FCi$_4$-14000 Manual

C-Cam Technologies

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IMPORTANT NOTICE

The screw-locking connectors used on our cameras have been chosen for their industrial qualities and are not intended to be “hot-pluggable”.
The data interface cable should never be plugged or unplugged at the camera end while under power. Failure to observe this restriction can result in damage to the camera’s interface.

Contents

1 Introduction

The FCi4-14000 camera is a linear response camera using an IBIS4-14000 CMOS imager which is a 13.9 M pixel sensor arranged in 4560 horizontal and 3048 vertical pixels, with a horizontal rolling shutter. The sensor measures 24mm by 36mm, which corresponds to the standard 35mm format, and can use the same lenses as conventional 35mm cameras.

The camera is available in color and monochrome versions. The color sensor is identical to the monochrome with the addition of a Bayer color filter array that is overlayed on top of the pixels.

The camera has a 12-bit digital output and is available with a Base Camera Link interface and a USB interface. Other features of the camera are: optically isolated external trigger input and flash output, non-volatile storage of camera parameters and first-order calibration algorithms inside the camera.

This document describes the usage of this camera and provides a software example.

If you have any questions regarding this document, please e-mail to c-cam@vector-international.be. We will be glad to help you.

The engineering team of C-Cam hopes you enjoy their effort in enhancing the industrial digital camera revolution.

C-Cam Technologies

2 Camera Specification

2.1 Windowing

The camera accepts a flexible Window-Of-Interest (WOI) command that allows selection of almost all possible windows in the focal plane of the sensor. The advantage of windowing is that, the smaller the window, the higher the frame rate will be. The word ‘almost’ is used because there are some minor restrictions.

The WOI is programmed by setting the X- and Y-start position and the X- and Y-end position of the window. These values are set in pixel numbers, using the corresponding WOI commands. There is a restriction in the X-direction, the start position and the width must be a multiple of 4 pixels.

When using USB to control the camera, use the `CC_SetWOI()` function from the Application Program Interface (API) library.

The maximum WOI is 4560 lines of 3048 pixels.

Note that the sensor aspect ratio is 3:2, and to achieve this aspect ratio a window of 4536 lines of 3024 pixels correctly matches this aspect ratio. The upper 24 lines are extra lines that can be read out, and the last 24 columns are extra columns that can be read out. For color versions of the camera these upper 24 lines and last 24 columns have a color filter array pattern that differs from the rest of the sensor and can thus not be used to make color images.

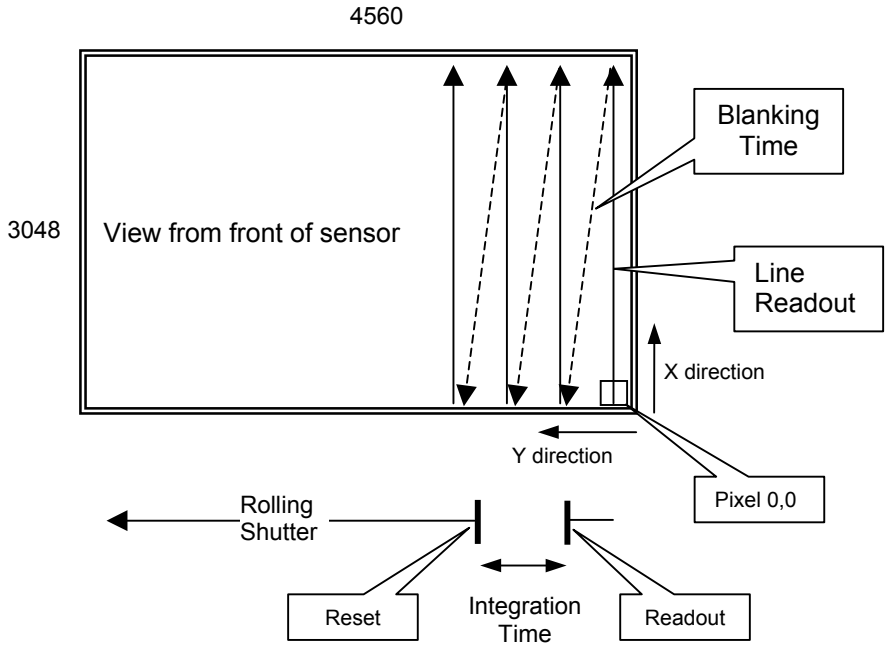
2.2 Readout

The sensor is dimensioned in “portrait” format. I.e. the height is greater than the width. However, the camera has the sensor mounted in “landscape” orientation.

The camera sensor is scanned using an electronic shutter rolling in the horizontal direction. This results in a readout line by line from right to left. (When looking at the sensor as mounted)

Note here that the “lines”, referred to by the Camera Link interface, are seen here as vertical columns.

The rolling shutter can be equated to the double curtain shutter in a classical film camera. The sensor is first reset line-by-line (curtain opening) then, after a time, it is read out in the same fashion (curtain closing). The time between the curtain opening and closing is the “exposure time” or integration time.



2.3 Frame Rate and Integration Time

2.3.1 Integration Time

The camera has a rolling shutter. Exposure of the pixels can occur simultaneously with the readout of the pixels. The line being read out can not be exposed to light at the same time.
The integration time can be as high as the frame readout time without reducing the frame rate. If the integration time becomes longer than the frame readout time, the frame rate will drop.

The integration time and the size of the active Window-Of-Interest (WOI) determine the total frame period.

The camera can work in continuous mode where the maximum frame rate can be achieved. I.e. without a pause between frames.

2.3.2 Frame Rate

To calculate the frame rate of the camera for any given Window-of-Interest we use the following formula:

Frame period = Width x (Height / 80 + RBT)

Where:

Height = WOI pixels in the vertical direction.
Width = WOI pixels in the horizontal direction.
RBT = Row blanking time = 28.5 us.
The pixel rate is equivalent to 60 Megapixels / second

E.g. Frame period of a full 4536 x 3024 image:

Frame period = 4536 x (3024 / 80 + 28.5) = 300,737 us.

This is equivalent to 3.32 frames per second.

