CMV20000

20 Megapixel machine vision CMOS image sensors

Evaluation System Manual

Change record

| Issue	Date	Modification
1	30/04/2013	Origination
1.1	31/7/2013	Removal of "Confidential" from footer
1.3	03/09/2014	Updated to reflects changes in software version 1.3

Table of Contents

1 SYSTEM DESCRIPTION

1.1 OVERVIEW

The purpose of this document is to give an overview of the test system which for the 20Mpxl machine vision image sensors produced by CMOSIS. This test system can be used for testing and verifying the operation of the CMV20000 image sensor.

1.2 BLOCK DIAGRAM
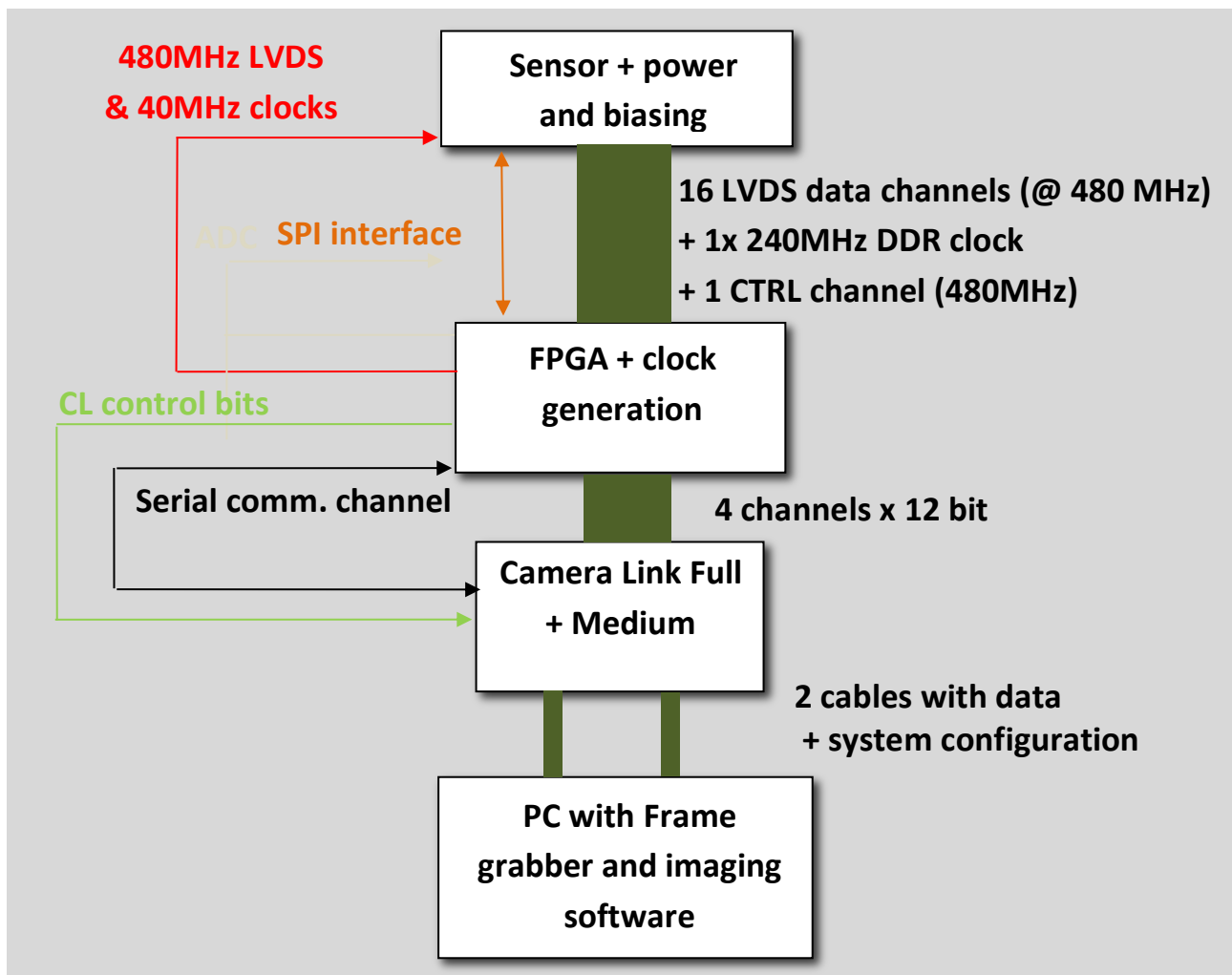
The block diagram above displays the different parts of the CMV20000 test system. The three upper blocks are implemented on one PCB.

The fourth block is a standard third party frame grabber card which plugs into a PC's PCI Express bus (NI PCIe-1433). For this frame grabber and the PCB dedicated software has been developed in a LabVIEW environment.

1.3 CONTENTS OF THE TEST SYSTEM

The following components should be present when the CMV20000 test system is delivered.

- CMV20000 board with lens holder
- Nikon F-Mount lens AF Nikkor 50mm f/1.8D

- Acrylic bottom and top plate
- 2 CameraLink cables (2m)
- NI PCI1433 frame grabber card (inside PC)
- Lenovo ThinkCentre mini tower model + demo software

1.4   CMV20000 BOARD

1.4.1   LENS HOLDER

The CMV20000 PCB is equipped with a lens holder and a Nikon 50mm F-mount lens. Place the lens on the lens holder and twist it to tighten the lens in the lens holder. Use the screws to hold the lens and ring in place.

1.4.2   SENSOR + POWER AND BIASING

This part of the test board includes the sensor, its power sources and biasing (decoupling to ground). The sensor is easily removable from the test board because of the ZIF (zero insertion force) socket. If you want the replace the sensor, simply lift the handle upwards 90°; this will open the socket. Remove the sensor and place one back in the correct pins. No force is needed to place the sensor in the socket. Now close the socket by pushing the handle down. The sensor is now tightened and cannot fall out. Due to the sensor's and connector's pin placement the sensor should only be mountable in the correct way.

