BCi4 Manual

C-Cam Technologies

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1 Introduction

The BCi4 camera is a linear response camera using an ibis 4 sensor with 1280 x 1024 pixels. The camera has a 12 bit digital output with 20 MHz pixel rate and is available with different types of interfaces.

This document describes the usage of this camera and a software example. It also supposes that the reader is familiar with the Programmers Reference Manual (or CCAPI manual). The library functions used in this manual are only references, for a descriptive explanation of these functions refer to this Programmers Reference Manual. Only functions and parameters for functions that are specific for this camera are described.

If you have 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 Parameters

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

Parameter	Values	Description
CC_PAR_XSTART	Max 1280	See “Programmers Reference Manual”
CC_PAR_XEND	Max 1280	
CC_PAR_XINC	Not used	
CC_PAR_YSTART	Max 1024	
CC_PAR_YEND	Max 1024	
CC_PAR_YINC	Not used	
CC_PAR_CAMERA_MODE	CC_CAMERA_NORMAL CC_CAMERA_DIAG_X CC_CAMERA_DIAG_Y CC_CAMERA_DIAG_X_XOR_Y	See “Programmers Reference Manual”
CC_PAR_DATA_MODE	8 bit, 16 bit (note 1)	See “Programmers Reference Manual”
CC_PAR_INTEGRATION_TIME	1 … 107374180	Sets the integration time of the ibis4 sensor in microseconds. Although you can program this value to about 107 seconds, max 2 seconds will give you a meaningful image. For higher integration times, extra efforts have to be done like cooling the sensor. Read below for more information.
CC_PAR_GAIN	0 … 15	Sets the output amplifier of the sensor. 0 = lowest, 15 = highest. See table below.
CC_PAR_OFFSET	0 … 255	Adds an analog offset to the output signal of the sensor. For a more detailed description see below.
CC_PAR_PIXEL_PRECHARGE	0 … 255	Programs the full well capacity. A low value results in a larger full well and vice versa. This influences the dynamic range.
CC_PAR_ANAVAL2	0 ... 255	Same as CC_PAR_OFFSET.

CC_PAR_ANAVAL3	0 … 255	Sets the centre voltage for sensors output signal. This acts as an additional offset parameter. Set to 250.
CC_PAR_LINE_TIME	1 … 419430	Sets the repetition rate of a single line in microseconds. Only used in line scan mode.
CC_PAR_NLIST_OPS	0 … 63	Sets the number of WOIs that has to be read out in a single pass. 0 = one WOI. Only used in area scan mode. See below for a description of how to program multiple WOIs.
CC_PAR_CTRLBIT	Bit 0, 1, 2, 6, 7	Bit 0 : 0 = fast calibration 1 = slow calibration Bit 1 : enables flash mode (areascan only) Bit 2 : sets unity gain. The non-linear part of the sensor becomes visible in the ADC range. Bit 6 : 0 = area scan mode 1 = line scan mode Bit 7 : 0 = continuous mode 1 = single shot mode

Note 1: This parameter is a camera setting for the USB version of the BCi4 camera and is an interface board setting for the other versions of the BCi4 camera.

2.1 Integration time

The integration time of the ibis4 sensor can be programmed to above 100 seconds, although these long exposure times are not usable. The dark current has a lot of influence on this. Therefore only integration times of up to 2 seconds are usable, depending on the camera and sensor temperature. The lower the temperature, the lower the dark current will be, and integration times can be higher. There is a cooled version of the BCi4 camera available with usable integration times of up to 10 seconds. The resulting dark current noise can be corrected for in the application program by subtracting a frame taken with the set integration time but with the iris closed.
Integration time can be almost as low as zero seconds, the minimum in fact being the time of reading 1 row.