E.g. Frame period of a WOI of 640 x 512 pixels:

Frame period = 640 x (512 / 80 + 28.5) = 22,336 us.

This is equivalent to 44.8 frames per second.

2.3.3 Relation between WOI, Integration time and Frame time

The three parameters: Window-of-Interest, Integration Time and Frame Time, all have an influence on the frame rate. The smaller the WOI, the higher the frame rate can be. If the Integration time is increased, there is a point where the frame rate will drop. Alternatively, the Frame time command can be used to set a pre-defined, fixed frame rate.

The frame rate is defined by which ever of the following values is the greatest:

- Frame period (calculated using the formula in 2.3.2)
- Integration time
- Frame time

2.4 Non-volatile memory

The camera contains non-volatile memory which can contain the FPGA configuration of the camera, a command list and calibration data.

When the camera is powered up, a micro-controller checks if a TTB configuration file is present and then loads it to the FPGA. When no configuration file is present, the FPGA remains un-configured and the user must load a configuration file before acquiring images. See the SDK manual for the commands to do this.

After FPGA configuration, a command file will be executed if present.

The maintenance program, “FCi4 control”, can be used to program the non-volatile memory with TTB and Command files. For more information refer to the user’s manual of this program.

The camera is factory calibrated but if the user wishes to calibrate for a specific environment, the calibration tool “FFC Wizard” (Flat Field Calibration Wizard) can be used to make new calibration data and to load this into the camera’s non-volatile memory.

Non-volatile memory type	Program	Remarks
FPGA configuration	FCi4 control	Factory programmed
Command list	FCi4 control	
Calibration data	FFC Wizard	Factory programmed

Please note that the API call `CC_LoadCamera()` does not program the non-volatile memory, but loads the configuration directly into the FPGA. After a power cycle, this configuration is lost.

3 Camera Control

The camera can be controlled via either the Camera Link interface or the USB interface. The following description explains how to control the camera via the Camera Link interface by using direct camera commands, and via USB by using API calls.

3.1 Image control

For diagnostic purposes, a test pattern can be generated by the camera.
When X-diag is set, a X pattern is generated with increasing values from left to right repeating each line.
When Y diag is set, a Y pattern is generated with increasing values from top to bottom repeating each column.

Direct camera command :

CC_MISC

-	-	X-diag	Y-diag	-	-	-	-
Bit 7	6	5	4	3	2	1	0

API call :

```
CC_SetParameter( hCam, CC_PAR_CAMERA_MODE, mode );
```

With hCam : Handle to the camera
mode : enumeration

- CC_CAMERA_NORMAL
- CC_CAMERA_DIAG_X
- CC_CAMERA_DIAG_Y

3.2 Data mode

The FCi4-14000 camera is a 12-bit camera, but the user can choose either 8-bit or 12-bit pixel resolution.

When the data mode bit is set, the camera outputs data in 12-bit format. When cleared, the camera outputs data in 8-bit format (8 most significant bits).

Direct camera command :

CC_MISC

-	-	-	-	Data mode	-	-	-
Bit 7	6	5	4	3	2	1	0

API call :

```
CC_SetParameter( hCam, CC_PAR_DATA_MODE, mode );
```

With hCam : Handle to the camera
mode : enumeration

- CC_DATA_8BIT_11_DOWNTO_4
- CC_DATA_16BIT_11_DOWNTO_0

3.3 Image processing

Several image processing algorithms are implemented inside the camera. All algorithms can individually be switched on or off by writing to one register.

Direct camera command :

C_PROC_CTRL

-	-	-	Mirror Y	Mirror X	Trans-pose	Photo mode	RAW
Bit 7	6	5	4	3	2	1	0

API call :

```
CC_SetParameter( hCam, CC_PAR_PROCESS_CONTROL, processing );
```

With hCam : Handle to the camera
processing : enumeration

- CC_PROCESS_RAW
- CC_PROCESS_PHOTO_MODE
- CC_PROCESS_TRANSPOSE
- CC_PROCESS_MIRROR_X
- CC_PROCESS_MIRROR_Y

3.3.1 Image correction

The FCi4-14000 camera is factory calibrated and will, by default, execute image correction using calibration information stored in the camera.
Image correction will perform Fixed Pattern Noise (FPN) and Photo Response Non-Uniformity (PRNU) correction for each pixel. Also bad or lazy pixels, columns or rows will be replaced by neighboring pixels in the image array.
When no image correction is required, or the user wants to make its own calibration under working conditions, image correction can be turned off and the camera will work in raw mode.
Re-calibration can be necessary, for example, for long exposure times.

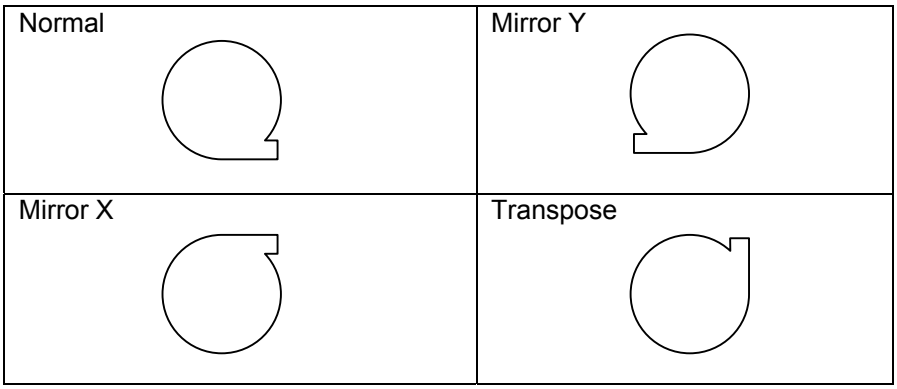
3.3.2 Photo mode

The CMOS image sensor of the FCi4-14000 camera is mounted in landscape format, and the sensors rolling shutter runs along the longest axis. Which actually means that images will be read out sideways (i.e. lines in portrait format). When the camera is mounted normally then a 90 degrees tilted image will result. For most industrial applications, this is no problem and in this mode, this highest frame rate can be achieved.
When a landscape image is required, the camera must be set into ‘photo’ mode. In photo mode, the user can select image-processing algorithms that are only available for this mode. When the camera operates in this mode, a frame must be completely stored in the cameras memory before it can be processed. This also means that the maximum frame rate will be lower.