The power supply cables are connected as in the picture below. One cable needs a 5V/1A supply and the other a 9 ~ 12VDC/1A.
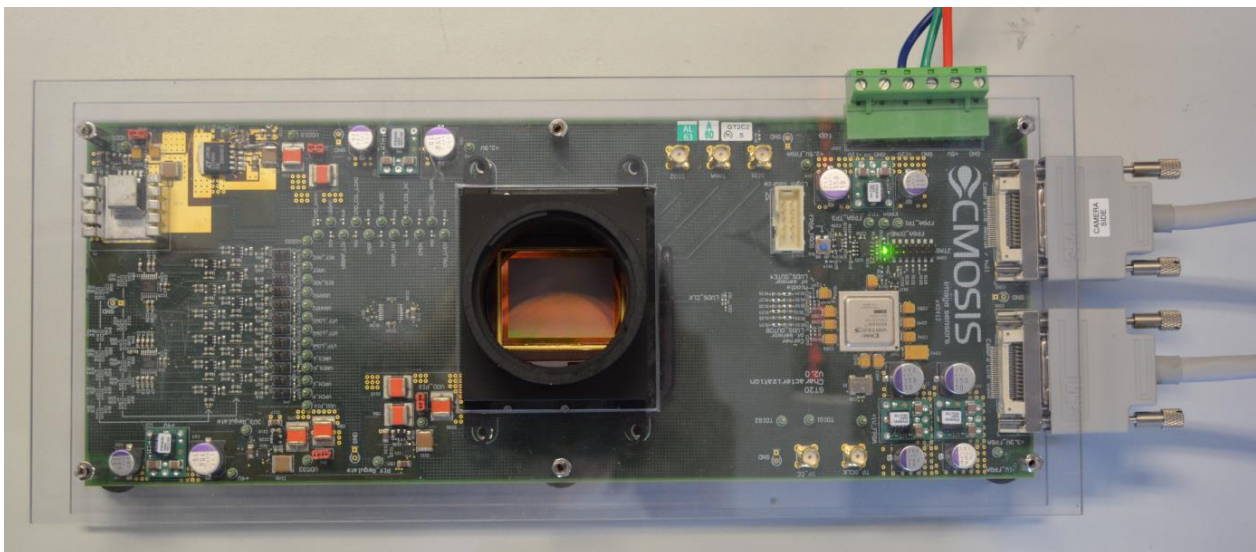
1.5   FPGA

The FPGA has 6 important roles in the test system:

1. Accept the LVDS data from the sensor (16 data channels @ 480Mbit/s, 1 LVDS clock channel @ 240MHz DDR and 1 control channel @ 480Mbit/s)
2. Generate the necessary driving signals for the sensor
3. Generate the clocks needed by the sensor and CameraLink interface
4. Communicate with the sensor over the SPI interface
5. Communicate with the PC over the serial interface of the CameraLink
6. Prepare the data for the CameraLink interface
7. Send the data to the CameraLink interface together with the control bits and clocks

Taking the requirements above into account, we have chosen Xilinx Virtex5 FPGA for our test system. All functionality described in the requirements above is programmed into the FPGA. Communication between the PC and FPGA is possible using the serial channel of the CameraLink interface.
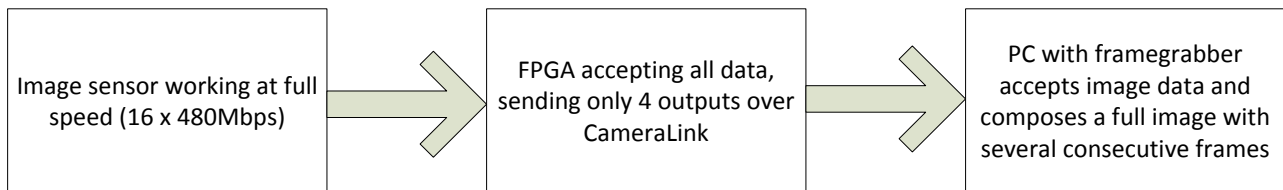
1.6 CAMERALINK INTERFACE

The interface between the test board (camera) and the PC uses the CameraLink standard. This standard is supported by many frame grabber cards on which the raw image data will be dumped. The test board is able to grab images at the 480Mbps. More information is in the next chapter.

1.6.1 FULL SPEED VS. FULL RESOLUTION

Because of the large image (20Mp) and the CameraLink only supports 4 channels simultaneously, a full image is composed of some consecutive frames (fpga settings register). For example when a full image is taken when using 16 channels output; the fpga will trigger the sensor to take 4 consecutive frames with different output channels. These 4 frames are then stitched to have a full resolution image on the screen. This means the frame rate at which movies or snapshots can be made will drop with 4 (in this case). When taking images of moving objects, this can give some image distortion in the final full resolution image.

When multiplexing the CMV20000's outputs to 8 channels (Mode 1) one full image can be made taking 2 frames.

If you disable remapping in the software you can select 4 sensor channels (displayed next to each other without any remapping) at full speed but no full image will be built from multiple frames.

Image sensor working at full speed (16 x 480Mbps) → FPGA accepting all data, sending only 4 outputs over CameraLink → PC with framegrabber accepts image data and composes a full image with several consecutive frames

2   FRAME GRABBER AND PC

A frame grabber card which can accept the Medium and Full CameraLink interface was chosen to complete the test system interface. The NI PCIe-1433 allows raw image data to be dumped at 4.8Gbit/s on the PC. This card is fitted in a PCI Express slot of the test system PC and uses two dedicated cables to connect to the CMV20000 board.

The PCIe-1433 frame grabber card comes with an API, which can easily be used in LabVIEW. This API is used to communicate with the frame grabber card and read the image from memory to display it on the screen.

See http://www.ni.com/pdf/manuals/372015a.pdf for more details on the PCIe-1433 frame grabber card.

The PC in which the frame grabber card is inserted and on which the software is running has the following minimum requirements:

- Intel Core i3
- 4 GB DDR memory
- 500GB SATA hard disk
- Intel HD Graphics
- 16x DVD-ROM
- PCI-Express slots

On this PC, the LabVIEW RunTime Engine and the Vision Development Module will be installed. A dedicated CMV20000.vi executable is written to grab and save images from the camera board. A detailed description of the software can be found in the next sections.

