



celepixel

CelePixel
CeleX-5 Chipset
SDK Reference

CelePixel Technology Co. Ltd.

Content

Version Control.....	4
1. Overview	5
1.1. Introduction of CeleX-5 Chipset	5
1.1.1 Basic working principle of CeleX-5 Chipset	5
1.1.2 Terminology.....	5
1.2. Working Principle of CeleX-5 Sensors	7
1.2.1. Fixed Mode of CeleX-5 Sensor	7
1.2.1.1. Event Mode with ADC Disabled (<i>Event Address Only Mode</i>)	7
1.2.1.2. Event Mode with Optical-Flow (<i>Event Optical-flow Mode</i>).....	7
1.2.1.3. Event Mode with Pixel Intensity (<i>Event Intensity Mode</i>).....	8
1.2.1.4. Full-Frame Picture Mode.....	8
1.2.1.5. Single Full-Frame Optical-Flow Mode	9
1.2.1.6. Multiple Full-Frame Optical-Flow Mode	9
1.2.2. Loop Mode of CeleX-5 Sensor	10
1.2.3. Data Format of CeleX-5 Sensor	10
1.2.3.1. Data Format Output by CeleX-5 Sensor	10
1.2.3.2. Data Types Output by SDK.....	10
1.2.4. Methods to Create Full Picture and Event Frame	12
1.2.4.1. Method to Create Full Picture Frame	12
1.2.4.2. Method to Create Event Picture Frame.....	12
2. CeleX-5 API Reference	15
2.1. Overview	15
2.2. CeleX5DataManager Class Reference	18
2.3. CeleX5 Class Reference	21
2.3.1 openSensor	22
2.3.2 isSensorReady	23
2.3.3 getSensorRawData	23
2.3.4 setFpnFile	23
2.3.5 generateFPN.....	23
2.3.6 setSensorFixedMode	24
2.3.7 getSensorFixedMode.....	24
2.3.8 getFullPicBuffer	24
2.3.9 getFullPicMat	25
2.3.10 getEventPicBuffer	26
2.3.11 getEventPicMat	27
2.3.12 getEventDataVector.....	27
2.3.13 getOpticalFlowPicBuffer.....	27
2.3.14 getOpticalFlowPicMat	28
2.3.15 getFullPicFrameTime	28
2.3.16 setEventFrameTime.....	29
2.3.17 getEventFrameTime	29
2.3.18 setOpticalFlowFrameTime	29
2.3.19 getOpticalFlowFrameTime	29

2.3.20	setSensorLoopMode	30
2.3.21	getSensorLoopMode	30
2.3.22	setLoopModeEnabled	30
2.3.23	isLoopModeEnabled	31
2.3.24	setEventDuration	31
2.3.25	setPictureNumber	31
2.3.26	setThreshold	31
2.3.27	getThreshold	32
2.3.28	setBrightness	32
2.3.29	getBrightness	32
2.3.30	setISOLevel	32
2.3.31	getISOLevel	33
2.3.32	setClockRate	33
2.3.33	getClockRate	33
2.3.34	reset	34
2.3.35	startRecording	34
2.3.36	stopRecording	34
2.3.37	openBinFile	34
2.3.38	readBinFileData	34
2.3.39	getBinFileAttributes	35



Version Control

Version	Date	Section	Description	Author
1.0	2019.03.11	All	New	Xiaoqin Hu

CelePixel Confidential

1. Overview

1.1. Introduction of CeleX-5 Chipset

1.1.1 Basic working principle of CeleX-5 Chipset

Fig. 1-1 shows the basic working principle of the CeleX-5+ZYNQ Chipset. Applications could configure the ZYNQ board and eventually configure the sensor. Similarly, Applications are able to obtain the sensor data from ZYNQ board over the network.

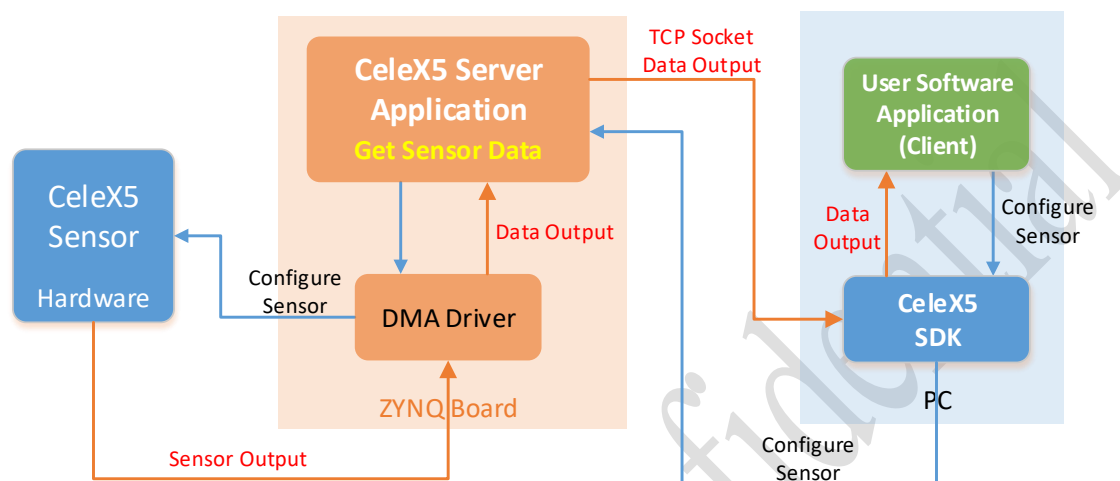


Fig. 1-1 Basic working principle of the CeleX-5+ZYNQ Chipset

1.1.2 Terminology

The following table lists some of the terms and their explanations that appear in this document.

No.	Terminology	Description
1	Event Mode	<i>Event Address-only Mode, Event Optical-flow Mode and Event Intensity Mode</i> are collectively referred to as Event Mode, in which the Sensor only detects the pixel whose intensity has changed and then marks it as an active pixel and outputs it.
2	Full-frame Mode	<i>Full-frame Picture Mode, Single Full-frame Optical-flow Mode and Multiple Full-frame Optical-flow Mode</i> are collectively referred to as <i>Full-frame Mode</i> , in which the Sensor outputs the information for each pixel in order (top to bottom, left to right) within a certain period of time.
3	Fixed Mode	For fixed mode, the sensor always works into only one of the six single modes unless being reconfigured.
4	Loop Mode	For loop mode, the sensor could automatically switch between three single modes.
5	Event Address-only Mode	A working mode of the CeleX-5 sensor, in which the sensor only outputs row/column address of the

		detected events. The pixel intensity and optical-flow information are not available in the mode.
6	Event Optical-flow Mode	A working mode of the CeleX-5 sensor, in which the sensor outputs row/column address of the detected events, together with the timing information. The pixel intensity information is not available in this mode.
7	Event Intensity Mode	A working mode of the CeleX-5 sensor, in which the sensor outputs row/column address of the detected events, together with the pixel intensity information. The optical-flow information is not available in this mode.
8	Full-frame Picture Mode	A working mode of the CeleX-5 sensor, in which the sensor could generate full-frame pictures with pixel intensity information, which is sampled at certain instant by all pixels simultaneously.
9	Single Full-frame Optical-flow Mode	A working mode of the CeleX-5 sensor, in which the sensor could generate a full-frame optical-flow picture after accumulating events in a specified time duration.
10	Multiple Full-frame Optical-flow Mode	A working mode of the CeleX-5 sensor, in which the sensor could generate several full-frame optical-flow pictures with pixel timing information within a time duration.
11	Event Binary Pic	The event binary frame output from the SDK
12	Event Gray Pic	The event gray frame from the SDK
13	Event Accumulated Gray Pic	The event accumulated gray frame output from the SDK

1.2. Working Principle of CeleX-5 Sensors

CeleX™ is a family of smart image sensor specially designed for machine vision. Each pixel in CeleX™ sensor can individually monitor the relative change in light intensity and report an event if it reaches a certain threshold. Asynchronous row and column arbitration circuits process the pixel requests and make sure only one request is granted at a time in fairly manner when they received multiple simultaneous requests. The output of the sensor is not a frame, but a stream of asynchronous digital events. The speed of the sensor is not limited by any traditional concept such as exposure time and frame rate. It can detect fast motion which is traditionally captured by expensive, high speed cameras running at thousands of frames per second, but with drastic reduced amount of data. Besides, our technology allows post-capture change of frame-rate for video playback. One can view the video at 10,000 frames per second to see high speed events or at normal rate of 25 frames per second.