Following algorithms are currently supported:

- Transposition: rows and columns are exchanged which results in landscape images.
- Mirror X: mirrors the image along the X axis.
- Mirror Y: mirrors the image along the Y axis.

Any combination of the above algorithms can be activated.
Please note that the Mirror X and Mirror Y processing when combined with transposition applies to the original 'non-transposed' image.



Note for Camera Link users :
When the Camera Link interface is used, then the geometry changes from 2-tap to 1-tap when using photo mode. This does not slow down the transmission process because in photo mode, the line blanking time of the Camera Link interface is almost zero.

When transposition is enabled, the Camera Link interface will enable the use of the DVAL signal.

Photo mode	Algorithm	Camera Link geometry
No	-	Dual tap, no DVAL
Yes	No transposition	Single tap, no DVAL
Yes	Transposition	Single tap with DVAL

Remarks :

1. After applying the transposition operation, a call to the `CC_SetWOI()` function must be done with the x and y parameters switched, otherwise an incorrect window of interest will be returned.

2. The DVAL signal is always used but will be equal to the LVAL signal for other processing algorithms then transposition.

3.4 Trigger modes

The FCi4-14000 camera can be triggered in several ways. The various trigger modes have an influence on the frame rate, integration time or camera operation.

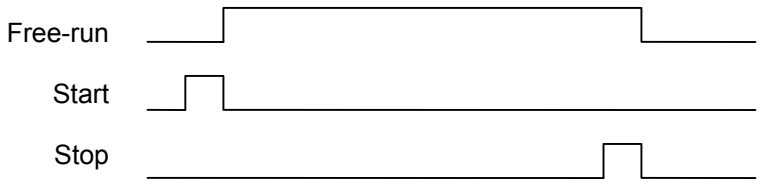
There are three possible trigger sources:

- Software trigger by means of a Start command.
- External trigger applied to the trigger connector of the camera (trigger input).
- Camera Link trigger applied on the control lines (CC1 – CC4) of the camera link interface. (Activated by the frame grabber)

The external trigger input and the Camera Link control lines are referred to as external syncs or ExtSync in the following diagrams.

3.4.1 Software trigger

When a Start command is sent to the camera, the camera starts transmitting a single frame or frames continuously (free-run) until a Stop command is sent to the camera.

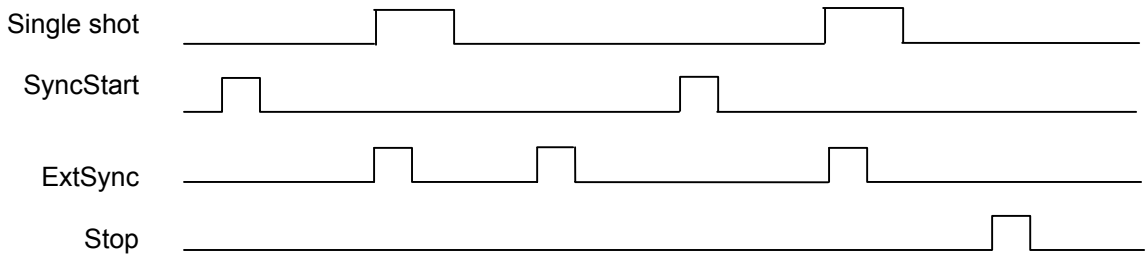


The table shows which commands apply to this mode:

Command	Remarks
FF80	To start the camera in single shot
FF82	To start the camera continuously based on frame time
FF86	To start the camera in continuous mode. (as fast as possible)
FFFC	To stop the camera

3.4.2 ExtSync trigger

When a SyncStart command is sent to the camera, the camera waits for the ExtSync signal before starting free-run. The polarity of the ExtSync signal can be set with the Trigger Control command. A Stop command stops the camera.



The table shows which commands are needed to use this mode:

Command	Remarks
D5xx	Trigger command parameter (see 3.4.5)
FC29, FDxx	Trigger source (see below)
FF81	To arm the camera to wait for the ExtSync signal
FFFC	To stop the camera

To make the camera sensitive to every ExtSync signal without the need of a SyncStart signal, use the command D504.

Specify the trigger source using the command pair FC29, FDxx where xx is as follows:

Trigger source

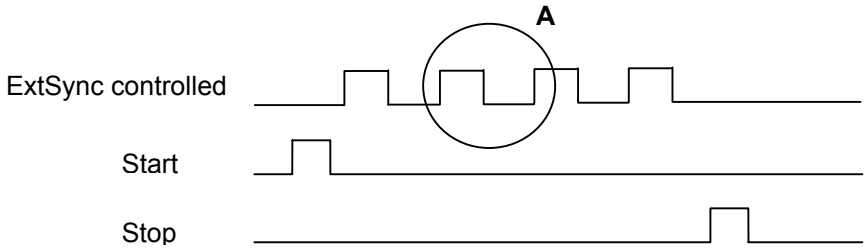
-	-	-	-	Trigger source			
Bit 7	6	5	4	3	2	1	0

Bits 4 .. 7 : future use

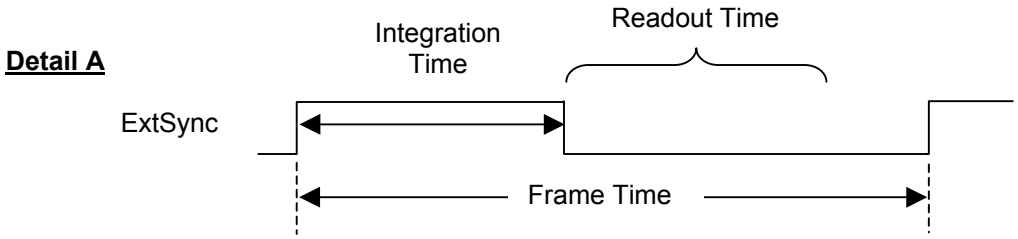
0	Local camera ext. trigger
1	CC1 on CameraLink
2	CC2 on CameraLink
3	CC3 on CameraLink
4	CC4 on CameraLink
5..15	(future use)

3.4.3 ExtSync controlled integration time

When a start command is sent to the camera, the camera starts transmitting frames controlled by the ExtSync signal until a stop command is sent to the camera. The ExtSync controlled mode can be enabled or disabled by a separate command.