3 INSTALLING THE SYSTEM

When installing the system, the following connections have to be made:

1. Connect the PC to its peripherals (keyboard, mouse and monitor)
2. Connect the PCB to power supplies (hook up +5V +9VDC and ground and connect the grounds of the two power supplies)
3. Connect the PCB to the PC via the two camera link cables. Use either cable to connect the camera link connector on the PCB labeled 'base' to the PC camera link port labeled 'base'. Use the other cable (medium) to connect PCB port 'medium' to the other frame grabber port on the PC. Next two figures show these connections.
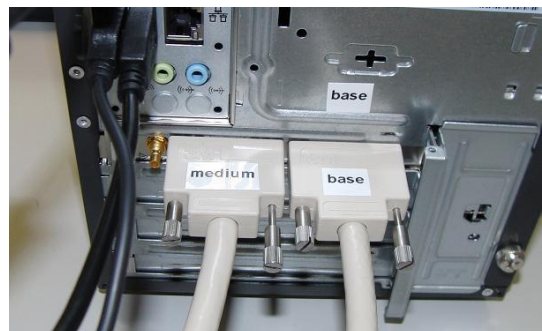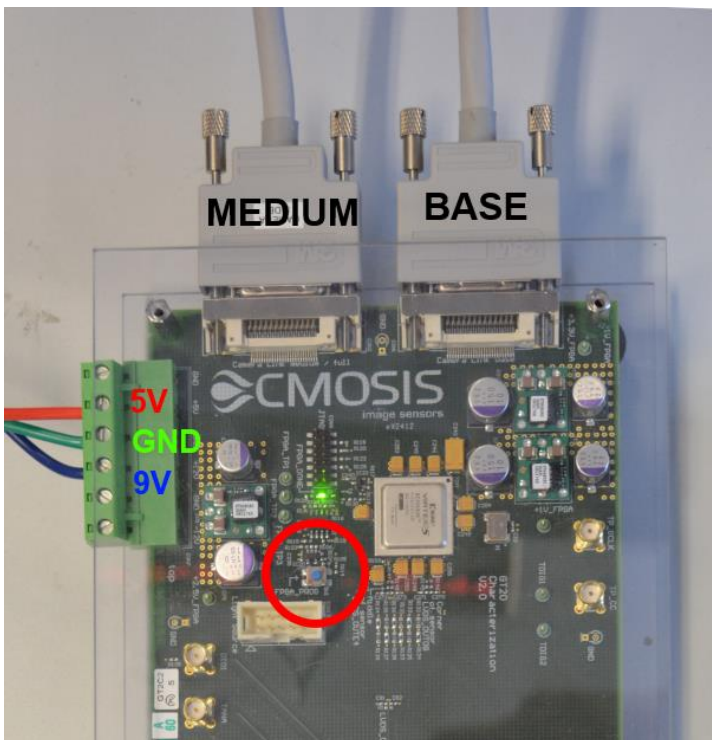
Note:

The FPGA configuration is stored in an EPROM on the PCB. The FPGA is configured automatically when the power is switched on. On the PCB, there is a push button (labeled reset) that can be used to manually reconfigure the FPGA (resets the FPGA and initialize configuration when pressed).

4 RUNNING THE SYSTEM

4.1 STARTING THE SOFTWARE

Power on the power supply and wait for the green LED to light up (FPGA is programmed) before starting the software.

Log on to the PC using the 'demo user' account. No password is needed.

On the Desktop, there is a link to the demo software executable, called "Demo Software CMV20000.exe". Double clicking this shortcut will launch the demo software.

4.2 SOFTWARE OVERVIEW

Next figure shows a screenshot of the demo software.
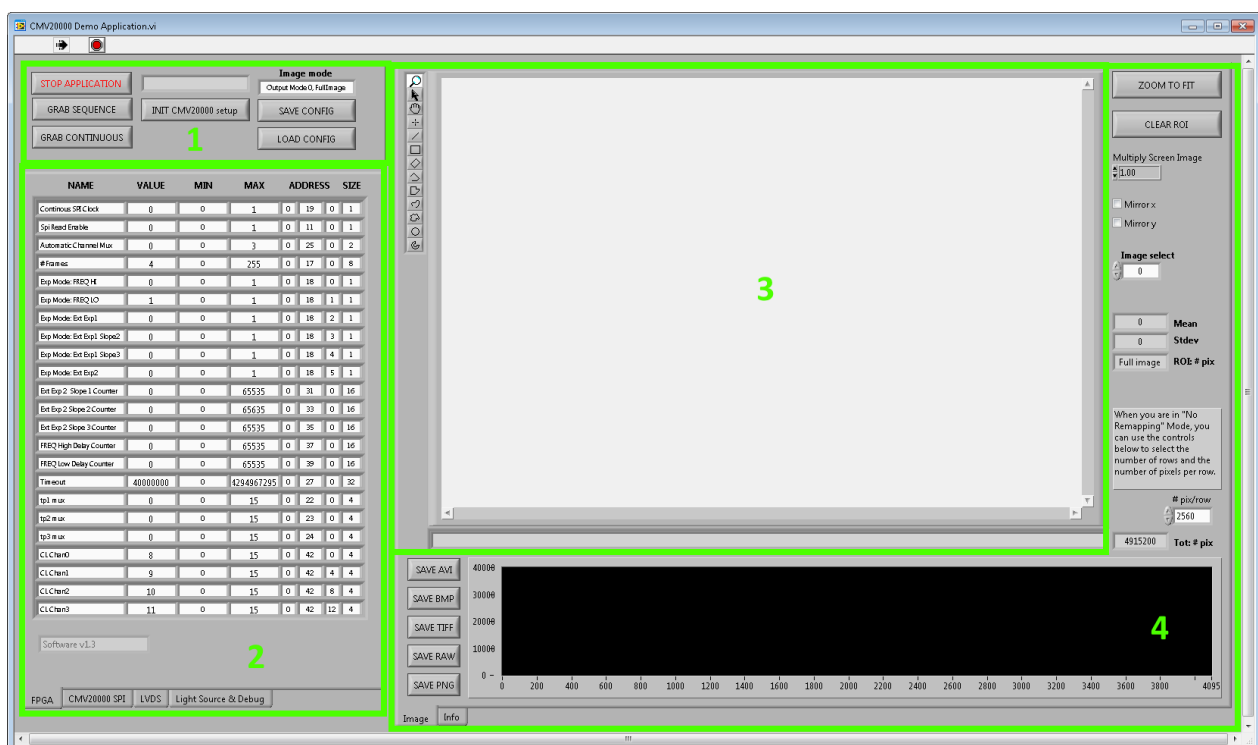
The four main areas of the software are:

1. **Control area:** The user can control the software (grab frames, save and load configuration files …) via a number of push buttons.
2. **Register settings area:** The user can set the registers of the sensor. The registers are grouped into a number of tabs for better readability.
3. **Image area:** The images acquired from the sensor are displayed in this image viewing plane.
4. **Image statistics area:** A number of image and software statistics are displayed here.

