10.   Line timings in PWC control mode.

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.

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:

$$OFFSET \approx 50 \: / \: GAIN - 50$$

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.

The <offset> is a positive or negative integer within the range of -1023 to 1023. This equals ± 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 FFC 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 FFC function OFF. Default setting.

7.3   Group C: Commands affecting image output format

7.3.1 CL MODE - Camera Link® mode

This command selects the output mode for the final image data.

Command	Description
CL MODE ?	Returns the command syntax and list of available modes.
CL MODE	Returns the present CL MODE setting.
CL MODE SINGLE 8	8 bits per pixel.
CL MODE SINGLE 10	10 bits per pixel.
CL MODE SINGLE 12	12 bits per pixel.
CL MODE DUAL 8	8 bits per pixel, 2 pixels in parallel. Default setting.
CL MODE DUAL 10	10 bits per pixel, 2 pixels in parallel
CL MODE DUAL 12	12 bits per pixel, 2 pixels in parallel
CL MODE TRIPLE 8	8 bits per pixel, 3 pixels in parallel

7.3.2 CL RATE - Camera Link® pixel rate

Sets the pixel clock frequency within the range of 20 to 85 MHz. Parameter MIN sets the slowest suitable rate in respect to the current line rate in the LINE CTRL INT mode. Both are in steps of 5 MHz. Maximum value in TRIPLE 8 mode is 60 MHz.

Command	Description
CL RATE ?	Returns the CL RATE command syntax.
CL RATE	Returns the present CL RATE setting.
CL RATE <cl_rate>	Sets the Camera Link clock frequency to <cl_rate> in MHz. Default value is 85 MHz. Maximum value in TRIPLE 8 mode is 60 MHz.
CL RATE MIN	Sets the Camera Link clock frequency to the slowest rate sufficient for the existing line rate in the LINE CTRL INT mode.

7.3.3 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.

7.3.4 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**[TM] **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:

Region #1		Region #2		Region #3		Region #4	
□□□□□…□□□□□□		□□□□□□□…□□□□□□□□		□□□…□□□		□□□…□□□	
↑	↑	↑	↑	↑	↑	↑	↑
X0	X1	X2	X3	X4	X5	X6	X7
97	352	401	656	993	1280	1409	2048

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.

7.3.5 BINNING – paring 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.

7.4 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.
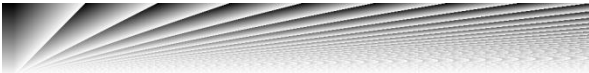
The lowest value is actually always the same as what the vertically changing pattern P3 would have, if it had been started at the same time as P5. Thinking of the visual look of the pattern P3, the correct look of this pattern (P5) can be better understood: the base level or the darkest part of the pattern 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	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. 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. 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.
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	baud rate for Camera Link serial communications	CL SERIAL	9600, 19200, 38400, 57600 or 115200	bps, 9600 after restart
11	Save capture settings	CS SAVE CS SAVE2		affected commands: SENSOR
12	Load capture settings	CS LOAD CS LOAD2		LINE RATE LINE PERIOD
13	Restore factory settings for image capture and save	CS FACTORY RESET		LINE CTRL LINE IT GAIN OFFSET CL MODE CL RATE READOUT ROI BINNING FFC

B – Commands affecting exposure				
	Command Function	**Command Format**	**Parameter**	**Remarks**
1	Quantum Well size 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 µs, from 15.3 to 100 000	Minimum depends on CL mode and rate, ROI and binning.
3	Line rate	LINE RATE <rate>	Lines per second, from 10 to 65,000	Maximum depends on CL mode and rate, ROI, binning and MODE.
4	Timing source	LINE CTRL <mode>	INT = internal EXT = external 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 µs	Maximum depends on line rate.
6	Integration time as percentage	LINE IT <time>%	0.10 % to 100.00 %	
7	Digital gain	GAIN <gain>	0.100 to 32.000	
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		