CeleX™ sensor can produce three kinds of outputs in parallel: logarithmic picture, motion, and full-frame optical flow. The sensor can greatly improve the performance for applications in broad areas including assisted/autonomous driving, UAV, robotics, surveillance, etc.

CeleX-5 is a multifunctional smart image sensor with 1Mega-pixels and some additional features integrating on-chip. The sensor supports several different output formats: pure binary address-events, address-events with either pixel intensity information or timing information.

In addition, the readout scheme of the sensor could either be asynchronous data stream or synchronous full frames. Different combinations of the output format and readout scheme lead to great flexibility of this sensor, which supports 6 separate operation modes in total.

To further meet the requirements of different applications, the sensor could also be configured into a loop-mode, in which it could automatically switch among three separate modes.

1.2.1. Fixed Mode of CeleX-5 Sensor

CeleX-5 Sensor provides six fixed working modes of CeleX-5 Sensors: *Event Address Only Mode*, *Event Optical-flow Mode*, *Event Intensity Mode*, *Full-frame Picture Mode*, *Single Full-frame Optical-flow Mode*, *Multiple Full-frame Optical-flow Mode*.

1.2.1.1. Event Mode with ADC Disabled (*Event Address Only Mode*)

In this mode, the sensor detects motions in field of view and outputs row/col address of the detected events. The column ADC is disabled in this mode, so the pixel intensity or timing information is not available.

The advantage of this mode is that short event latency is achieved as the time for AD conversion has been saved, thus the sensor could process the events in higher speed. Its working principle is shown in Figure 1-2.

1.2.1.2. Event Mode with Optical-Flow (*Event Optical-flow Mode*)

In this mode, the sensor detects motions in field of view and outputs row/col address of the detected events, together with the timing information indicating the instant when the event generated. The pixel intensity information is not available in this mode.

The address and timing information of the events could be used for further optical-flow analysis. Its working principle is shown in Figure 1-2.

1.2.1.3. Event Mode with Pixel Intensity (*Event Intensity Mode*)

In this mode, the sensor detects light intensity change and outputs row/col address of the detected events, together with the pixel intensity information sampled at the instant when the event generated. The timing information is not available in this mode. Its working principle is shown in Figure 1-2.

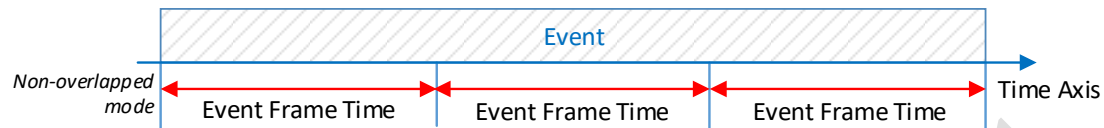


Fig. 1-2 Event data mode

The address and intensity information of the events could be used for further analysis.

For this mode, it could obtain several formats of frame simultaneously through APIs: one is event accumulated gray frame (the grayscale image accumulating the gray values of active pixels newly changed), event binary frame (the gray values of active pixels are marked as 255, while inactive pixels are 0), event gray frame and so on.

In the Event mode, the Event Frame Time can be adjusted (range: 1~1000ms), and you can modify this time by calling the API interface [setEventFrameTime](#). The method of creating an Event image frame is described in section [1.2.4.2](#).

1.2.1.4. Full-Frame Picture Mode

In this mode, the sensor could generate full-frame pictures with pixel intensity information, which is sampled at certain instant by all pixels simultaneously. Because the sensor could generate continuous full frames, it could be used as a frame-based APS sensor.

The operating frequency of the Sensor is linear with the frame rate of the transmitted data, ie the frequency is x MHz, then fps is x frames per second. If the operating frequency of the Sensor is 100MHz, it means that the Sensor can generate about 100 full-frame image frames per second, that is, the Transmission Time is 10ms. You can modify the Transmission Time (or Frame Time) by calling the API [setFullPicFrameTime](#), for example, if it is set to 100ms, that means the sensor could generate about 100 full-frame pictures per second.

Additionally, you can modify the working frequency of the Sensor by calling the API interface [setClockRate](#) to modify the transmission time (or Frame Time), and also improve the image quality by calling the API interfaces [setBrightness](#) and [setISOLevel](#).

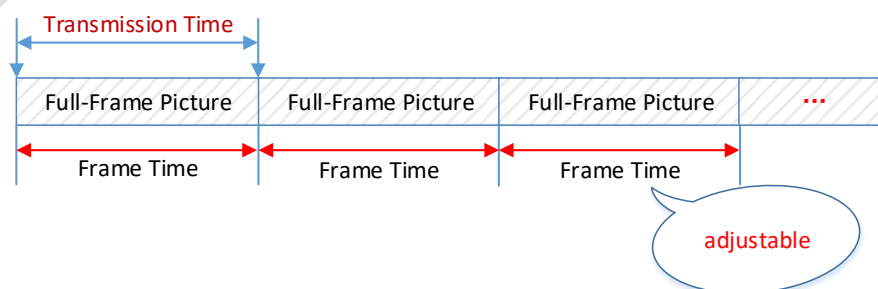


Fig 1-3. Full-Frame Picture Mode

1.2.1.5. Single Full-Frame Optical-Flow Mode

In this mode, the sensor could generate a full-frame picture with pixel timing information. The sensor first accumulates events in a specified duration (*Accumulated Time*). After that, the sensor produces a full-frame picture with pixel timing information.

Parameters users could set are a) accumulated time (hardware parameter), b) transmission time (hardware parameters, related to main clock frequency).

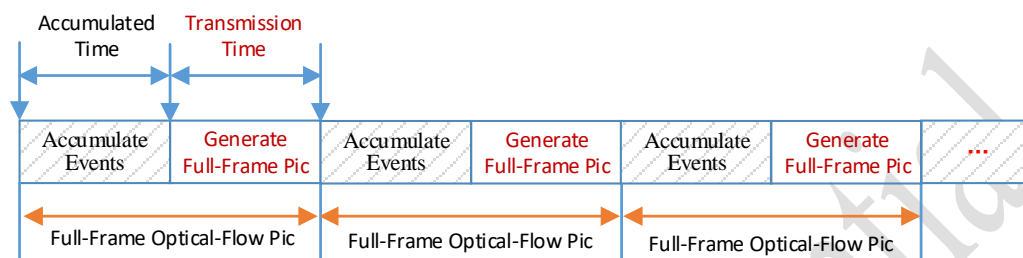


Fig 1-4. Full-Frame Optical-Flow (Single) Mode

1.2.1.6. Multiple Full-Frame Optical-Flow Mode

In this mode, the sensor could generate several full-frame pictures with pixel timing information within a time duration. Different from *Event Optical-flow Mode*, sensor operating in this mode produces full-frame pictures instead of asynchronous events stream. Different from *Single Full-frame Optical-flow Mode*, the sensor could produce multiple full-frame pictures within a time duration.

It's not recommended to use this mode as a fixed mode, it's good to use it as one of the three mode in the *Loop Mode*. You could modify the duration of this mode in the loop by calling the API interface [setPictureNumber](#).