2.2 Gain

The gain value can be set in 16 steps according to the following table:

Gain setting	DC gain	Relative gain	ADC relative gain
0	1.28	1.00	1.18
1	1.51	1.18	1.39
2	1.82	1.42	1.68
3	2.13	1.66	1.96
4	2.60	2.03	2.40
5	3.11	2.43	2.87
6	3.71	2.90	3.42
7	4.40	3.44	4.06
8	5.33	4.16	4.91
9	6.37	4.98	5.87
10	7.41	5.79	6.83
11	8.91	6.96	8.21
12	10.70	8.36	9.86
13	12.65	9.88	11.66
14	15.01	11.73	13.84
15	17.53	13.70	16.16

The DC gain follows a logarithmic curve according to the formula:

$$DCgain = 1.074 * 2^{0.246*(Gainsetting+1)}$$

It should be noted that at gain setting 0, the linear range of the sensor is mapped on the ADC range (see conversion diagram), the logarithmic range (above 1 V output signal is clipped of). If someone wants to make use of the logarithmic part of the curve also, then unity gain has to be set which is actually a DC gain of 1. Unity gain can be set with the `CC_PAR_CTRLBIT` parameter. (See also pixel precharge for working with the logarithmic range)

We include the graphic from Fillfactory's Ibis4 datasheet.

1.1.3 Charge conversion - Conversion of electrons in an output signal

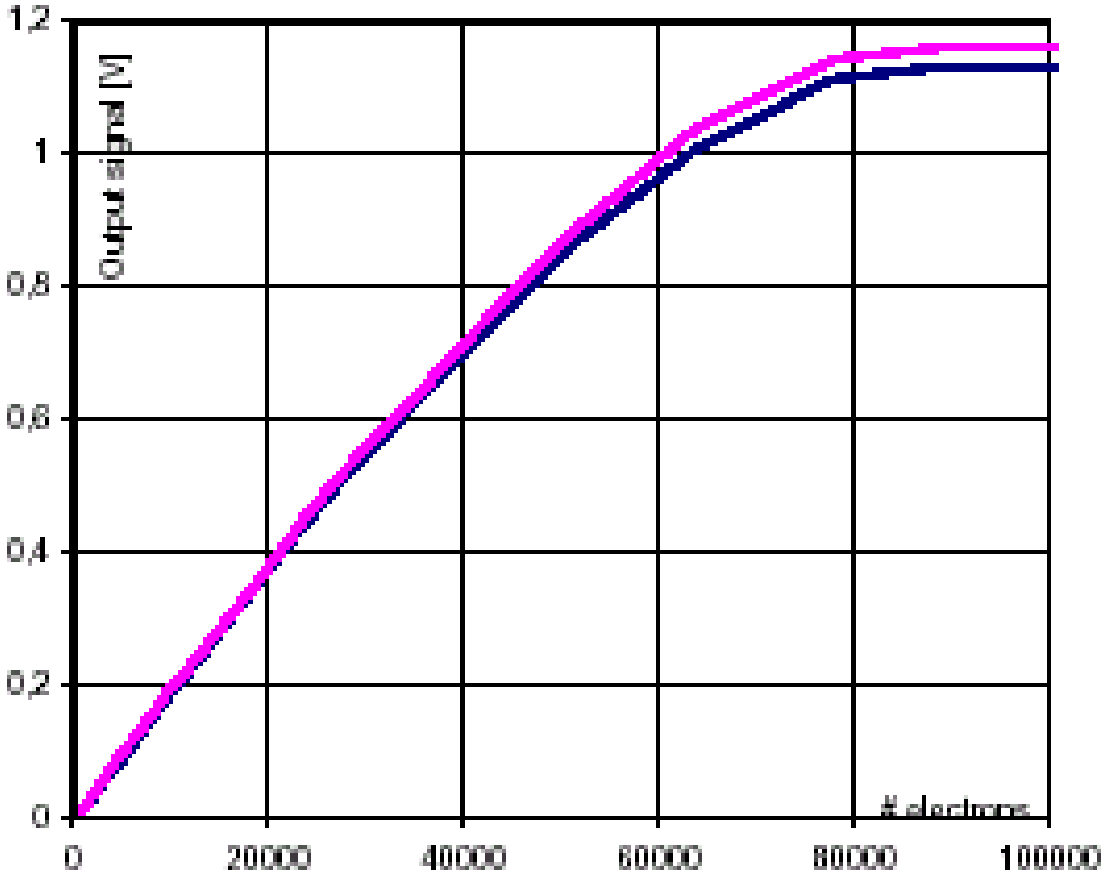

Figure 5: IBIS4 response curve – two pixels – lowest gain setting (0000)

2.3 Offset

The offset adds an analog voltage to the output signal of the image sensor and can be set in 256 steps. Increase this value if too many pixels in the image stay “black” (a value of zero). Decrease this value if a dark frame cannot reach the black level.
Use the `CC_PAR_OFFSET` parameter to change to offset.
An additional offset can be set before the signal is fed to the sampling electronics. This can be set with the `CC_PAR_ANAVAL3` parameter. It is advised to keep this additional offset to a value of about 250.
Note that the offset value in line scan mode differs from the offset value in area scan mode.