	Command Function	Command Format	Parameter	Remarks
	Command Function	**Command Format**	**Parameter**	**Remarks**
1	Camera Link® mode	CL MODE <mode>	SINGLE 8 SINGLE 10 SINGLE 12 DUAL 8 DUAL 10 DUAL 12 TRIPLE 8	8 bits, 1 pixel/clock 10 bits, 1 pixel/clock 12 bits, 1 pixel/clock 8 bits, 2 pixels/clock 10 bits, 2 pixels/clock 12 bits, 2 pixels/clock 8 bits, 3 pixels/clock
2	Camera Link clock frequency	CL RATE <rate> CL RATE MIN	From 20 to 85 MHz. MIN is to use the slowest sufficient rate in the LINE CTRL INT mode.	Both in steps of 5 MHz. Maximum of 60 MHz in TRIPLE 8 mode.
3	Readout direction	READOUT	Normal or Reverse.	
4	Set the regions of interest	ROI <regions>	Pixel numbers, 1 to 4 regions.	Check the list of requirements below.
5	Activate ROI	ROI ON		
6	Deactivate ROI	ROI OFF		
7	Pixel binning	BINNING <mode>	AVG, SUM or OFF	

C – Commands affecting image output format

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.

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	Command Function	Command Format	Parameter	Remarks
	D – Utilities			
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		http://10.10.10.10

9   Software tools for camera communications

The camera can communicate either via its Camera Link® port 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.

Camera Link port supports GenICam™ for use with compatible user software like the JAI SDK, which can be downloaded from 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 SweepConf

The SweepConf offers a graphical user interface with sliders and pop down menus for the most common functions as well as a telnet terminal. The same tool works for either Camera Link or Ethernet.
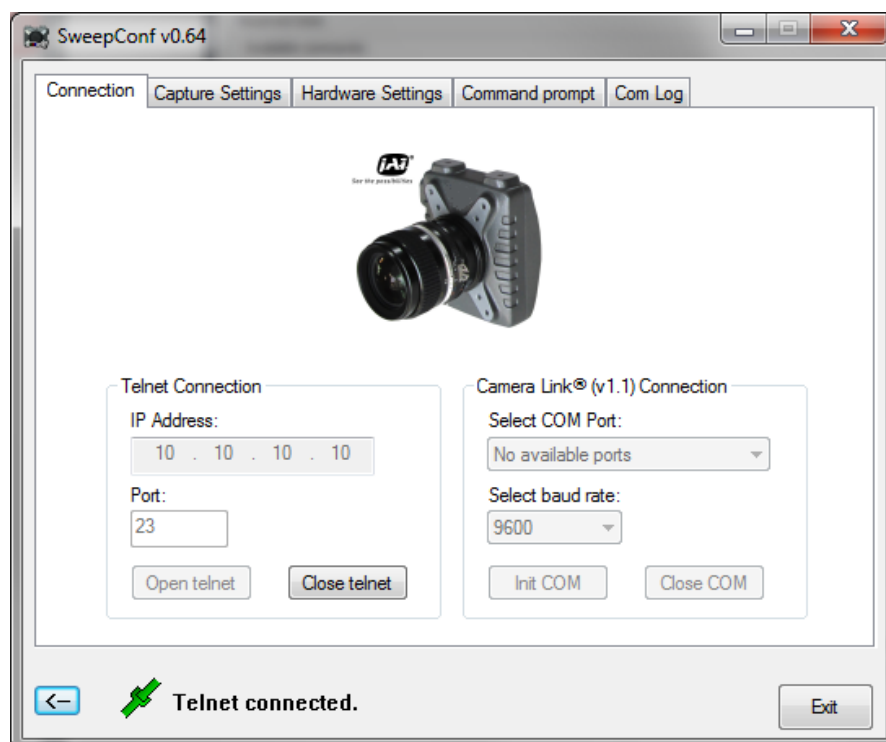

Fig.11.   Front page after initialization.