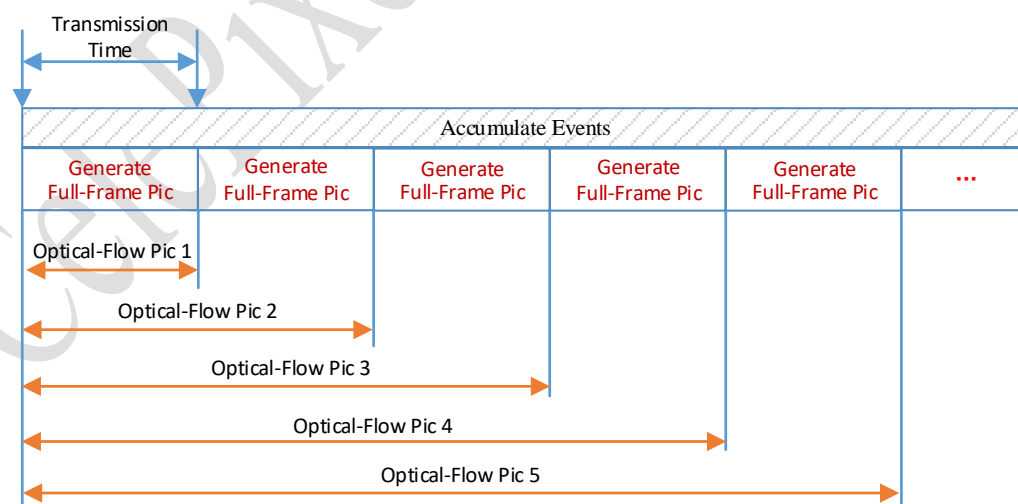


Fig 1-5. Full-Frame Optical-Flow (Multiple) Mode

1.2.2. Loop Mode of CeleX-5 Sensor

The detailed operation of each single mode has been illustrated above. For fixed mode, the sensor always works into only one of the six single modes unless being reconfigured. For loop mode, the sensor could automatically switch between three single modes.

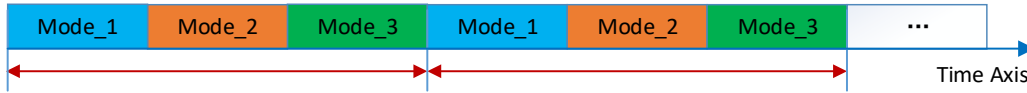


Fig. 1-6. Loop Mode

Fig. 1-6 shows the diagram of sensor operating in loop mode. After the select mode is configured to loop mode, the sensor would operate between Mode_1, Mode_2 and Mode_3 alternatively. This loop would continue until being reconfigured.

Here are some tips to select modes for the loop mode:

- a) The best choice is one full-frame picture mode, one event mode and one full-frame optical-flow mode;
- b) Only choose one full-frame optical-flow mode in the loop.

By default, the first loop (Mode_1) is *Full-frame Picture Mode*, in which the time duration is **10ms** and you could modify the duration of this mode by calling the API interface [setPictureNumber](#).

The second loop (Mode_2) is *Event Mode*, in which the time duration is **20ms** and you could modify the event duration of this mode by calling the API interface [setEventDuration](#).

The third loop (Mode_3) is *Full-frame Optical-flow Mode*, in which the time duration is **30ms** and you could modify the duration of this mode by calling the API interface [setPictureNumber](#).

1.2.3. Data Format of CeleX-5 Sensor

1.2.3.1. Data Format Output by CeleX-5 Sensor

The output of CeleX™ Chipset is a stream of pixel events. These events contain the information of pixel locations/coordinates (row, col), the sample value of absolute brightness or optical-flow information when the pixel event is triggered (A), and the timestamp of the event being output (T).

Since the raw sensor data is complicated, the method of parsing the sensor data is not introduced in this document. Users can check out our source code to learn how to parse the data.

1.2.3.2. Data Types Output by SDK

The data types output by the SDK are different when the CeleX-5 Sensor works in a different mode. The table below shows the types of data that users can obtain in different modes.

Sensor Mode	Data Types Output by SDK
Full-frame Picture Mode	Full Pic Buffer/Mat
Event Address-only Mode	Event Binary Pic Buffer/Mat Event Vector<row, col, timestamp>
Event Optical-flow Mode	Event Optical-flow Pic Buffer/Mat Event Vector<row, col, optical-flow info, timestamp>
Event Intensity Mode	Event Binary Pic Buffer/Mat Event Gray Pic Buffer/Mat Event Accumulated Pic Buffer/Mat Event Superimposed Pic Buffer/Mat Event Vector<row, col, brightness, polarity, timestamp>
Single Full-frame Optical-flow Mode	Event Optical-flow Pic Buffer/Mat Event Optical-flow Direction Pic Buffer/Mat Event Optical-flow Speed Pic Buffer/Mat

xxx Pic Buffer is a single channel image array with row = 1280 and column = 800, and **xxx Pic Mat** is a single channel OpenCV mat with row = 1280 and column = 800.

Additionally, the **timestamp** in the Event Vector has different range and time accuracy (T-Unit) at different frequencies, as shown in the following table.

Clock (MHz)	T-Unit (us)	The number of time units corresponding to 30ms $30*1000 / \text{T-Unit}$
20	6.40	4687
30	4.27	7025
40	3.20	9375
50	2.56	11718
60	2.13	14084
70	1.83	16393
80	1.60	18750
90	1.42	21126
100	1.28	23437

1.2.4. Methods to Create Full Picture and Event Frame

CeleX-5 sensor can output a continuous stream of pixel events after powering-up. As illustrated in the last section, the X, Y, A, T information can be decoded from the events. Next, we will introduce how to create a visual frame with (X, Y, A, T) information.

1.2.4.1. Method to Create Full Picture Frame

- 1) Call the API interface [setClockRate](#) to set the working frequency of the Sensor, indicating that the Sensor generates a complete frame (Full Picture) after user-set Full-Picture Frame Time. This mode is compatible with the traditional Sensor, that is, regardless of whether there is a change of intensity on the pixel or not, its gray value can be retrieved.
- 2) Switch the sensor mode to Full-Picture mode.
- 3) Construct a 2D array to represent the Full Pic, regarded as $M[800][1280]$, which has 800 rows and each row consists of 1280 pixels. Initialize every pixel's brightness value to 0 at first.
- 4) When an event E is decoded into X, Y, A and T, the value of each pixel on $M[Y][X]$ is given brightness value of A, i.e., $M[Y][X] = A$. Repeat the same process for each decoded event. In the Full-Picture mode, the (T) information is invalid.
- 5) Repeat step 4 in the next Full-Picture frame time.

The above frame creation process is implemented by the API. You can directly call the API [getFullPicBuffer](#) to obtain the data array of the Full Picture frame.

1.2.4.2. Method to Create Event Picture Frame

There are many ways to create image frames in Event mode. The following content only describes the method to create Event Binary Pic, Event Gray Pic and Event Accumulated Gray Pic in the SDK.

- 1) Call the API [setEventFrameTime](#) to set the Event frame time, indicating that the SDK will combine the Event outputs from the Sensor after a certain time interval (i.e., the Event Frame Time set by the user) to generate an Event binary frame.
- 2) Switch the sensor mode to Event mode.
- 3) Construct three 2D array $M1[800][1280]$, $M2[800][1280]$ and $M3[800][1280]$ to represent the Event Binary Pic, Event Gray Pic and Event Accumulated Gray Pic. Initialize every pixel's brightness value to 0 at first.
- 4) Parse the data obtained from the data stream from the USB driver. When each event E is decoded as (X, Y, A, T), the value of the pixel on $M1[Y][X]$ is 255, and the value of the pixel on $M2[Y][X]$ and $M3[Y][X]$ is the brightness value A of the pixel.
- 5) In the new Event Frame Time, first set the value of each pixel in the 2D arrays M1 and M2 to 0. M3 remains unchanged. Then repeat step 4. That is, in each Event Frame Time, M1 and M2 are cleared each time, and the M3 array is updated based on the array created by the previous Event Frame Time.