2.4 Pixel Precharge

This parameter determines the full well capacity of each pixel. The lower this value, the higher the full well. A higher full well capacity results in a higher dynamic range (more electrons can be held on one pixel).
If someone wants to make use of the logarithmic part of the conversion curve, unity gain has to be set. By lowering the pixel precharge value, the linear part is shortened and the logarithmic part becomes even more visible to the ADC.

3 Camera operation

The BCi4 camera can operate in 2 main modes: area scan mode and line scan mode.
In area scan mode, the camera can read out a specific area of interest from the sensor.
In line scan mode, the camera reads out one specific line continuously and suits very well for conveyor belt applications. The scan mode can be set with the `CC_PAR_CTRLBIT` parameter.
Caution for the USB version :
After the `CC_LoadCamera` function be sure to leave 5 ms of settling time for the electronics to become stable before using any of the parameter functions.

3.1 Area Scan mode

In this mode one or multiple windows of interest (WOI) can be set for a single readout. Be careful that if using more the one WOI, all WOIs must have the same XSTART and XEND parameter. The different regions are thus stacked vertically and may not overlap. The advantage of multiple WOI scanning is that if there are some uninteresting parts in between the WOIs, the sensor readout can quickly skip those uninteresting lines without reading them out resulting in higher frame rates.
You can program multiple WOIs as follows:

1. Set the `CC_PAR_NLIST_OPS` parameter to the number of WOIs you want to program. A value of zero means one WOI.
2. Set your WOI by using the `CC_SetWOI` function.
3. Repeat step 2 until all WOIs are programmed (max 64).
4. Again set the `CC_PAR_NLIST_OPS` parameter to the number of WOIs you have programmed.

If you request a frame with the CC_CaptureSingle function for example, be sure to enter the correct transfer size which is the sum of all the WOI sizes.

3.1.1 Flash mode

The BCi4 camera has a sensor which has a rolling shutter. This means there are 2 line pointers, the first pointer opens a line and makes it sensitive for light. The second pointer closes a line and reads out its contents. Both pointers advances with the same speed which is the readout time of 1 line. The time difference between these 2 pointers is the integration time. If the integration time is smaller then the readout time of the WOI, there is no moment in time where all lines in the WOI are sensitive to light at the same time. And this makes it unusable for flashes.
In flash mode, the 2 pointers do not advance with the same speed anymore. The first pointer quickly opens all lines in the WOI, then a flash event can occur in a way that all lines will be sensitive to that flash. Afterwards the second pointer reads out all those lines at the normal speed. A trigger out pulse will be generated on the trigger connector on the right moment.
Be careful that this mode is only effective in low light conditions because during the readout of the lines integration will continue with all lines below the current line being read out. This results in lighter parts at the bottom of a frame.
The flash mode can be set with the `CC_PAR_CTRLBIT` parameter.

3.1.2 Continuous mode

In continuous mode, the camera continues to read out the requested WOIs until the CC_CaptureAbort function is called and can be combined with external triggering. (See the TriggerIO manual)
The continuous mode can be set with the `CC_PAR_CTRLBIT` parameter.

3.2 Line Scan mode

In line scan mode, the BCi4 camera continuously reads out one particular line. This mode is very interesting when the camera has to capture moving objects with a continuous speed for example conveyor belts. There is no limit in vertical image size.
The line scan mode differs from the area scan mode in that a line can be read out at a certain frequency different then the integration time.
This line frequency can be set with the `CC_PAR_LINE_TIME` parameter in microseconds. The line time has to be greater then the integration time + 10.
The line to be read out can be set with the `CC_SetWOI` function. Where the selected line is given with the YSTART parameter, the YEND parameter has no effect.
The line scanning can be started with one of the capture functions and has to be stopped with the `CC_CaptureAbort` function.
Note that slow calibration has to be activated in line scan mode. Slow calibration takes about 200 lines to settle. Slow calibration can be set with the `CC_PAR_CTRLBIT` parameter.