9.2 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).
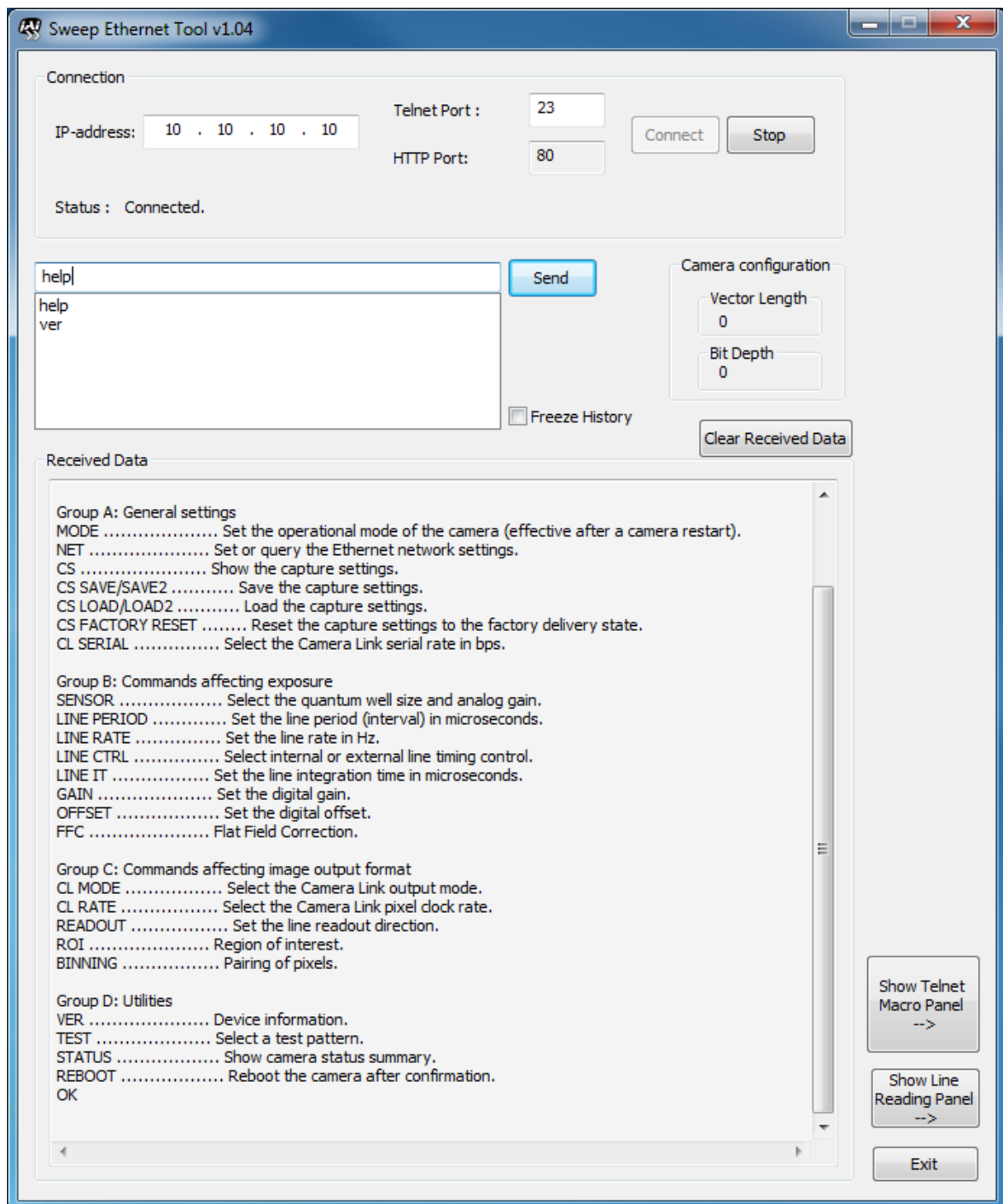