The above frame creating process is implemented by the API. The user can directly call the API [getEventPicBuffer](#) to obtain the data arrays of Event frames. To help users understand the difference between Event Gray Pic and Event Accumulated Gray Pic, the above process is further illustrated in Fig. 1-16 and 1-17.

Fig. 1-16 and 1-17 describes the process above with a 5*5 array. We only list the first five frames, and each frame is an event gray frame in Fig. 1-16 and event accumulated gray frame in Fig. 1-17.

“x” represents gray value in event gray frame and event accumulated gray frame. The red “x” indicates the pixels that changed in the first Event Frame Time, the blue “x” indicates the second, the green “x” indicates the third, and the purple “x” indicates the fourth, and the black “x” indicates the fifth.

In Fig. 1-8, it should be noted that when a pixel has changed before and it changed again, we replace the old gray value with the new one directly, which are marked in location (row0, col0) and location (row2, col4).

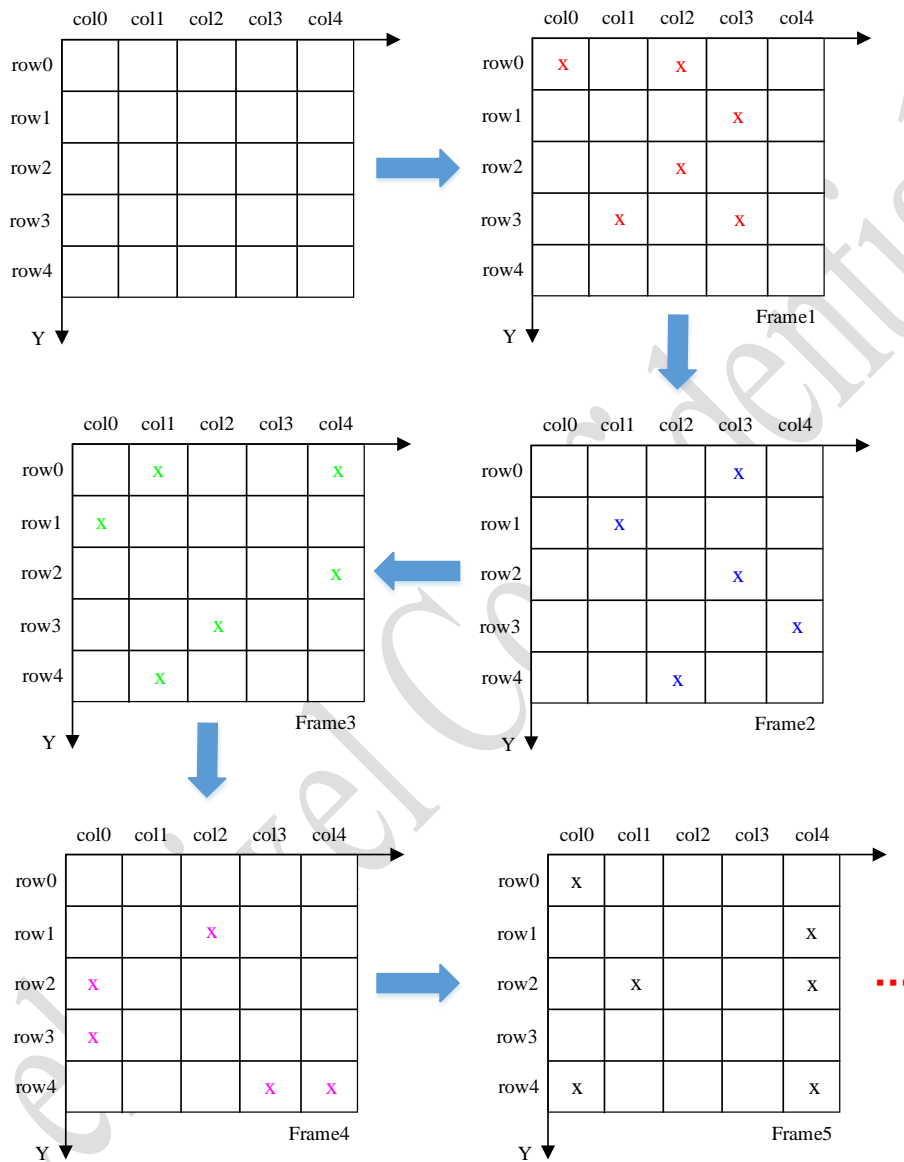


Fig. 1-16 Event Gray Pic in Event mode

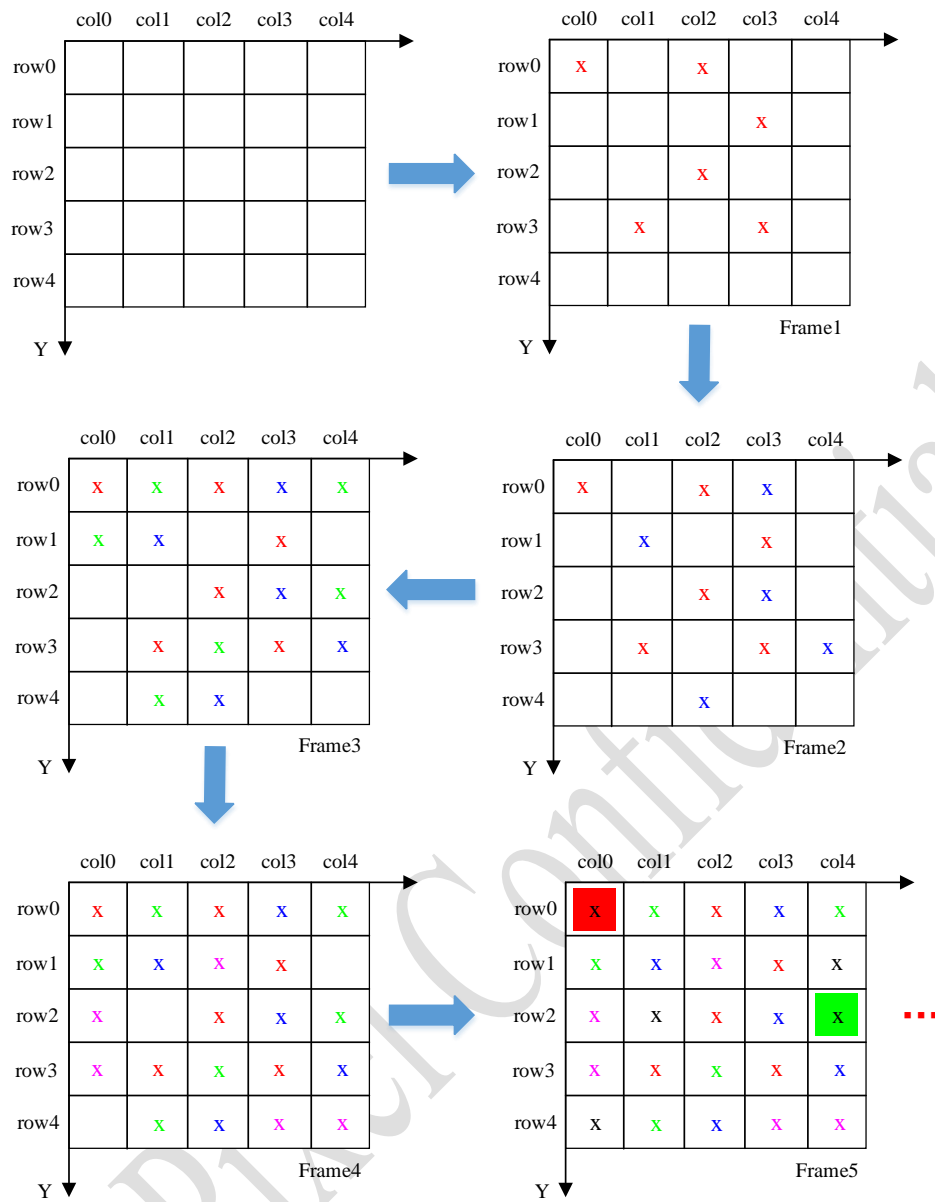


Fig. 1-17 Event Accumulated Gray Pic in Event mode

2. CeleX-5 API Reference

2.1. Overview

The CeleX API provide a C++ interface to communicate with CeleX-5 Sensor.