The period of the ExtSync signal determines the frame rate of the camera. Integration of the sensor is determined when the ExtSync signal is high. The frame time must not be shorter then the sum of the integration time and the readout time.



The table shows which commands are needed to use this mode:

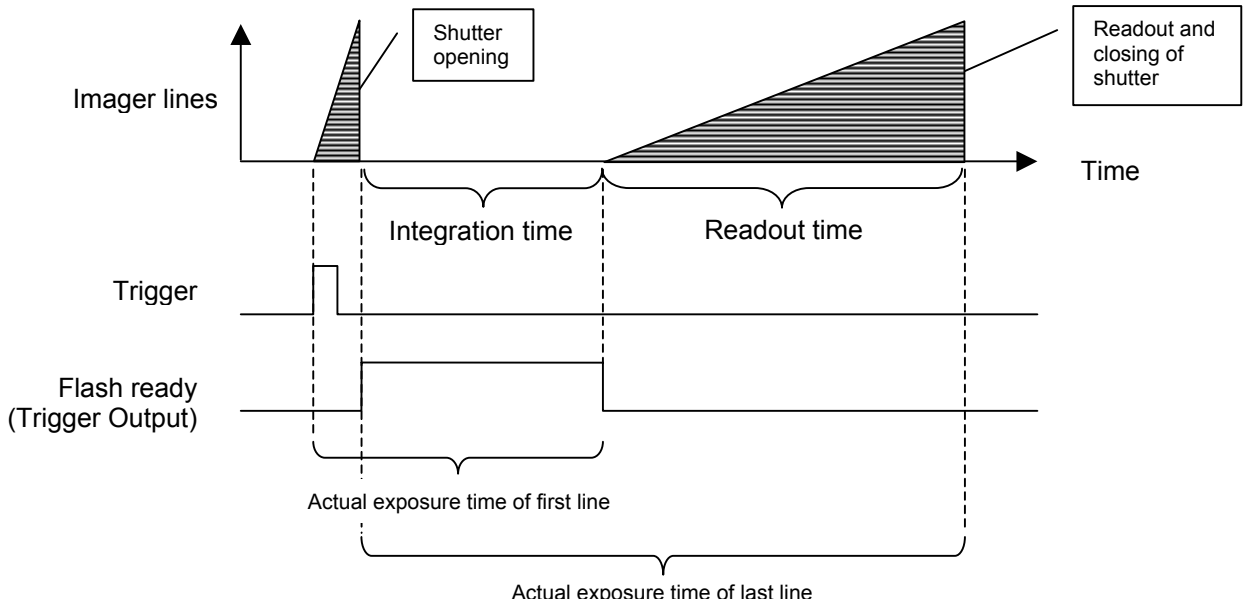
Command	Remarks
D5xx	Trigger command parameter (see 3.4.5)
FC29, FDxx	Trigger source (see 3.4.2)
FFC9	Enable ExtSync controlled integration time
FFC8	Disable ExtSync controlled integration time
FFFC	To stop the camera

3.4.4 Flash mode

Since the imager of the FCi4-14000 camera has an electronic rolling shutter, a snapshot of a moving object can give a slanted image. This effect is caused by the time difference of each line that is exposed to light. To overcome this, the flash mode can be useful.

In normal operation the electronic shutter is opened at the same speed as pixel readout, the opening shutter rolling over the sensor like a curtain.
When the camera is set to flash mode, the shutter is opened very quickly (approx. 30 ms for a full frame) and stays open during the programmed integration time,
During this period an optional “flash ready” signal can be set on the trigger output. This signal can be used to trigger an external flash unit.
After the integration time the imager is readout at normal speed.

Please note that, during the readout period, the image sensor is still sensitive to light causing the last line to be exposed to light longer than the previous lines. With constant lighting this would create an image with a gradient from darker (first line) to lighter (last line). The flash mode is therefor best used in dark or low light conditions. Alternatively the user can compensate for this effect in software.



The trigger can be a software trigger or an ExtSync trigger.
The table shows which commands are needed to use this mode:

Command	Remarks
D5xx	Trigger command parameter (see 3.4.5)
FFCD	Enable flash mode
FFCC	Disable flash mode
FFFC	To stop the camera

To activate the flash ready trigger output, use the command 0xD520.

3.4.5 Trigger command parameter

This parameter can be set with the D5xx command when using Camera Link interface, or can be set with the API function `CC_SetParameter( MyCam, CC_PAR_CAMERA_TRIGGER_SETTINGS, Value );`
The bit name column refers to the use with the API, the bit# column refers to the use with Camera Link commands.

Bit name	Bit #	Description
CC_CAMERA_TRIGGER_INVERT_TRIGGER_IN	0	Makes the trigger input active high, the default is active low.
CC_CAMERA_TRIGGER_INVERT_TRIGGER_OUT	1	Makes the trigger output active high, the default is active low.
CC_CAMERA_TRIGGER_ARM	2	Use this setting if the camera should be armed without using one of the capture functions.
CC_CAMERA_TRIGGER_ARMED_OUTPUT	3	To use the trigger output signal as an arm ready signal. The default is that the trigger output is used as a flash output (see flash settings).
CC_CAMERA_TRIGGER_FLASH_ENVELOPE	5	To use the trigger output signal as a flash enable signal when the camera is in flash mode.

For a complete description on using the external triggering of the camera refer to the “Trigger IO” manual.

4 Camera Commands

4.1 Camera Link serial channel

Camera commands are sent via the Camera Links serial channel. All Camera Link compatible frame grabbers provide user-functions that can be used to send commands to the camera. These functions all reside in a separate library or DLL file. The filename of this DLL is CLSERxxx.DLL where xxx is specific to each vendor. These functions are:

- `clSerialInit`
- `clSerialWrite`
- `clSerialRead`
- `clSerialClose`

Please refer to the Camera Link specification for more information.
The serial channel of the camera operates at 9600 baud, 8N1 format.