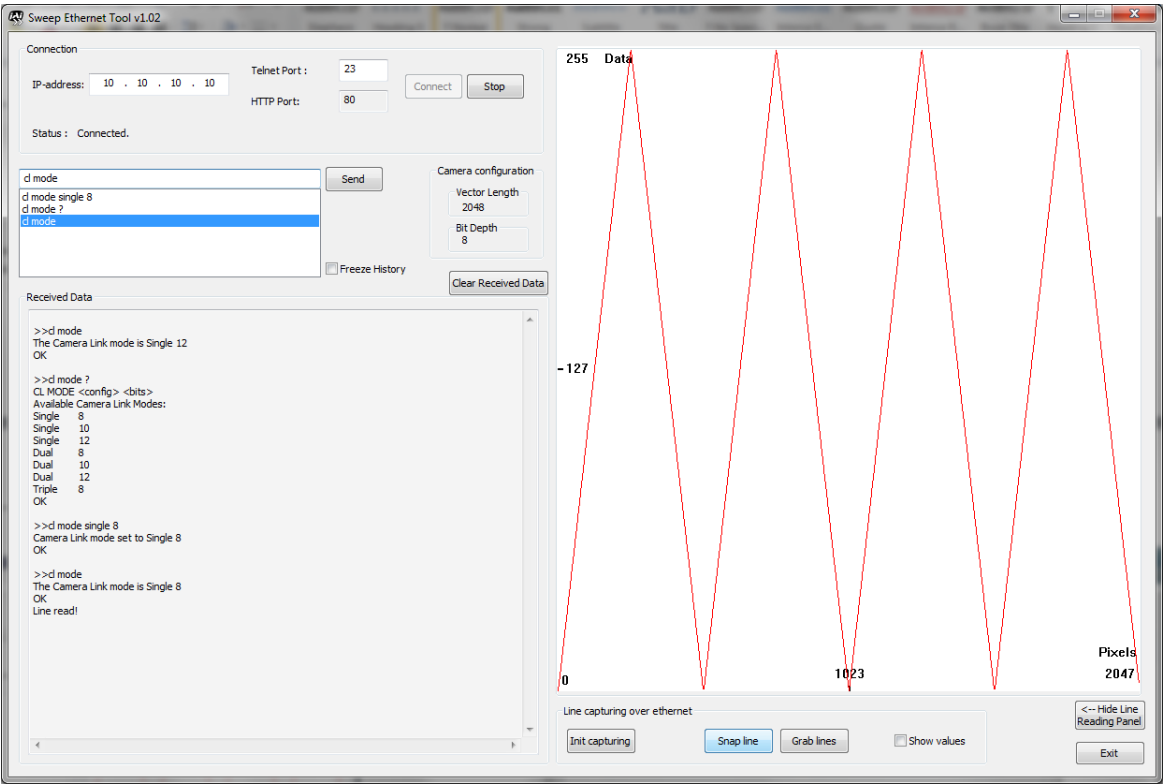Fig.12. Front page after initialization and the help command.