To build an application using this API, you need to include the files in the *include* directory in you project. These contain all the functions that will make calls to the shared library. You will also need to include the CeleX.dll (Windows) library in the same directory as your executable or libCeleX.so (Linux) in the lib directory (e.g. /usr/local/lib).

To use the library, you could create an instance of [CeleX5](#) which encapsulated communication the CeleX-5 sensor. You can call [openSensor](#) to open the sensor that has connected to your PC and then you can call [getFullPicBuffer](#) and [getEventPicBuffer](#) to get various of frames that calculated using the raw data the sensor outputted.

You can also obtain the processed frame buffer by deriving your own data manager subclass from class [CeleX5DataManager](#) and override its virtual [onFrameDataUpdated](#) methods to receive the notification that the frame buffers are ready.

Here are enums and structs with brief descriptions:

<pre>enum CeleX5Mode { Unknown_Mode = -1, Event_Address_Only_Mode = 0, Event_Optical_Flow_Mode = 1, Event_Intensity_Mode = 2, Full_Picture_Mode = 3, Full_Optical_Flow_S_Mode = 4, Full_Optical_Flow_M_Mode = 6, };</pre>	<p>Unknown_Mode - Unknown mode</p> <p>Event_Address_Only_Mode - Event Mode with ADC Disabled (<i>Event Address Only Mode</i>)</p> <p>Event_Optical_Flow_Mode - Event Mode with Optical-Flow (<i>Event Optical-flow Mode</i>)</p> <p>Event_Intensity_Mode - Event Mode with Pixel Intensity (<i>Event Intensity Mode</i>)</p> <p>Full_Picture_Mode - Full-frame picture mode</p> <p>Full_Optical_Flow_S_Mode - Single full-frame optical-flow mode</p> <p>Full_Optical_Flow_M_Mode - Multiple full-frame optical-flow mode</p>
<pre>enum DeviceType { Unknown_Devive = 0, CeleX5_MIPI = 1, CeleX5_OpalKelly = 2, CeleX5_ZYNQ = 3 };</pre>	<p>Unknown_Device - Unknown device</p> <p>CeleX5_MIPI - CeleX5 MIPI device</p> <p>CeleX5_OpalKelly - CeleX5 OpalKelly device</p> <p>CeleX5_ZYNQ - CeleX5 ZYNQ device</p>
<pre>enum emEventPicMode { EventBinaryPic = 0, EventAccumulatedPic = 1, EventGrayPic = 2,</pre>	<p>EventBinaryPic - The frame buffer (a matrix) contains Gray values(255) of active pixels obtained from Sensor, and other inactive pixels value is filled with Gray value(0).</p> <p>EventAccumulatedPic - The frame buffer (a matrix)</p>



<pre> EventCountPic = 3, EventDenoisedBinaryPic = 4, EventSuperimposedPic = 5 }; </pre>	<p>contains light intensity of active pixels obtained from Sensor, and other inactive pixels value is filled by their existing light intensity value.</p> <p>EventGrayPic - The frame buffer (a matrix) contains light intensity (not 255) of active pixels obtained from the Sensor, and other inactive pixels value is filled with Gray value(0).</p> <p>EventCountPic - The event trigger number frame buffer (matrix).</p> <p>EventDenoisedBinaryPic - The frame buffer (matrix) is similar to the event binary buffer, except that it is a denoised event binary buffer with a simple custom algorithm.</p> <p>EventSuperimposedPic - The frame buffer (matrix) that superimposes event binary picture onto event accumulated picture in Event mode.</p>
<pre> enum emFullPicType { Full_Optical_Flow_Pic = 0, Full_Optical_Flow_Speed_Pic = 1, Full_Optical_Flow_Direction_Pic = 2 }; </pre>	<p>Full_Optical_Flow_Pic - The full-frame optical flow buffer.</p> <p>Full_Optical_Flow_Speed_Pic - The speed frame buffer of each pixel calculated on the optical flow raw frame.</p> <p>Full_Optical_Flow_Direction_Pic - The direction frame buffer of each pixel calculated on the optical flow raw frame.</p>
<pre> typedef struct BinFileAttributes { uint8_t data_type; uint8_t loopA_mode; uint8_t loopB_mode; uint8_t loopC_mode; uint8_t event_data_format; uint8_t hour; uint8_t minute; uint8_t second; uint32_t package_count; } BinFileAttributes; </pre>	<p>data_type - bit0: 0: fixed mode; 1: loop mode. - bit1: 0: no IMU data; 1: has IMU data.</p> <p>loopA_mode - The first working mode of the loop.</p> <p>loopB_mode - The second working mode of the loop.</p> <p>loopC_mode - The third working mode of the loop.</p> <p>event_data-format - The event data format used.</p> <p>hour, minute, second - The time length of the bin file recording.</p> <p>package_count - The package count of the recorded bin file.</p>
<pre> typedef struct EventData { uint16_t col; uint16_t row; uint16_t brightness; uint32_t t; int8_t p; } </pre>	<p>col - The column information of one pixel in the frame buffer.</p> <p>row - The row information of one pixel in the frame buffer.</p> <p>brightness - The brightness of one pixel in the frame buffer.</p>

}EventData;	<p>t - The time of one pixel in the frame buffer.</p> <p>p - The polarity of one pixel in the frame buffer.(-1: intensity weakened; 1: intensity is increased; 0 intensity unchanged)</p>
-------------	--

CelePixel Confidential

2.2. CeleX5DataManager Class Reference

This class allows to be notified about the processed frame buffer that is ready. To receive these notifications, you need to derive your own data manager subclass from this class and override its virtual *onFrameDataUpdated* methods.

```
#include <opencv2/opencv.hpp>
#include <celex5/celex5.h>
#include <celex5/celex5datamanager.h>
#include <celex5/celex5processeddata.h>

#ifdef _WIN32
#include <windows.h>
#else
#include <unistd.h>
#endif

#define FPN_PATH    "./FPN.txt"

class SensorDataObserver : public CeleX5DataManager
{
public:
    SensorDataObserver(CX5SensorDataServer* pServer)
    {
        m_pServer = pServer;
        m_pServer->registerData(this, CeleX5DataManager::CeleX_Frame_Data);
    }
    ~SensorDataObserver()
    {
        m_pServer->unregisterData(this, CeleX5DataManager::CeleX_Frame_Data);
    }
    virtual void onFrameDataUpdated(CeleX5ProcessedData* pSensorData); //overrides Observer operation
    CX5SensorDataServer* m_pServer;
};

void SensorDataObserver::onFrameDataUpdated(CeleX5ProcessedData* pSensorData)
{
    if (NULL == pSensorData)
        return;
    CeleX5::CeleX5Mode sensorMode = pSensorData->getSensorMode();
    if (CeleX5::Full_Picture_Mode == sensorMode)
    {
        //get fullpic when sensor works in FullPictureMode
        if (pSensorData->getFullPicBuffer())
        {
```

```
        cv::Mat matFullPic(800, 1280, CV_8UC1, pSensorData->getFullPicBuffer()); //full pic
        cv::imshow("FullPic", matFullPic);
        cv::waitKey(1);
    }
}

else if (CeleX5::Event_No_ADC_Mode == sensorMode)
{
    //get buffers when sensor works in EventMode
    if (pSensorData->getEventPicBuffer(CeleX5::EventBinaryPic))
    {
        cv::Mat matEventPic(800, 1280, CV_8UC1,
            pSensorData->getEventPicBuffer(CeleX5::EventBinaryPic)); //event binary pic
        cv::imshow("Event Binary Pic", matEventPic);
        cvWaitKey(1);
    }
}

else if (CeleX5::Event_Intensity_Mode == sensorMode)
{
    //get buffers when sensor works in FullPic_Event_Mode
    if (pSensorData->getEventPicBuffer(CeleX5::EventBinaryPic))
    {
        cv::Mat matEventPic1(800, 1280, CV_8UC1,
            pSensorData->getEventPicBuffer(CeleX5::EventBinaryPic)); //event binary pic
        cv::Mat matEventPic2(800, 1280, CV_8UC1,
            pSensorData->getEventPicBuffer(CeleX5::EventGrayPic)); //event gray pic
        cv::imshow("Event Binary Pic", matEventPic1);
        cv::imshow("Event Gray Pic", matEventPic2);
        cvWaitKey(1);
    }
}
}

int main()
{
    CeleX5 *pCeleX = new CeleX5;
    if (NULL == pCeleX)
        return 0;

    pCeleX->openSensor(CeleX5::CeleX5_MIPI);
    pCeleX->setFpnFile(FPN_PATH);
    CeleX5::CeleX5Mode sensorMode = CeleX5::Event_Intensity_Mode;
    pCeleX->setSensorFixedMode(sensorMode);
    SensorDataObserver* pSensorData = new SensorDataObserver(pCeleX->getSensorDataServer());

    while (true)
```

```
{  
#ifdef _WIN32  
    Sleep(5);  
#else  
    usleep(1000 * 5);  
#endif  
}  
return 1;  
}
```