4.2 Command Message format

Two message formats are implemented into the camera, a complex message format and a simple message format. The complex format is used when large records are to be sent to the camera and checksum control is needed. The simple format is best used to change camera parameters and can easily be implemented into the custom format messages of the framegrabber software of your specific vendor.

4.2.1 Complex message format

Complex Command messages use the standard (Intel) format for HEX records.

The message consists of ASCII characters 0 to 9 and A to F except for the first character, which is a colon.

Commands sent to the camera with the `clSerialWrite` function have the following message format:

:	Length	Address	Record type	Data	Checksum

Field explanation :

:	The first character indicating the start of a new message
Length	The length of the Data field in bytes (= number of characters / 2). Is always ‘02’
Address	This field always contains ‘0000’
Record type	Must always be ‘BC’
Data	This field contains 2 bytes (4 characters) that contains the actual camera command (see command list)
Checksum	8 bit checksum code. Sum, modulo 256, of all fields (bytes) except the ‘:’ including checksum field must be zero.

Example :

`:020000BCFF80C3` (Camera start command = FF80 hexadecimal)

Checksum = 256 – Mod^{256}(02 + 00 + 00 + 0xBC + 0xFF + 0x80) = 0xC3

4.2.1.1 Complex message response format

The camera always responds with one of two characters:

ACK	0x06	Command accepted
NACK	0x15 (21 decimal)	Checksum or length error

4.2.2 Simple message format

The simple message format is defined as follows :

```
#<cmd>=<value><cr>
```

with :

#	Command format indicator.
<cmd>	Command existing of 2 or 3 characters (A – Z) or 2 characters with an index of 2 hexadecimal numbers (eg XB08), for a list of possible commands see paragraph 4.3.
=	command and value seperator
<value>	Decimal or hexadecimal value ranging from 0 to 4294967295 (32 bit). If the number is hexadecimal, then an 'h' must follow the value (eg E560h).
<cr>	Carriage return (0x0d) indicating the end of the message.

Example : set the window of intrest to full frame

```
#WYS=0<cr>
#WYH=4560<cr>
#WXS=0<cr>
#WXW=3048<cr>
```

4.2.2.1 Simple message response format

When a message is recognized and accepted then the camera will respond with :

```
<lf>OK<lf><cr>
```

In all other cases the camera will respond with :

```
<lf>?<value><lf><cr>
```

with :

<lf>	Line feed (0x0a)
<value>	The translated hexadecimal value of the command message, containing 8 characters.
<cr>	Carriage return (0x0d) indicating the end of the message.

4.3 Command list

The commands are always 16-bit values with an op-code field of 4, 8, 12 or 16 bits and a parameter field of respectively 12, 8, 4 or 0 bits depending on the type of command. The parameter field is indicated by the 'x' symbol in the Command column.

Parameter	Simple command	Command (HEX)	Description
WOI Y start	WYS	FC38 FExx (LSB) FExx (MSB)	To define the width and height of the WOI, two possibilities exist : WXE and WYE requires the end pixel to be set. WXH and WYW requires the width and height of the window to be set. It is required that the WYS is followed by the WYE or WYH command. It is required that the WXS is followed by the WXE or WXW command. See also paragraph 2.1
WOI Y end	WYE,WYH	FC3A FExx (LSB) FExx (MSB)	
WOI X start	WXS	FC34 FExx (LSB) FExx (MSB)	
WOI X end	WXE,WXW	FC36 FExx (LSB) FExx (MSB)	
WOI Y increment	WYI	C0xx	Sets the Y increment value for sub-sampling (set to 1)
WOI X increment	WXI	D0xx	Sets the X increment value for sub-sampling (set to 1)
Integration time	INT	E0xx (LSB) E1xx E2xx E3xx (MSB)	Sets the integration time in units of 33 ns. (32 bit)
Frame rate	FT	FC10 FExx (LSB) FExx FExx FExx (MSB)	Sets the frame rate in microseconds. (32 bit value)
Camera start	SS	FF80	Start the camera, single shot
Camera triggered start	ST	FF81	Start the camera and wait for external trigger
Camera timed start	SF	FF82	Start the camera and run based on frame time
Camera start continuous	SC	FF86	Start the camera continuous
Camera stop	SX	FFFC	Stop the camera
Reset	RE	FFFD	Reset the camera's internal logic
Trigger control	TC	D5xx	See paragraph 3.4.5
Image control	DM	E7xx	See paragraph 3.1 and 3.2
Processing control	PC	FBxx	See paragraph 3.3
Sensor control		E8xx	Adjust Vddr voltage
		E9xx	Adjust VDDarray voltage
		EAxx	Adjust Offset

Control switches	CB	FFCx	Set / Clear control switches Where x denotes: Bits 3,2,1 = bit number Bit 0 = 0 for Clear = 1 for Set
Action		**Command**	**Effect**
Clear bit 2 Set bit 2 Clear bit 4 Set bit 4 Clear bit 6 Set bit 6 (other Bits are used for testing purposes)		FFC4 FFC5 FFC8 FFC9 FFCC FFCD	Image output via Camera Link Image output via USB Disable ExtSync controlled mode Enable ExtSync controlled mode Disable flash mode Enable flash mode

5 Camera control using USB

When using the USB interface for controlling the camera and / or capturing images from the camera, the SDK can be used for implementation in a user application.
Below is a summary of API calls that are used for the FCi4-14000 camera.

5.1 Camera parameters

The Window Of Interest can be set using the `CC_SetWOI` function.