Fig.13.   Line graph display with no frame grabber. Test pattern 2.

9.3   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.
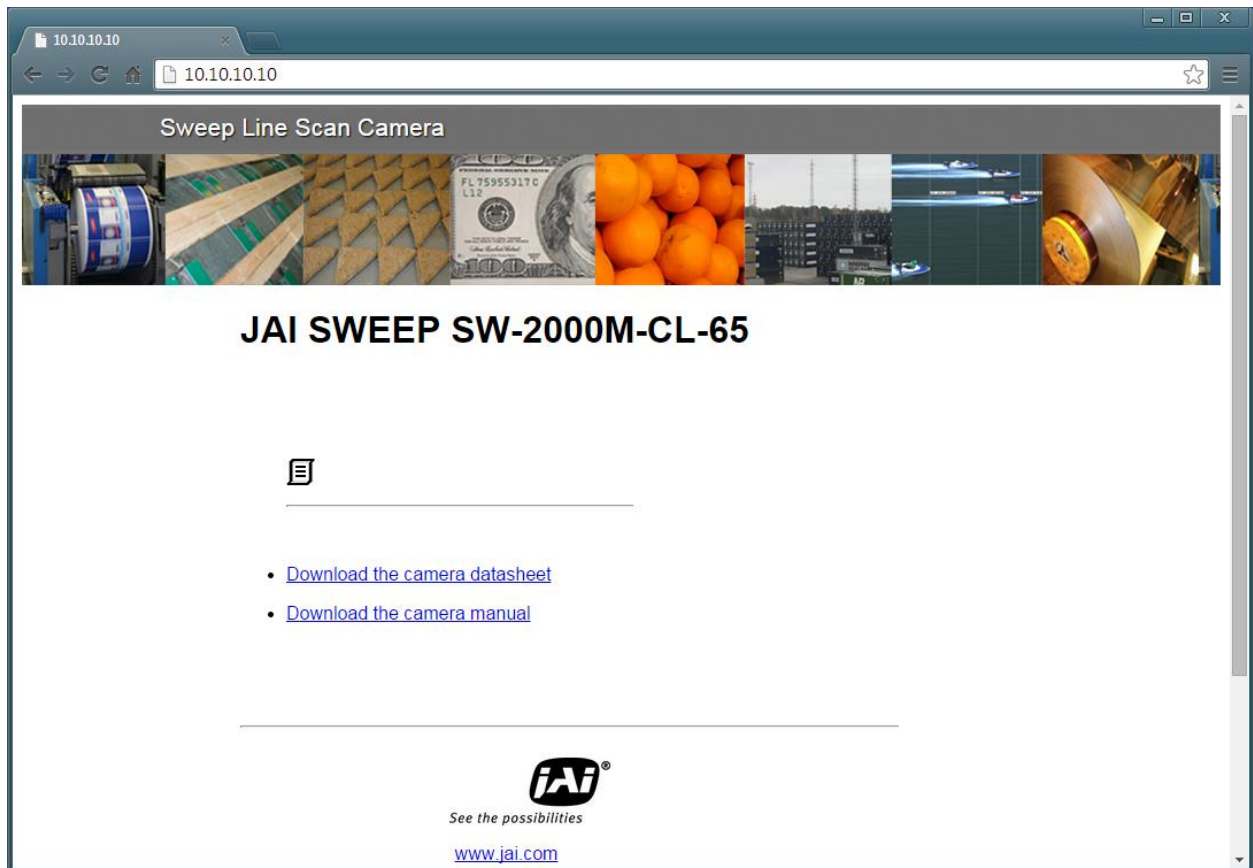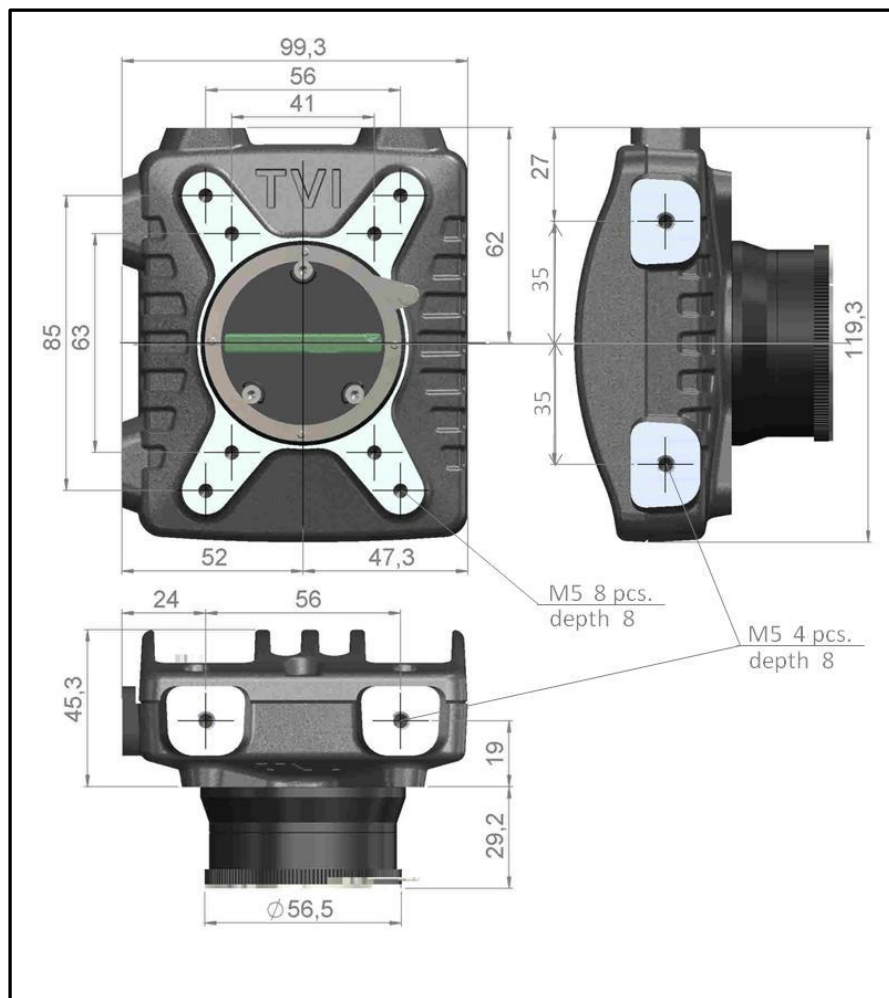

Fig.14.   Home page.