CelePixel Confidential

2.3. CeleX5 Class Reference

This is the class that encapsulates the methods to get the data from the sensor as well as the functionality to adjust the working mode and configuration register parameters of the sensor.

Public Member Functions:

API Name	Description
<u>openSensor</u>	Start sensor via calling this interface
<u>isSensorReady</u>	Check whether CeleX-5 sensor is successfully initialized
<u>getSensorRawData</u>	This method is used to read sensor raw data from a TCP socket
<u>setFpnFile</u>	Configure FPN used for creating a visual frame
<u>generateFPN</u>	Generate FPN
<u>setSensorFixedMode</u>	Set the fixed working mode of CeleX-5 sensor
<u>getSensorFixedMode</u>	Obtain the fixed working mode of CeleX-5 sensor
<u>getFullPicBuffer</u>	Obtain a visual frame in Full-Picture mode
<u>getFullPicMat</u>	Obtain the mat form of full picture buffer.
<u>getEventPicBuffer</u>	Obtain a visual frame in Event mode
<u>getEventPicMat</u>	Obtain the mat form of each event type picture buffer.
<u>getEventDataVector</u>	Get vector of event data in each frame time.
<u>getOpticalFlowPicBuffer</u>	Obtain the optical flow raw frame buffer.
<u>getOpticalFlowPicMat</u>	Obtain the mat form of frame buffer.
<u>getFullPicFrameTime</u>	Obtain the time of generating a full-frame picture when the CeleX-5 sensor works in <i>Full-frame Picture Mode</i>
<u>setEventFrameTime</u>	Set the frame time when CeleX-5 sensor is in the <i>Event Mode</i>
<u>getEventFrameTime</u>	Obtain the frame time when CeleX-5 sensor is in the <i>Event Mode</i>
<u>setOpticalFlowFrameTime</u>	Set the time of generating a full-frame picture when the CeleX-5 sensor works in <i>Full-frame Optical-flow Mode</i>
<u>getOpticalFlowFrameTime</u>	Obtain the time of generating a full-frame optical-flow picture when the CeleX-5 sensor works in <i>Full-frame Optical-flow Mode</i>
<u>setSensorLoopMode</u>	Set the working mode of one of three loops when CeleX-5 sensor works in the <i>Loop Mode</i>
<u>getSensorLoopMode</u>	Obtain the working mode of one of three loops when CeleX-5 sensor works in the <i>Loop Mode</i>
<u>setLoopModeEnabled</u>	Enable or disable the loop mode
<u>isLoopModeEnabled</u>	Check whether the loop mode is enabled
<u>setEventDuration</u>	Set the time duration of working in the event mode when the CeleX-5 sensor is in the <i>Loop Mode</i>
<u>setPictureNumber</u>	Set the picture number of working in the <i>Full-frame Mode</i> when the CeleX-5 sensor is in the loop mode

setThreshold	Configure the threshold value where the event triggers (the change of light intensity happen to a pixel is greater than the threshold, the pixel can be marked as an event/active pixel)
getThreshold	Get the threshold value for triggering an event
setISOLevel	Configure the contrast and dynamic range of the image CeleX-5 sensor generated
getISOLevel	Get the value associated with the contrast and dynamic range of the image that the CeleX-5 sensor generated
setBrightness	Configure the brightness
getBrightness	Get the brightness
setClockRate	Set the clock rate of the sensor
getClockRate	Obtain the clock rate of the sensor
reset	Reset the sensor and clear the data in the FIFO buffer
startRecording	Start to record the raw data of sensor and saved as bin format
stopRecording	Stop to record the raw data of sensor
openBinFile	Open the bin file in the user-specified directory
readBinFileData	Read data from the opened bin file
getBinFileAttributes	Obtain attributes of the bin file.

2.3.1 openSensor

bool CeleX5::openSensor(**DeviceType** type)

Parameters

[in] **type** The device type of CeleX-5 sensor.

Returns

The state whether the CeleX-5 sensor is successfully started up.

This method is used to start up the CeleX-5 sensor. If the currently used CeleX-5 chipset supports serial output, type is *CeleX5_MIPI*, if it supports parallel output is supported, type is *CeleX5_Parallel*. For more details about type, please refer to the explanation of [DeviceType](#).

```
#include <celex5/celex5.h>

{
    CeleX5 *pCeleX = new CeleX5;
    if (pCeleX == NULL)
        return 0;
    pCeleX->openSensor(CeleX5::CeleX5_MIPI);
}
```

See also

[isSensorReady](#)



2.3.2 isSensorReady

bool CeleX5::isSensorReady()

Returns

The state of the CeleX-5 sensor

This method is used to check whether the CeleX-5 sensor is successfully started up. It returns true if the sensor is ready, or it returns false.

See also

[openSensor](#)

2.3.3 getSensorRawData

int CeleX5::getSensorRawData(**unsigned char*** buffer, **int** length)

Parameters

[in] **buffer** The buffer to store the data have been read.

[in] **length** The length of the buffer

Returns

The length of the data on successful completion

This method is used to read sensor raw data from a TCP socket.

2.3.4 setFpnFile

bool CeleX5::setFpnFile(**const string** &fpnFile)

Parameters

[in] **fpnFile** The directory path and file name of FPN file required.

Returns

The state of loading FPN file.

This method is used to set the FPN path, then the API will use this FPN to calculate the full frame picture. It returns true if the FPN file load successfully, or it returns false.

See also

[generateFPN](#)

2.3.5 generateFPN

void CeleX5::generateFPN(**std::string** fpnFile)

Parameters

[in] **fpnFile** The directory path and file name of generated FPN file to be saved.

This method is used to generate FPN file. Normally we are intending to name the generated FPN as "FPN.txt" and save it in the directory where the execution application is running.

FPN, known as Fixed Pattern Noise, is the term given to a particular noise pattern on digital

imaging sensors often noticeable during longer exposure shots where particular pixels are susceptible to giving brighter intensities above the general background noise.

See also

[setFpnFile](#)

2.3.6 setSensorFixedMode

void **CeleX5::setSensorFixedMode**(**CeleX5Mode** mode)

Parameters

[in] **mode** The fixed working mode of CeleX-5 sensor.

This method is used to set the fixed working mode of CeleX-5 sensor including *Event Address-only Mode*, *Event Optical-flow Mode*, *Event Intensity Mode*, *Full-frame Picture Mode*, *Single Full-frame Optical-flow Mode* and *Multiple Full-frame Optical-flow Mode*. For more details, please refer to the explanation of [CeleX5Mode](#).