Next section will explain the different software functions in more detail.

4.3   SOFTWARE DETAILS

4.3.1   CONTROL AREA
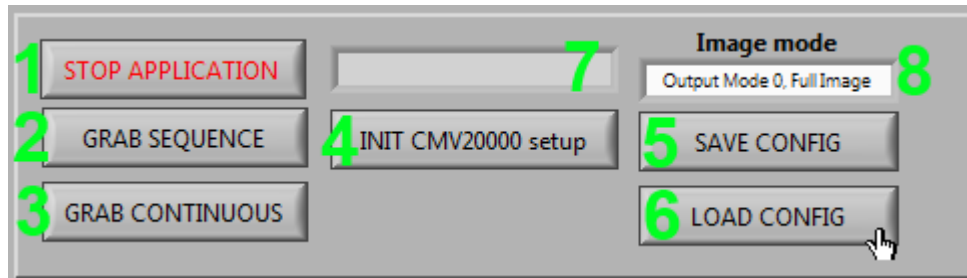
The 9 controls in the Control Area are:

1. **STOP APPLICATION** button: Click this button to stop the application from running and exit to the labview run-time environment. Then the window can be closed. It is required to use this button to stop the program, instead of closing the window while it is still running.
2. **GRAB SEQUENCE** button: Click this button to grab a single sequence of frames. The number of frames in the sequence is set in the 'register settings area' of both sensor and fpga (needed for possible composing of a full resolution image with multiple frames). When the single grab has finished, the 'image 'area' will be updated.
3. **GRAB CONTINUOUS** button: This button has the same function as the 'grab single' button. The difference is that this button has a different latching action. By clicking it once, it will be enabled. As long as it is enabled, the software will continuously request sequences of frames and update the image area. This mode is also called 'video mode'. To stop the video mode, click the 'grab continuous button' again. This will reset the button to its disabled state.
4. **INITIALIZE** button: Click this after you have loaded a config file or after some strange behavior of the program. This will reload the fpga with the register settings in the register settings area (which are set by a config file), reset the sensor, upload the registers to the sensor and do an LVDS training.
5. **SAVE CONFIG** button: By clicking this button, a configuration file can be saved. A configuration file is a human-readable version of the sensor register map. The saved text file has the same information as the register map that is saved using the 'save regmap button'. The advantage of a configuration file is that it can be reloaded into the software using the 'load config button'. (Tip: save the configuration files with a .txt extension).
6. **LOAD CONFIG** button: By clicking this button, a configuration file can be loaded into the software. When this is done, all settings from the 'register settings area' are overwritten with the information from the configuration file. The new settings are automatically transferred to FPGA and sensor (no need to click the 'reload FPGA button' after loading a configuration file). (Tip: it is allowed to load a configuration file while in video mode. The new settings will reflect in the images immediately.)
7. **MESSAGE**: This text box contains information about what the sensor is currently doing or if an error occurs during image grabbing, it is reported in this text box.
8. **IMAGE MODE**: Here you can select which output mode and remapping you want to use (16/8/4ch)

Note: On the Desktop of the evaluation PC, there is a configuration file. This file has been saved using the 'save config button'. You can load this configuration file into the software with the 'load config button'. This configuration file contains the advised values for optimal sensor operation.

4.3.2 REGISTER SETTINGS AREA

The 'register settings area' can be used to change all sensor and fpga registers. All registers in the sensor can be changed or readout from here. Most of these settings can be left unchanged by the user of the evaluation system.

Every register setting in this list refers to a sensor register (see data sheet for complete register map). The user of the evaluation system can only change the 'value' of the registers. The other entries are informational. (Tip: the register addresses (third column from the right) match the address values in the register map in the datasheet).

Upon hitting the enter key after changing a value of a register, it is uploaded to the FPGA; pressing the up/down arrow key will increase/decrease the value and immediately upload it to the sensor/fpga. The changes will reflect immediately in the displayed images.

NAME	VALUE	MIN	MAX	ADDRESS				SIZE
Nr Frames Lo	4	0	65535	1	22	0	16	
Start Lo	0	0	3840	1	24	0	16	
Nr Lines Lo	3840	0	3840	1	26	0	16	
Sub1 Lo	0	0	65535	1	28	0	16	
Sub2 Lo	0	0	65535	1	30	0	16	
Exp Time1 Lo	200	0	65535	1	32	0	16	
Exp Time2 Lo	0	0	65535	1	34	0	16	
Exp dual Lo	0	0	1	1	36	0	1	
Nr slopes Lo	1	0	3	1	37	0	2	
Exp S2 Lo	0	0	65535	1	39	0	16	
Exp S3 Lo	0	0	65535	1	42	0	16	
Multiwin_en	0	0	1	1	44	0	1	
Number Lines	0	0	3840	1	45	0	16	
Start1	0	0	3840	1	47	0	16	
Start2	0	0	3840	1	49	0	16	
Start3	0	0	3840	1	51	0	16	
Start4	0	0	3840	1	53	0	16	
Start5	0	0	3840	1	55	0	16	
Start6	0	0	3840	1	57	0	16	
Start7	0	0	3840	1	59	0	16	
Start8	0	0	3840	1	61	0	16	
Nr Lines1	0	0	3840	1	63	0	16	
Nr Lines2	0	0	3840	1	65	0	16	
Nr Lines3	0	0	3840	1	67	0	16	
Nr Lines4	0	0	3840	1	69	0	16	
Nr Lines5	0	0	3840	1	71	0	16	

| FPGA | CMV20000 SPI | LVDS | Light Source & Debug |

4.3.3 IMAGE AREA

The images that are acquired from the sensor are displayed in the 'image area'. Only one image is displayed. If a sequence of frames is acquired, the entire burst is in the memory. A selection switch in the 'image statistics area' can be used to select which frame from the sequence is displayed. With right-clicking on the image you can save the image as is shown on the screen. This will not save the image as it comes out of the sensor (see next section).

Next to the image plane is a small toolbar with image controls. These can be used to zoom in the image and to select region of interest (ROI) contours for the image statistics. Next figure shows this toolbar.