The following parameters can be used with the `CC_SetParameter` function:

Parameter	Values	Description
CC_PAR_CAMERA_MODE	CC_CAMERA_NORMAL CC_CAMERA_DIAG_X CC_CAMERA_DIAG_Y	Diagnostic mode. See “Programmers Reference Manual”
CC_PAR_DATA_MODE	Enumeration	Set the cameras data mode for USB and Camera Link output. See “Programmers Reference Manual”
CC_PAR_PROCESS_CONTROL	Bit setting	See paragraph 3.3
CC_PAR_INTEGRATION_TIME	0 … 143165576	Sets the integration time in microseconds.
CC_PAR_REPEAT_TIME	32 bit value	Sets the frame rate in microseconds.
CC_PAR_SENSOR_RESET	-	Resets the cameras internal logic.
CC_PAR_CAMERA_TRIGGER_SETTINGS	Bit settings	See paragraph 3.4.5 and trigger IO manual.
CC_PAR_ANAVAL0	0 .. 255	Adjust Vddr voltage. Default = 0.
CC_PAR_ANAVAL1	0 .. 255	Adjust VDDarray voltage. Default = 0.
CC_PAR_ANAVAL2	0 .. 255	Adjust Offset. Set by calibration, if not calibrated then set to 195.

5.2 Capture functions

5.2.1 Sending images to the Camera Link interface

Use the following commands to send images to the Camera Link interface:

Function Call	Description
`CC_CaptureArm( hCam, CC_NO_TRIGGER );`	Make a single snapshot.
`CC_CaptureArm( hCam, CC_CAMERA_CONTINUOUS_TIMED );`	Continuous running single shots at a frame rate defined by frame rate parameter.
`CC_CaptureArm( hCam, CC_CAMERA_TRIGGER_SINGLE );`	Wait for trigger and make a single snapshot.
`CC_CaptureArm( hCam, CC_CAMERA_CONTINUOUS_ROLLING );`	Continuous running.
`CC_CaptureAbort( hCam );`	Aborts a continuous running process.

Please refer to the CCAPI manual for a detailed description of these functions.

5.2.2 Capturing images through the USB interface

To capture images through the USB interface, the same 'Arm' functions as described above can be used to initiate the transfer. The user must then call `CC_CaptureData()` to acquire the data of the images.
Also other capture functions can be used, please refer to the CCAPI manual.
See also the programming example in paragraph 6.

6 Programming example

6.1 Control via USB interface using the Software Development Kit (SDK)

This C programming example uses only basic functions from the programmers interface (API) with no error checking. This example is only meant to show what functions are needed and in which order. For a more complete and working example see the examples in the application directory.

This example opens the camera and initialises it, then it captures an image into a buffer and finally it closes the camera :

```
USHORT      buffer[3048*4560] ;
ULONG       picture_size ;
BOOL        ret ;
HANDLE      MyCam ;

MyCam = CC_Open( "FCi4-14000 USB", 0, CC_CAPTURE_WAIT ) ;
// following line not needed when camera is auto starting
ret = CC_LoadCamera( MyCam, "fci14000.ttb" ) ;
ret = CC_SetWOI( MyCam, 0, 0, 3047, 4559, 1, 1, CC_WOI_LEFTTOP_RIGHTBOTTOM,
     &picture_size ) ;
ret = CC_SetParameter( MyCam, CC_PAR_INTEGRATION_TIME, 30000 ) ;
// following line not needed when camera is calibrated
ret = CC_SetParameter( MyCam, CC_PAR_ANAVAL2, 195 ) ;
ret = CC_SetParameter( MyCam, CC_PAR_CTRLBIT, 513 ) ;
ret = CC_SetParameter( MyCam, CC_PAR_DATA_MODE, CC_DATA_16BIT_11_DOWNTO_0 );
ret = CC_SetParameter( MyCam , CC_PAR_CAMERA_MODE , CC_CAMERA_NORMAL ) ;
ret = CC_CaptureSingle( MyCam, buffer, picture_size*2, CC_NO_TRIGGER, 1, NULL ) ;
ret = CC_Close( MyCam ) ;
```

CC_Open must be the first function called before using any other function. (Note that the handle returned by CC_Open is used by all other functions).
The next functions to call is CC_LoadCamera if the camera is not self-starting.
All other functions before the CC_CaptureSingle function can be called in any order.
The last function to call is CC_Close.

For proper error correction, the returned value `ret` should be checked for TRUE. If `ret` is FALSE, then an error has occurred and you should call `GetLastError` to find out what went wrong.
You can find the appropriate error-value in CCAPIERR.H

6.2 Control by Camera Link interface

The following command sequence starts the camera running at full frame full speed.
The commands must be formatted according to the format specified in chapter 4.

Command	Remarks
FC38	Y-start = 0
FE00	
FE00	
FC3A	Y-end = 4559
FECF	
FE11	
FC34	X-start = 0
FE00	
FE00	
FC36	X-end = 3047
FEE7	
FE0B	
C001	Y-inc = 1
D001	X-inc = 1
FC10	Frame time = 0
FE00	
FE00	
FE00	
FE00	
E060	Integration time = 50 ms (value = 0x16E360)
E1E3	
E216	
E300	
E708	Data mode = 12 bit
EAC3	Only when camera is not calibrated
FF86	Start the camera in continuous mode

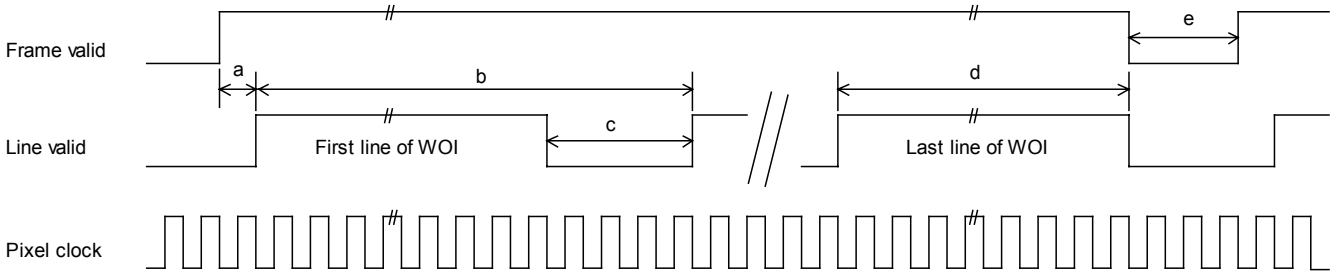
7 Camera Interface

7.1 Camera Link

7.1.1 Camera Link output signals

The FCi4-14000 has a Base Camera Link interface.
The signals provided are:

- Pixel Clock:
  The Pixel Clock is used by frame grabbers to synchronize with the cameras signals. Data is sampled and transmitted on the rising edge. The pixel clock frequency is 40 MHz. 2 pixels of 12 bits are transmitted during each clock cycle.
- Frame Valid:
  This signal becomes active when the transmission of a frame starts and stays valid during the complete transmission of the frame. The Line Valid and Video Data are only valid when this signal is valid.
- Line Valid:
  Line Valid indicates that the transmission of one line is busy. Between two lines, Line Valid will be inactive for a certain period of time depending on the row blanking time of the sensor.
- Data Valid:
  Data Valid indicates when the data bits contain valid pixel information. Data Valid is only used in one mode, in all the other modes, the Data Valid signal becomes equal to the Line Valid signal.
- Video Data:
  The Video Data contains 24 bits grouped in 2 taps of 12 bit. Data is only valid when Data Valid, Line Valid and Frame Valid are active.



Symbol	Min (ns)	Typical (ns)	Max (ns)
a	-	25	-
b		Depending on WOI and integration time	
c	100		
d		Depending on WOI and integration time	
e	100		-

7.1.2 Camera Link bit assignments

In the 2-taps configuration two consecutive pixels (A & B) are transmitted in each Camera Link transfer.

The following table lists the bit assignments that are used by the FCi4-14000 camera where DA refers to the data from the first pixel, and DB the second.

Configuration: 2 taps of 12-bits

Channel X	
Signal name	28-bit solution pin name TX/RX
LVAL	24
FVAL	25
DVAL	26
SPARE	23
DA_0	0
DA_1	1
DA_2	2
DA_3	3
DA_4	4
DA_5	6
DA_6	27
DA_7	5
DA_8	7
DA_9	8
DA_10	9
DA_11	12

Signal name	28-bit solution pin name TX/RX
DB_0	15
DB_1	18
DB_2	19
DB_3	20
D1_4	21
DB_5	22
DB_6	16
DB_7	17
DB_8	13
DB_9	14
DB_10	10
DB_11	11
Clk	Clk

7.2 USB 2.0

The camera can also be operated using the USB interface. It is even possible to control the camera via the USB interface and output images via the Camera Link interface, thereby replacing the rather slow serial communication channel of the Camera Link interface.

Please note that, for camera configuration and control, the USB interface takes precedence. The USB cable must be disconnected in order to allow control via the Camera Link serial channel.

When using USB, the Software Development Kit can be used to write application software for controlling the camera and for grabbing images. Please refer to the SDK manual for detailed information. (See also Section 4)

7.3 LED indicators

The green LED indicator on the back panel show the status of the camera during power up. The LED flashes, to indicate that the camera is configuring itself, or that the camera is being configured remotely.
When a configuration file has been programmed into the camera, then the camera will configure itself at start-up.
After the configuration phase the green LED stays on.
If no configuration file is present, the LED only flashes once and then stays on immediately after start-up.

The Yellow LED indicator on the back panel gives camera status information. When the camera is correctly configured the LED lights. If the LED is off there has been no configuration of the camera, or an incorrect configuration has been performed. During operation, the LED will go out for a short time when a frame is transmitted via the Camera Link or USB interface.
Note: According to the frame size, this may be difficult to see if the frame duration is short.

Addition to the camera firmware :

- The green LED will go on and off with a frequency of about 1Hz when no USB connection is made with the camera.
- The green LED will flash once each time a command is received via the USB or CameraLink channel.

8 Color filter geometry

The FCi4-14000 camera is available with a monochrome sensor or color sensor with a Bayer color filter array applied.

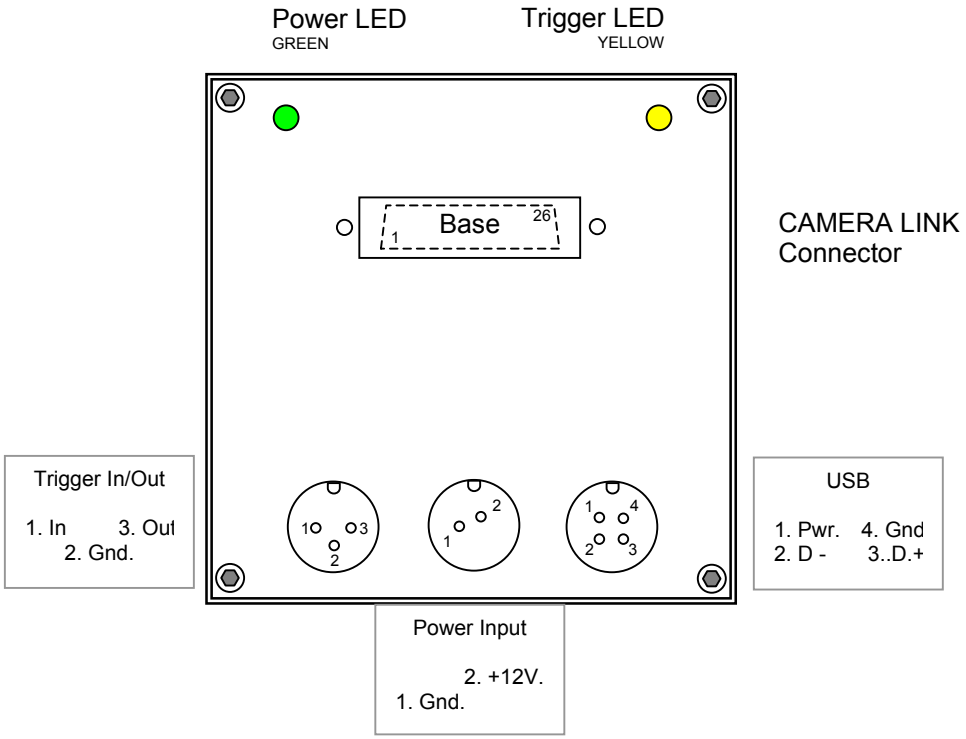
Starting from pixel coordinate (0;0) to the end of the first line (0;3047) and then all subsequent rows.
The layout of the Bayer pattern:

GRGRGRG ...
BGBGBGB ...
GRGRGRG ...
BGBGBGB ...
...