See also

[getSensorFixedMode](#)

2.3.7 getSensorFixedMode

CeleX5Mode **CeleX5::getSensorFixedMode**()

Returns

The fixed working mode of CeleX-5 sensor.

This method is used to obtain the fixed working mode of CeleX-5 sensor.

See also

[setSensorFixedMode](#)

2.3.8 getFullPicBuffer

void **getFullPicBuffer**(**unsigned char*** buffer)

Parameters

[in] **buffer** The frame buffer (size is 1280 * 800) in *Full-frame Picture Mode*.

This method is used to obtain a full-frame picture buffer when sensor works in the *Full-frame Picture Mode*. You can get the buffer if the sensor is opened successfully. For example,

```
#include <opencv2/opencv.hpp>
#include <celex5/celex5.h>
int main()
{
    CeleX5 *pCeleX = new CeleX5;
    if (NULL == pCeleX)
        return 0;
    pCeleX->openSensor(CeleX5::CeleX5_MIPI);
```



```

pCeleX->setFpnFile(FPN_PATH);
pCeleX->setSensorFixedMode(CeleX5::Full_Picture_Mode);
int imgSize = 1280 * 800;
unsigned char* pBuffer1 = new unsigned char[imgSize];
while (true)
{
    if (sensorMode == CeleX5::Full_Picture_Mode)
    {
        //get fullpic when sensor works in Full-frame Picture Mode
        pCeleX->getFullPicBuffer(pBuffer1); //full pic
        cv::Mat matFullPic(800, 1280, CV_8UC1, pBuffer1);
        cv::imshow("FullPic", matFullPic);
        cvWaitKey(10);
    }
}
}

```

See also

[getFullPicMat](#)

2.3.9 getFullPicMat

cv::Mat CeleX5::getFullPicMat()

Returns

The frame buffer (cv::Mat(800, 1280)) in *Full-frame Picture Mode*.

This method is used to obtain a full-frame picture mat. It is similar to call [getFullPicBuffer](#), for example,

```

#include <opencv2/opencv.hpp>
#include <celex5/celex5.h>
int main()
{
    CeleX5 *pCeleX = new CeleX5;
    if (pCeleX == NULL)
        return 0;
    pCeleX->openSensor(CeleX5::CeleX5_MIPI);
    pCeleX->setFpnFile(FPN_PATH);
    pCeleX->setSensorFixedMode(CeleX5:: Full_Picture_Mode);
    while (true)
    {
        if (sensorMode == CeleX5::Full_Picture_Mode)
        {
            if (!pCeleX->getFullPicMat().empty())

```

```

        {
            cv::Mat fullPicMat = pCeleX->getFullPicMat();
            cv::imshow("FullPic", fullPicMat);
            cv::waitKey(10);
        }
    }
}
}

```

See also

[getFullPicBuffer](#)

2.3.10 getEventPicBuffer

void getEventPicBuffer(**unsigned char*** buffer, **emEventPicType** type = EventBinaryPic)

Parameters

[in] **type** The event frame buffer (size is 1280 * 800) according to the type you specify.

[in] **type** The event picture type.

This method is used to obtain an event picture buffer by the given event pic type when the sensor works in *Event Mode*. For more details, please refer to the explanation of [emEventPicMode](#).

```

#include <opencv2/opencv.hpp>
#include <celex5/celex5.h>
int main()
{
    CeleX5 *pCeleX = new CeleX5;
    if (NULL == pCeleX)
        return 0;
    pCeleX->openSensor(CeleX5::CeleX5_MIPI);
    pCeleX->setFpnFile(FPN_PATH);
    pCeleX->setSensorFixedMode(CeleX5::Event_Address_Only_Mode);
    int imgSize = 1280 * 800;
    unsigned char* pBuffer1 = new unsigned char[imgSize];
    while (true)
    {
        if (sensorMode == CeleX5::Event_Address_Only_Mode)
        {
            //get buffers when sensor works in Event Mode
            pCeleX->getEventPicBuffer(pBuffer1, CeleX5::EventBinaryPic);
            cv::Mat matEventPic(800, 1280, CV_8UC1, pBuffer1);
            cv::imshow("Event-EventBinaryPic", matEventPic);
            cvWaitKey(10);
        }
    }
}

```

}

See also

[getEventPicMat](#)

2.3.11 getEventPicMat

cv::Mat CeleX5::getEventPicMat(emEventPicMode type)

Parameters

[in] **type** The event picture type.

Returns

The event frame buffer (cv::Mat(800, 1280)) according to the type you specify.

This method is used to obtain an event picture mat by the given event pic type when the sensor works in *Event Mode*. This method can obtain seven different types of pictures include binary, gray, count etc. For more details about these types, please refer to [emEventPicType](#).

See also

[getEventPicBuffer](#)

2.3.12 getEventDataVector

bool CeleX5::getEventDataVector(std::vector<EventData>& data)

bool CeleX5::getEventDataVector(std::vector<EventData> &vector, uint64_t& frameNo)

Parameters

[out] **data** The vector of event data at each frame time.

[out] **frameNo** The frame number of the event data vector.

Returns

If the vector of event data is not empty, return true. Otherwise it will return false.

This method is used to obtain vector of event data at each frame time. Default frame time is 30ms. Each event data contains rows, columns, brightness and time information. For more details, please refer to the explanation of [EventData](#). It can be used in real-time or in the offline bin files.

2.3.13 getOpticalFlowPicBuffer

void CeleX5::getOpticalFlowPicBuffer(unsigned char* buffer, emFullPicType type = Full_Optical_Flow_Pic)

Parameters

[in] **buffer** The Optical-Flow frame buffer (size is 1280 * 800).

[in] **type** The full-frame optical flow type.

This method is used to obtain the Optical-flow frame buffer. For more type of the Optical-Flow, see [emFullPicType](#).

For example,

```
#include <opencv2/opencv.hpp>
#include <celex5/celex5.h>

int main()
{
    CeleX5 *pCeleX = new CeleX5;
    if (NULL == pCeleX)
        return 0;

    pCeleX->openSensor(CeleX5::CeleX5_MIPI);
    pCeleX->setSensorFixedMode(CeleX5::Full_Optical_Flow_1_Mode);
    int imgSize = 1280 * 800;
    unsigned char* pOpticalFlowBuffer = new unsigned char[imgSize];
    while (true)
    {
        //get optical-flow data when sensor works in EventMode
        //optical-flow raw data - display gray image
        pCeleX->getOpticalFlowPicBuffer(pOpticalFlowBuffer, CeleX5:: Full_Optical_Flow_Pic);
        cv::Mat matOpticalRaw(800, 1280, CV_8UC1, pOpticalFlowBuffer);
        cv::imshow("Optical-Flow Buffer - Gray", matOpticalRaw);
        cvWaitKey(10);
    }
    return 1;
}
```

See also

[getOpticalFlowPicMat](#)

2.3.14 getOpticalFlowPicMat

cv::Mat CeleX5:: getOpticalFlowPicMat (**emFullPicType** type)

Returns

The optical flow frame buffer (cv::Mat(800, 1280)).

This method returns the optical flow picture buffer in cv::Mat form when it is called. For more type of the Optical-Flow, see [emFullPicType](#).

See also

[getOpticalFlowPicBuffer](#)

2.3.15 getFullPicFrameTime

uint32_t CeleX5::getFullPicFrameTime()

Returns

The time of generating a full-frame picture, unit is ms.

This method is used to obtain the time of generating a full-frame picture when the CeleX-5 sensor works in *Full-frame Picture Mode*.

2.3.16 setEventFrameTime

void CeleX5::setEventFrameTime(uint32_t msec)

Parameters

[in] msec The frame time of *Event Mode*, unit is ms.

This method is used to set the frame time when CeleX-5 sensor is in the *Event Mode*. It modifies the frame length when the software creates event frames without changing the hardware parameters.