Of these tools, the following 5 are most commonly used:

1. **ZOOM**: When selected, the mouse pointer turns into a magnifying glass when moved over the image. Every click will zoom into the image by 1X. When holding the SHIFT key on the keyboard, the mouse pointer will turn into a magnifying glass with a small 'minus sign' in it. Clicking in the image with the SHIFT key held will zoom the image out by 1X.
2. **PAN**: When the image is zoomed, this function allows the user to pan the image.
3. **POINT ROI**: Allows the user to set an ROI in the image of exactly 1 pixel. Click on the image to place the point ROI.
4. **LINE ROI**: Allows the user to set a line ROI in the image. Click on the image to set the first point of the line. Hold the left mouse key and drag to where the end point of the line should be. Release the left mouse button to place the line.
5. **RECTANGLE ROI**: Allows the user to set a rectangular ROI in the image. Click on the image to set the first corner of the rectangle. Hold the left mouse key and drag to the point where the opposite corner of the rectangle should come. Release the left mouse button to place the rectangle.

More information on the ROI statistics can be found in the 'image statistics area' section.

4.3.4 IMAGE STATISTICS AREA

Next figure shows the image statistics area.
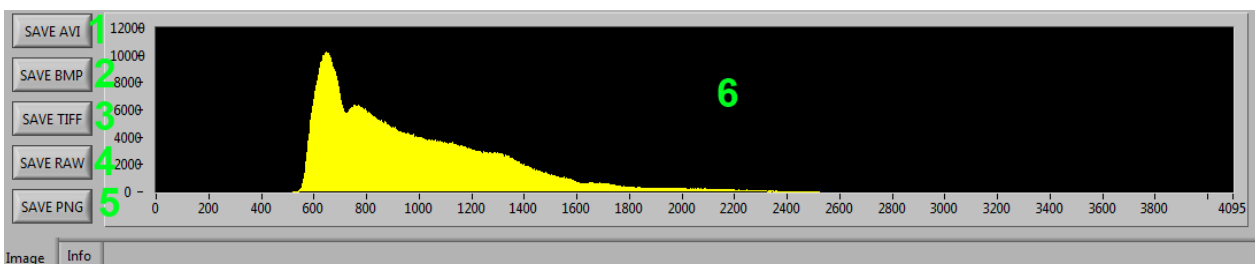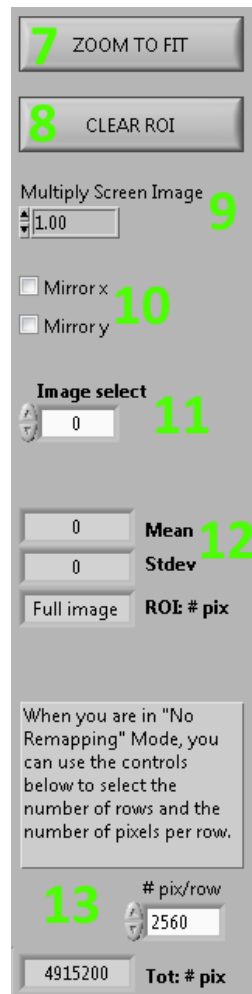
The 'image statistics area' consists of:

1. **SAVE AVI** button: If a sequence of images is acquired, the entire sequence can be saved as a movie (5fps) with the avi format. Click the button and select the path and file name for the movie.
2. **SAVE BMP** button: Clicking this button will save the requested images in a bmp file format. Set the path and name and the software will automatically add the frame number per image. Because of bmp limitations the files will be split up in an 8bit file containing the 8MSB's and a 8bit file with the 8 LSB's.
3. **SAVE TIFF** button: Clicking this button will save the requested images in a 16bit tiff file format. Set the path and name and the software will automatically add the frame number per image.
4. **SAVE RAW** button: Clicking this button will save the requested images in a raw file format. Set the path and name and the software will automatically add the frame number per image. The raw files have an image offset of 8 bytes.
5. **SAVE PNG** button: Clicking it will save the images in a 16bit lossless PNG file format.
6. **HISTOGRAM**: Shows the 12-bit histogram of the image that is displayed in the 'image area'. (Note: see next section for explanation of ROI image statistics)
7. **ZOOM TO FIT**: Clicking this button will zoom so the image on screen fits the window.
8. **CLEAR ROI**: Clicking this button will clear the selected ROI.
9. **Multiply**: This will digitally amplify the image on screen. This will only be showed in the image on screen and not in the images when clicking the SAVE buttons. Right-clicking on the image will give you the option to save the image as it is shown on screen.
10. **MIRROR**: This will mirror the image on screen in the X- or Y-axis. This is not saved when clicking the SAVE buttons.

11. **IMAGE SELECTION** control: If a sequence of more than one image is grabbed from the sensor, this control is used to select which of the images is displayed in the 'image area'. The index number '0' identifies the first image of the sequence. If the selection index is larger than the number of frames-1, the 'image area' shows no image.

12. **IMAGE INFORMATION**: Show the average and standard deviation of the selected image in 12-bit values. (Note: see next section for explanation of ROI image statistics). Also the size of the ROI is shown.

13. **#ROWS and #PIX/ROW**: When you select the "No Remapping" mode, you can here select how many rows and how many pixels per row will be showed. (#ROWS is automatically using the sensor window register Nr Lines Lo in v1.3).

4.3.4.1 IMAGE STATISTICS IN ROI MODE

By default, the image statistics apply to the entire image. If statistics of certain areas in the image are desired, the ROI functionality can be used. If an ROI is placed on the image, all statistics that are displayed (histogram, average and standard deviation) are of all pixels that are defined by the ROI.