9 Electrical Details

The camera must be provided with a 12 volt, 4W. DC supply.

View of the back panel



9.1 Connector Specifications

Connector	**Configuration** (connector on camera)	**Suitable type**
Cameralink	26-pole MDR Shielded Connector	3M 102-Series
Power Input	2-pole male	Binder 712-Series
Trigger I/O	3-pole male	Binder 712-Series
USB	4-pole male	Binder 712-Series

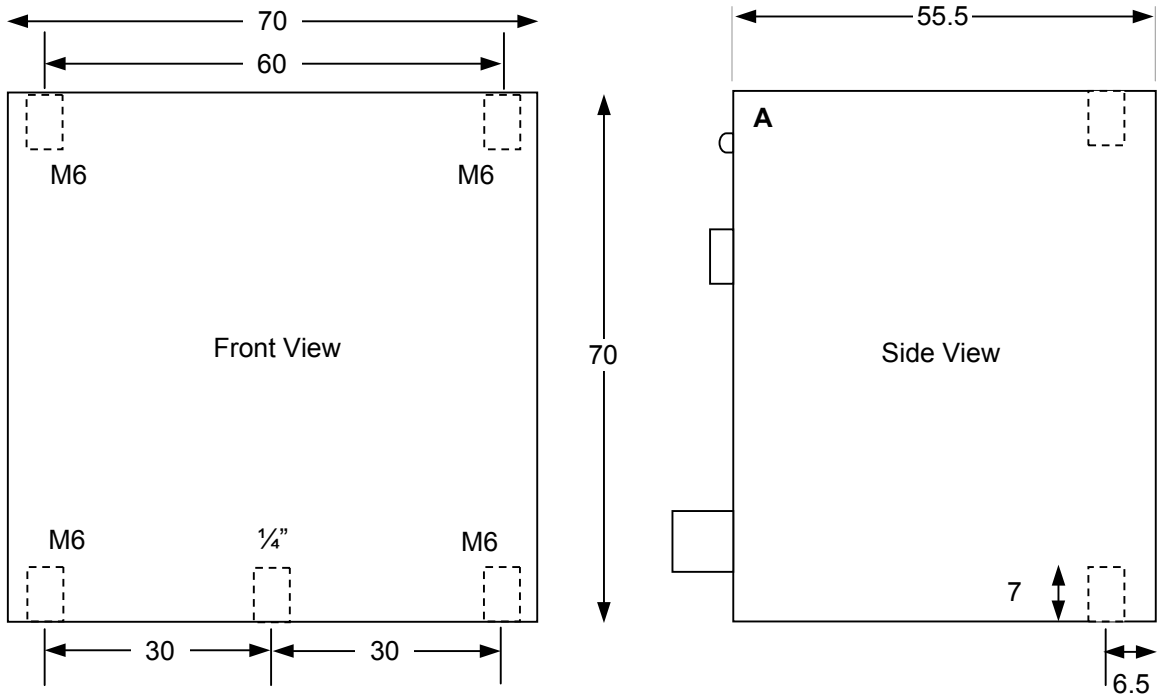
9.2 Cameralink connector – Pin assignments

'Base' Connector

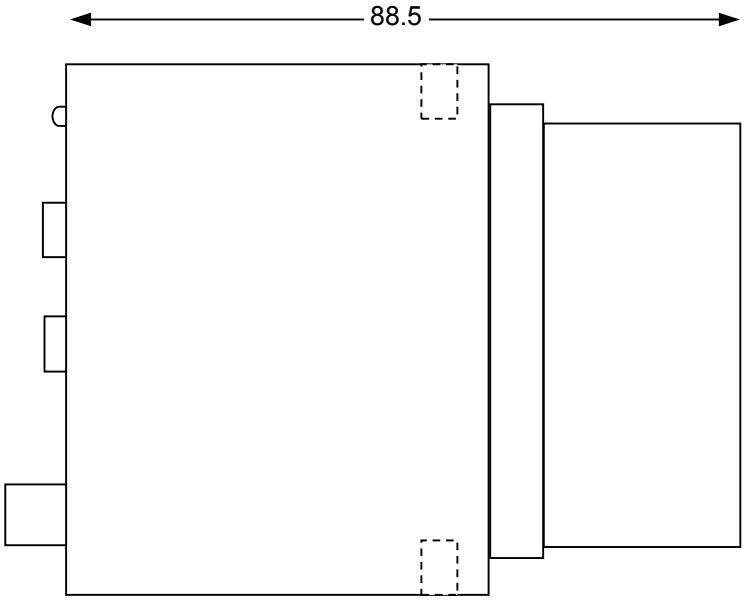
Ground (Shield)	1	14	Ground (Shield)
Channel X0 -	2	15	Channel X0 +
Channel X1 -	3	16	Channel X1 +
Channel X2 -	4	17	Channel X2 +
Clock X -	5	18	Clock X +
Channel X3 -	6	19	Channel X3 +
Rx +	7	20	Rx -
Tx -	8	21	Tx +
CC1 -	9	22	CC1 +
CC2 +	10	23	CC2 -
CC3 -	11	24	CC3 +
CC4 +	12	25	CC4 -
Ground	13	26	Ground

10 Mechanical Details

Fixing centres. (Dimensions in mm.)
The camera has 4 mounting holes for M6 screw and one for a standard ¼" tripod mount.



Side view of camera with F-Mount adapter assembled.



11 Document History

Issue	Date	Changes
0.1	21/3/2006	First Issue
1.0	5/7/2006	Document completely rewritten
1.1	4/12/2006	Updated paragraph 3.4
1.2	2/8/2007	Changed ACK/NACK in 4.3
1.3	12/10/2007	Added WOI restrictions in 2.1 Updated paragraph 2.3.2 Changed chapter 4 Added LED info in 7.3
1.4	24/01/2008 pmb	USB cable warning