See also

[getEventFrameTime](#)

2.3.17 getEventFrameTime

uint32_t CeleX5::getEventFrameTime()

Returns

The frame time of *Event Mode*, unit is ms.

This method is used to obtain the frame time when CeleX-5 sensor is in the *Event Mode*.

See also

[setEventFrameTime](#)

2.3.18 setOpticalFlowFrameTime

void CeleX5::setOpticalFlowFrameTime(uint32_t msec)

Parameters

[in] msec The time of generating a full-frame optical-flow picture, unit is ms.

This method is used to set the time of generating a full-frame picture when the CeleX-5 sensor works in *Full-frame Optical-flow Mode*. It changes the hardware parameters. The default value is 30ms, which means the sensor could generate about 33 full-frame optical-flow pictures per second. For more details about this time, please refers section [1.2.1.5](#).

See also

[getOpticalFlowFrameTime](#)

2.3.19 getOpticalFlowFrameTime

uint32_t CeleX5::getOpticalFlowFrameTime()

Returns

The time of generating a full-frame optical-flow picture, unit is ms.

This method is used to obtain the time of generating a full-frame optical-flow picture when the CeleX-5 sensor works in *Full-frame Optical-flow Mode*.

See also

[setOpticalFlowFrameTime](#)

2.3.20 setSensorLoopMode

void CeleX5::setSensorLoopMode(**CeleX5Mode** mode, **int** loopNum)

Parameters

[in] **mode** The working mode of CeleX-5 sensor.

[in] **loopNum** The number of the loop.

This method is used to set the working mode of one of three loops when CeleX-5 sensor works in the *Loop Mode*, the value of *loopNum* is 1, 2, and 3, which represent the first, second and third loop in the loop mode. For more details of the loop mode, see section [1.2.2](#).

See also

[getSensorLoopMode](#)

2.3.21 getSensorLoopMode

CeleX5Mode CeleX5::getSensorLoopMode(**int** loopNum)

Parameters

[in] **loopNum** The number of the loop.

Returns

The working mode of the given loopNum.

This method is used to get the working mode of one of three loops when CeleX-5 sensor works in the *Loop Mode*, for more details of the loop mode, see section [1.2.2](#).

See also

[setSensorLoopMode](#)

2.3.22 setLoopModeEnabled

void CeleX5::setLoopModeEnabled(**bool** enable)

Parameters

[in] **enable** The state to enable or disable *Loop Mode*.

This method is used to enable the loop mode of the CeleX-5 sensor, for more details of the *Loop Mode*, see section [1.2.2](#).

See also

[isLoopModeEnabled](#)

2.3.23 isLoopModeEnabled

bool CeleX5::isLoopModeEnabled()

Returns

The state whether the *Loop Mode* is enabled.

This method is used to check whether the loop mode is enabled, for more details of the loop mode, see section [1.3.2](#).

See also

[setLoopModeEnabled](#)

2.3.24 setEventDuration

void CeleX5::setEventDuration(**uint32_t** value)

Parameters

[in] **value** The time duration of working in the *Event Mode*.

This method is used to set the time duration of working in the event mode when the CeleX-5 sensor is in the *Loop Mode*. For more details of the *Loop Mode*, see section [1.2.2](#).

See also

[setPictureNumber](#)

2.3.25 setPictureNumber

void setPictureNumber(**uint32_t** num, **CeleX5Mode** mode)

Parameters

[in] **num** The picture number.

[in] **mode** The mode to be set the picture number.

This method is used to set the picture number of working in the *Full-frame Mode* when the CeleX-5 sensor is in the loop mode. For more details of the *Loop Mode*, see section [1.2.2](#).

See also

[setEventDuration](#)

2.3.26 setThreshold

void CeleX5::setThreshold(**uint32_t** value)

Parameters

[in] **value** Threshold value.

This method is used to configure the threshold value where the event triggers (the light intensity change of a pixel exceeds this threshold, the pixel can be marked as an event or active pixel). The

large the threshold value is, the less pixels that the event will be triggered (or less active pixels). It could be adjusted from 50 to 511, and the default value is 171.

The threshold value only works when the CeleX-5 sensor is in the *Event Mode*, however, the Sensor still outputs a complete image regardless of the threshold value when it works in *Full-frame Picture Mode*.

See also

[getThreshold](#)

2.3.27 getThreshold

uint32_t CeleX5::getThreshold()

Returns

Threshold value.

This method is used to get threshold value where the event triggers.

See also

[setThreshold](#)

2.3.28 setBrightness

void CeleX5::setBrightness(uint32_t value)

Parameters

[in] **value** The value associated with the brightness of the image.

This method is used to configure register parameter, which controls the brightness of the image CeleX-5 sensor generated. It could be adjusted from 0 to 1023, and the default value is **130**.

See also

[getBrightness](#)

2.3.29 getBrightness

void CeleX5::getBrightness(uint32_t value)

Returns

The value associated with the brightness of the image.

This method is used to get the register value associated with the brightness of the image that the CeleX-5 sensor generated.

See also

[setBrightness](#)

2.3.30 setISOLevel

void CeleX5::setISOLevel(uint32_t value)

Parameters

[in] **value** The value associated with the contrast and dynamic range of the image.

This method is used to configure register parameter, which controls the contrast and dynamic range of the image CeleX-5 sensor generated. It could be adjusted from 1 to 4, and the default value is 2.

See also

[getISOLevel](#)

2.3.31 getISOLevel

uint32_t CeleX5::getISOLevel()

Returns

The value associated with the contrast and dynamic range of the image.

This method is used to get the value associated with the contrast and dynamic range of the image that the CeleX-5 sensor generated.

See also

[setISOLevel](#)

2.3.32 setClockRate

void CeleX5::setClockRate(uint32_t value)

Parameters

[in] **value** The clock rate of the CeleX-5 sensor, unit is MHz

This method is used to set the clock rate of the sensor. By default, the CeleX-5 sensor works at **40MHz** and the range of clock rate is from 20 to 100, step is **10**.

See also

[getClockRate](#)

2.3.33 getClockRate

uint32_t CeleX5::getClockRate()

Returns

The clock rate of the CeleX-5 sensor, unit is MHz

This method is used to obtain the clock rate of the CeleX-5 sensor. The range of clock rate is from 20 to 100.

See also

[setClockRate](#)



2.3.34 reset

void CeleX5::reset ()

This method is used to reset the sensor and clear the data in the FIFO buffer.

2.3.35 startRecording

void CeleX5::startRecording(std::string filePath)

Parameters

[in] **filePath** The directory path to save the bin file

This method is used to start recording the raw data of the sensor and save it as a bin file. The type in which data will be saved depends on which mode Sensor is working in.

See also

[stopRecording](#)

2.3.36 stopRecording

void CeleX5::stopRecording()

This method is used to stop recording the raw data of the sensor.

See also

[startRecording](#)

2.3.37 openBinFile

bool CeleX5::openBinFile(string filePath)

Parameters

[in] **filePath** The directory path and name of the bin file to be played.

Returns

The value whether the bin file is opened.

This method is used to open the bin file in the user-specified directory. It returns true if the bin file opens successfully, otherwise it returns false.

See also

[readBinFileData](#)

2.3.38 readBinFileData

bool CeleX5::readBinFileData()

Returns

The value whether the bin is read over.

This method is used to read data from the opened bin file. If reaching the end of the bin file it will return true, otherwise it will return false. Before reading the bin file, you need to open the file first.

See also

[openBinFile](#)

2.3.39 getBinFileAttributes

BinFileAttributes **CeleX5::getBinFileAttributes**(std::string& binFile)

Parameters

[in] **binFile** The path of the bin file.

Returns

A structure of the file attributes.

This method is used to obtain the attributes of the bin file. It will return a structure which includes hour, minute, second, mode, length, and clock rate when we call this method. For more details, please refer to the explanation of [BinFileAttributes](#).