3.3 Frame speed

The frame speed of the BCi4 camera depends on two factors: WOI size and integration time. The smaller the WOI size or the shorter the integration-time, the higher the frame speed. You can use following close approximation to calculate the frame speed in frames per second for one WOI:

$$FPS = \frac{10^6}{\left(\left(6.3 + \frac{Xsize}{20}\right) * Ysize\right) + integration\_time}$$

Xsize and Ysize in pixel units, integration-time in microseconds.

4 External triggering

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

5 Programming example

This programming example only uses basic functions from the programmers interface (API) without 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[1280*1024] ;
ULONG       picture_size ;
BOOL        ret ;
HANDLE      MyCam ;

MyCam = CC_Open( "BCi4 LS3", 0, CC_CAPTURE_WAIT ) ;
ret = CC_LoadInterface( MyCam, "pcils.ttb" ) ;
ret = CC_LoadCamera( MyCam, "bci4-3ls20nlf.ttb" ) ;
ret = CC_SetParameter( MyCam, CC_PAR_NLIST_OPS, 0 ) ; /* use only 1 WOI */
ret = CC_SetWOI( MyCam, 0, 0, 1279, 1023, 1, 1, CC_WOI_LEFTTOP_RIGHTBOTTOM,
                 &picture_size ) ;
ret = CC_SetParameter( MyCam, CC_PAR_NLIST_OPS, 0 ) ;
ret = CC_SetParameter( MyCam, CC_PAR_INTEGRATION_TIME, 30000 ) ;
ret = CC_SetParameter( MyCam, CC_PAR_GAIN, 0 ) ;
ret = CC_SetParameter( MyCam, CC_PAR_OFFSET, 200 ) ;
ret = CC_SetParameter( MyCam, CC_PAR_PIXEL_PRECHARGE, 64 ) ;
ret = CC_SetParameter( MyCam, CC_PAR_ANAVAL3, 250 ) ;
ret = CC_SetParameter( MyCam, CC_PAR_CTRLBIT, 1793) ; /* single shot */
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 to call before you can access any other function. (Note that the handle returned by `CC_Open` is used by all other functions). The next functions to call should be `CC_LoadInterface` and `CC_LoadCamera` in that order. The USB version doesn't have a `CC_LoadInterface` function and should therefore not be called. All other functions before the `CC_CaptureSingle` function can be called in any order except for the `CC_PAR_NLIST_OPS` parameter. And the last function to call should be `CC_Close`.

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

6 Color filter geometry

All BCi4 versions are available with a monochrome sensor or a sensor with a color filter array applied.
There are 2 types of color filter arrays available: diagonal and Bayer.

Starting from pixel coordinate (0;0) to the end of the first line (0;1279) and then all subsequent rows.
This is the layout of the diagonal pattern:

BRGBRGBRGB ...
RGBRGBRGBR ...
GBRGBRGBRG ...
…

The layout of the Bayer pattern:

BGBGBGBG ...
GRGRGRGR ...
BGBGBGBG ...
GRGRGRGR ...
...

The diagonal pattern can be very useful in a line-scan application.

3D Graphics for CCD cameras

7 Camera variations

The BCi4 camera is available in the following variations :

Camera	Camera interface	PCI interface board	Camera Logic file	PCI board logic file
BCi4 LS2 (1)	Serial LVDS	PCI-LS	Bci4ls20a.ttb	Pcils.ttb
BCi4 LS3	Serial LVDS	PCI-LS	Bci4-3ls20nlf.ttb	Pcils.ttb
BCi4 CL3	Camera link	PCI-CL	Bci4-3cl20nlf.ttb	Pcicl.ttb
BCi4 USB3	USB 2.0	-	Bci4-3usb20nlf.ttb	-

Use the name in the “Camera” column in the `CC_Open` command to open the corresponding camera.

(1) Camera not available anymore.

Application: Laser Beam Profiler with 3D Visualization