10   External dimensions

Fig.15.   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	
Pixel clock	20	-	85	MHz	adjustable
Line scan period in all modes	15.3	-	100k	μs	line rate: 10 Hz to 65 kHz
Electronic shutter in internal mode	2	-	99,998	μs	integration time
Electronic shutter, CC2, in external mode	2	-	99,998	μs	If CC2 is always zero, integration time is a constant time in the range of 0.7 to 1.1 μs depending on the MODE.
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	
Supply voltage	11.8	12 - 24	26.0	V_{dc}	**WARNING:** Overvoltage may damage the camera permanently.
Power consumption	4	-	5	W	
Operating temperature	+5	-	+50	°C	
Storage temperature	-10	-	+60	°C	
Humidity, operating	5	-	80	%	relative, non-condensing
Humidity, 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	External (external line rate, external shutter) Internal (internal line rate, internal shutter) Mixed (external line rate, internal shutter) Pulse Width Control, PWC (CC1 input for line rate and shutter)
Data interface	Camera Link® Base Configuration
Output modes	8, 10 or 12 bits x1 8, 10 or 12 bits x2 8 bits x3
Protective glass	1.0 mm BK7 with AR coating
Communication interface	Via Camera Link (CL) or 10/100 Mbps Ethernet. CL baud rates: 9600, 19200, 38400, 57600, or 115200 bps. GenICam™ compliant.
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$^-$	
Conversion factor		6.4	1.1	DN/ke$^-$	
Signal-to-noise ratio	SNR	240 : 1	580 : 1		
		48	55	dB	EMVA-1288
Dynamic range	DR	63	66	dB	
Temporal dark noise		2.9	1.9	DN	
Responsivity		480	80	DN/nJ/cm^2	
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

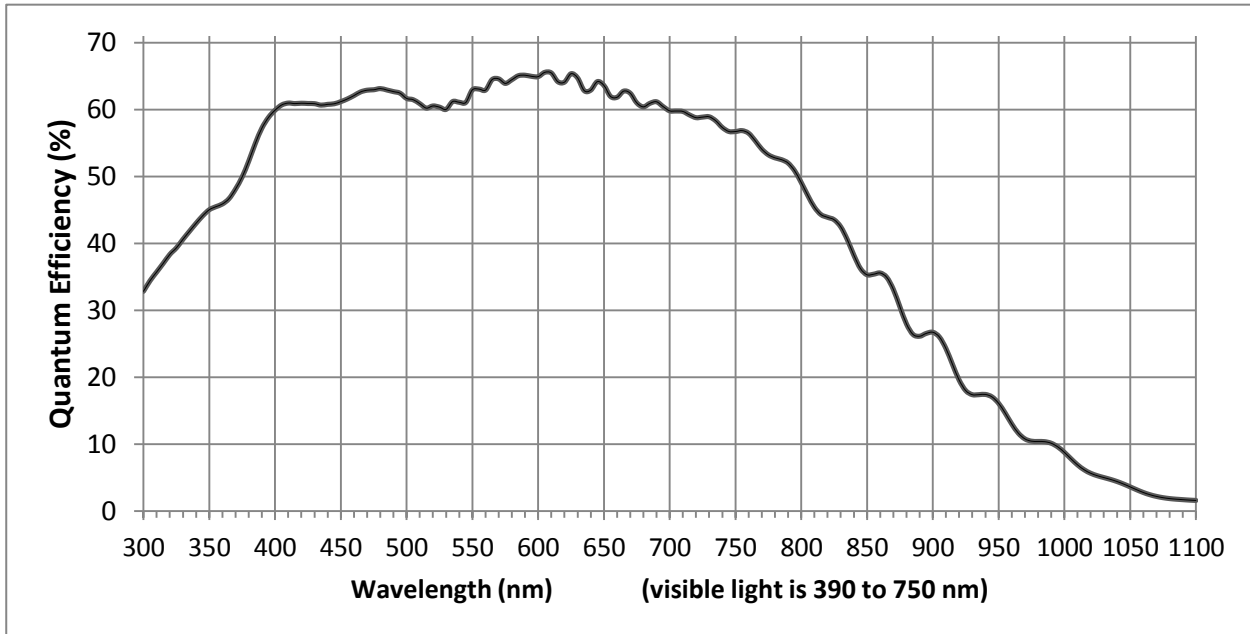   = 20 lg(SNR) dB

11.4 Spectral response

Fig. 16.   Total spectral response (typical, without lens)

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12 Change History

Date	Revision	Changes
12 June 2014	1.0	First Release (1.0).
28 Aug 2014	1.1	Firmware: 1.027/10.002.
3 Dec 2014	1.2	Firmware: 1.038/10.003. LINE CTRL PWC added; changes in ROI, FFC and NET NAME.
12 May 2015	1.3	Firmware: 1.074/10.009. New factory settings. Analog 2x gain option (SENSOR command). 40 kHz mode (MODE command). A simpler ROI.

User's Record

       Camera type: **Sweep SW-2000M-CL-65**

       Revision: Release A, **rev.1.3**

       Serial No.   ....

       Firmware version.   MCU: 1.074 (7 May 2015)
                                         Logic: 10.009 (25 Feb 2015)

Please contact your local JAI distributor for camera revision history.

User's mode settings.

User's modifications.

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