Next figures show examples of the ROI results for different ROIs on the same image. In the examples, note histogram, the average and standard deviation values and the 'ROI # pix' value.
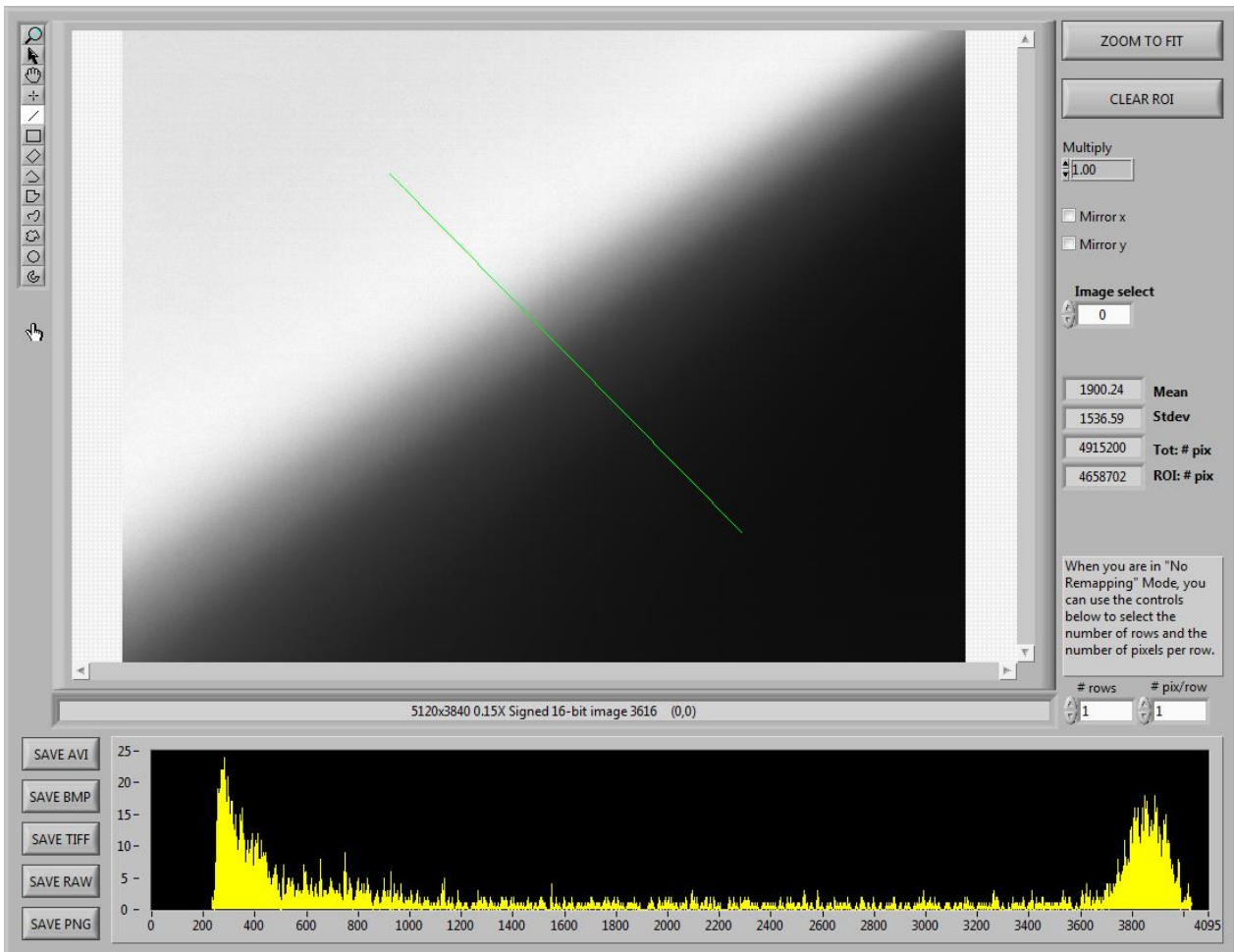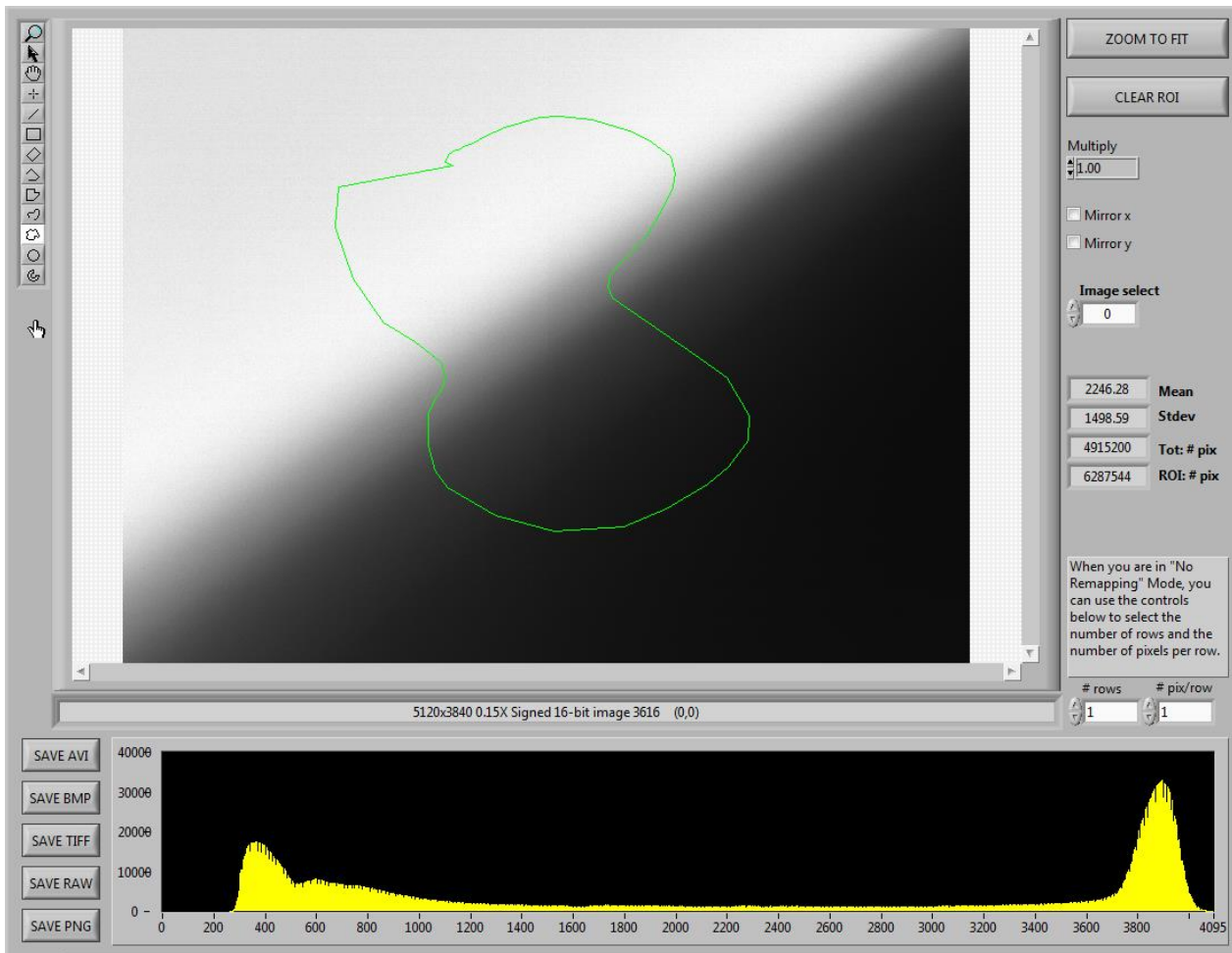
No ROI:
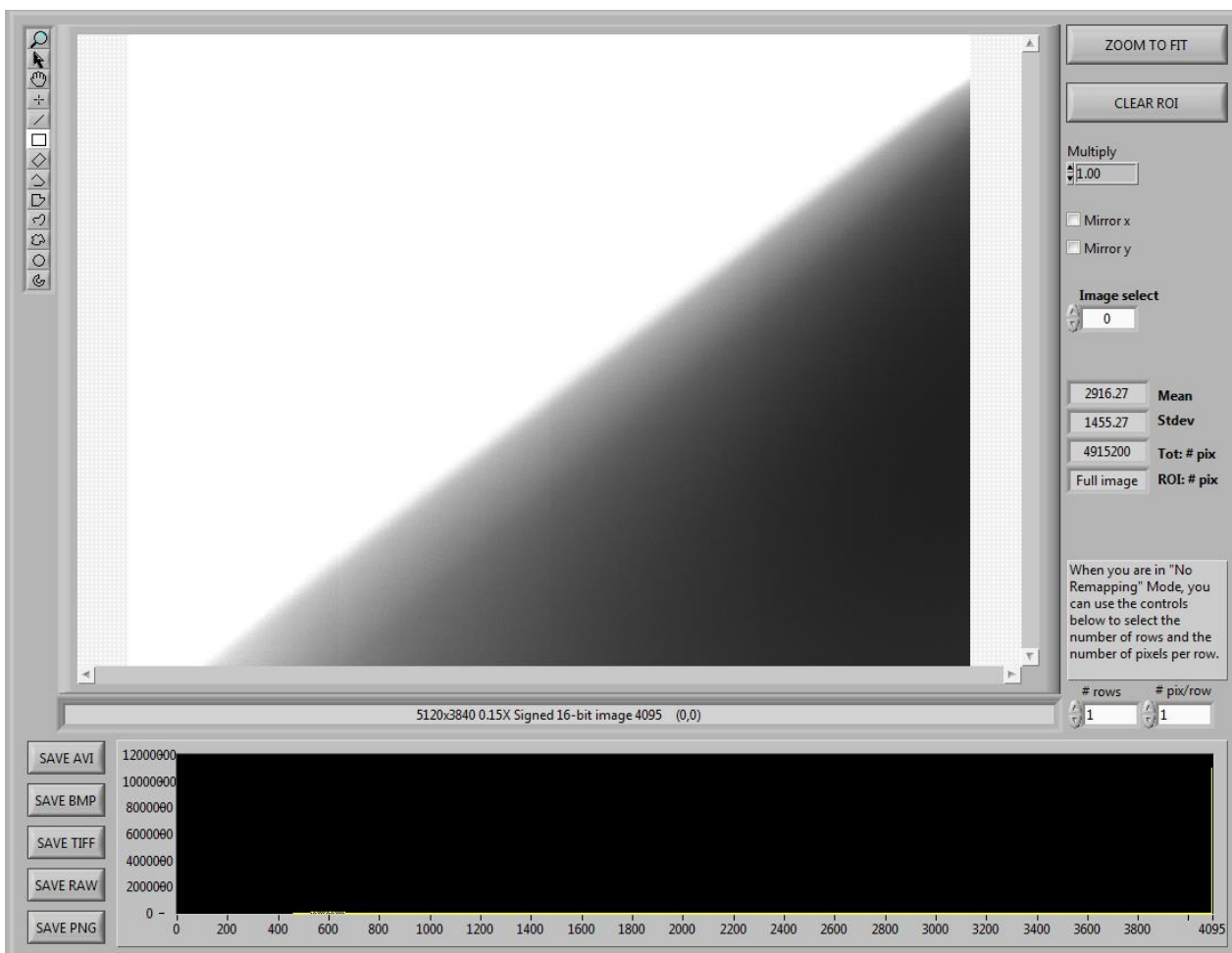
Rectangle ROI:
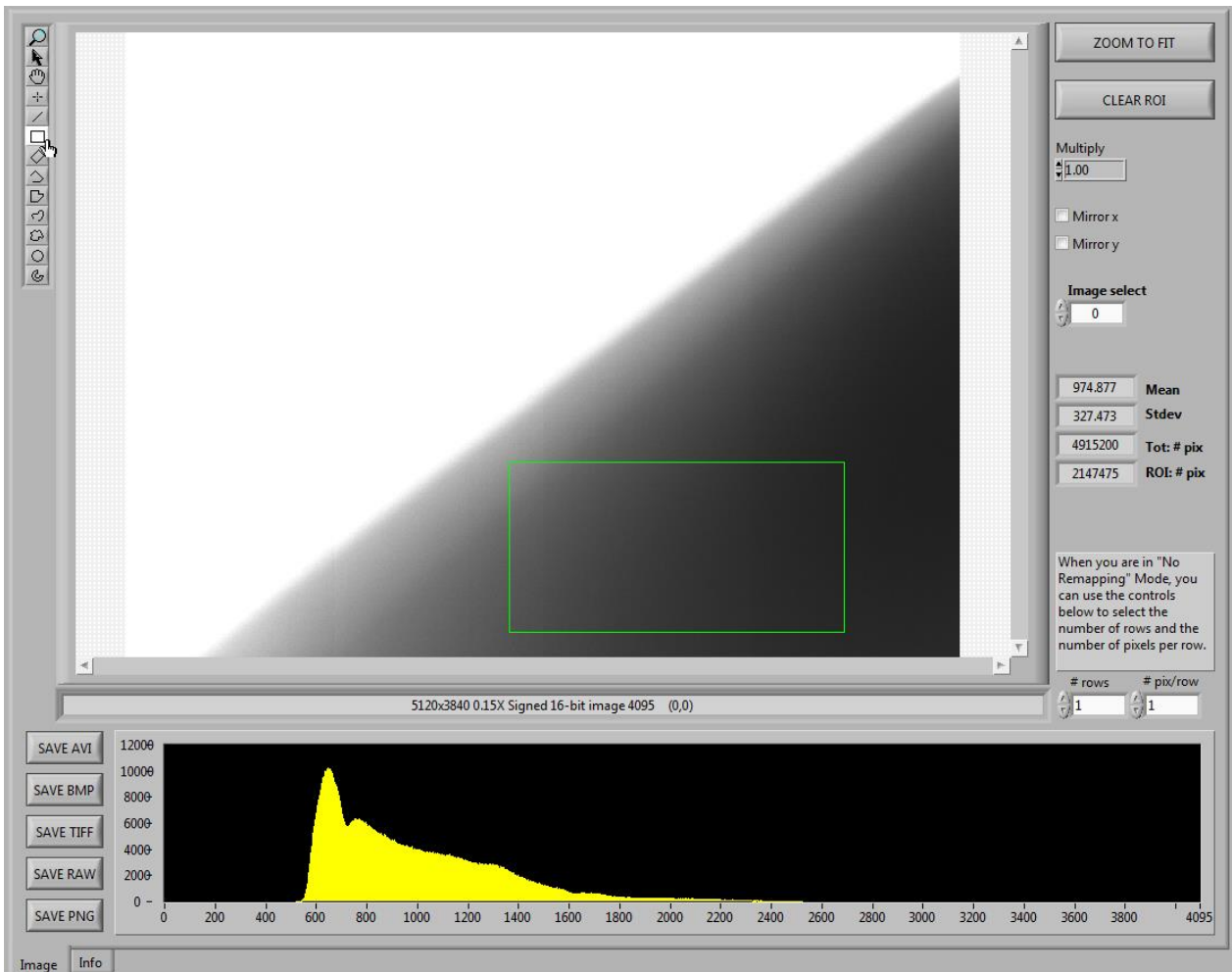
Line ROI:

Free form ROI:

4.3.5 SOFTWARE STARTUP

After the software is started, load a configuration file (LOAD CONFIG) and click the INITIALIZE button, to initialize the sensor. This does a sensor reset, uploads the registers currently filled in the register list and does LVDS training. If that is OK a frame will be taken. If you see an image, the system is working fine.
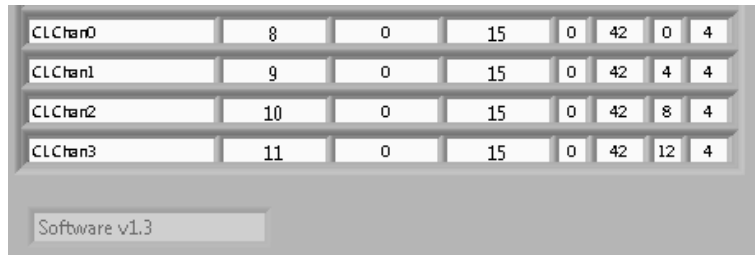
4.3.6 GRABBING MULTIPLE FRAMES

Because (in some modes) the sensor will take more frames to make one full resolution frame, you will have to set the number of frames you want to take in both the sensor register (SPI tab). In Mode 0, these will have to be set to a multiple of 4. In Mode 1 this has to be a multiple of 2. In No Remapping mode this can be any integer. Both registers have to bet set to the same value.

SENSOR REGISTER					
NAME	**VALUE**	**MIN**	**MAX**	**ADDRESS**	**SIZE**
Nr Frames Lo	4	0	65535	1	22	0	16
Start Lo	0	0	3840	1	24	0	16

FPGA REGISTER					
NAME	**VALUE**	**MIN**	**MAX**	**ADDRESS**	**SIZE**
Continous SPI Clock	0	0	1	0	19	0	1
Spi Read Enable	0	0	1	0	11	0	1
Automatic Channel Mux	0	0	3	0	25	0	2
# Frames	4	0	255	0	17	0	8
Exp Mode: FREQ HI	0	0	1	0	18	0	1

4.3.7 NO REMAPPING MODE

When selecting No Remapping in the Image Mode Selection box, 4 channels will be shown. These channels are placed net to each other in the image without any pixel remapping (like odd/even). In the FPGA registers tab, you can use the "CL Chanx" registers to select which 4 sensor channels you want to show in the image. If you grab multiple images in this mode, this will be consecutive images at full speed (but only 4/16th of the total resolution).

CLChan0	8	0	15	0	42	0	4
CLChan1	9	0	15	0	42	4	4
CLChan2	10	0	15	0	42	8	4
CLChan3	11	0	15	0	42	12	4

Software v1.3

4.3.8 ERRORS

When something goes wrong during frame grabbing you will get an Error message. The LabView program stops its running state. You will have to click on the black arrow on the left top side of the window to start the program again and enter its running state. Also closing the application and restarting the executable will work.

Try to fix the error by resetting the sensor (to the default register values as stated in the datasheet or given config file), initialize and then read-out the registers to see if there are any conflicts (=red light) in the registers.

Then look at the LVDS training on the LVDS tab, to see if the FPGA can train OK on the sensor data (the last column should all one's).

NAME	VALUE	MIN	MAX	ADDRESS		SIZE	
Training Pattern	63	0	4095	0	15	0	12
Training Channel End	0	0	16	0	21	0	5

start mid end word (n)ok

start	mid	end	word	(n)ok	
29	39	50	3	1	Control Channel
23	34	45	17	1	Output Channel Odd 8
32	43	54	17	1	
13	22	32	2	1	
22	32	42	2	1	
30	40	50	2	1	
9	19	30	3	1	
18	28	39	3	1	
27	38	49	3	1	Output Channel Odd 1
22	32	43	17	1	Output Channel Even 8
31	42	54	17	1	
12	22	32	2	1	
21	31	41	2	1	
30	40	50	2	1	
10	20	31	3	1	
18	28	39	3	1	
28	39	50	3	1	Output Channel Even 1

22	32	43

Read Registers
☑ OFF/ON

RUN TRAINING

FPGA   CMV20000 SPI   LVDS   Light Source & Debug

If everything fails, close the application, power off the power supply, check the CameraLink cables. Power on the supply, wait for the green PCB LED to come on and start the executable again.