



# FRAMOS Industrial Depth Camera D400e Series - Multi-Camera Synchronization

APPLICATION NOTE



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## List of Abbreviations

Abbreviation	Explanation
SDK	Software Development Kit
NIC	Network Interface Card
I/O	Input/output
DC	Direct Current
GND	Ground
VDC	Volts Direct Current
HW	Hardware
IN	Input
OUT	Output



# 1. Overview

The *FRAMOS Industrial Depth Camera D400e Series - Multi-Camera Synchronization* application note provides tips and recommendations on how to configure multiple FRAMOS D400e cameras to achieve synchronous streaming.

Multiple D400e cameras, in default configuration, will capture data at different points in time and streams from multiple cameras will therefore not be synchronized. Synchronous streaming from multiple cameras can be achieved by utilizing the camera's external synchronization interface. Additionally, the cameras need to be configured via the software interface in a way that the system consists of one master device and multiple slave devices.

To arrange a multi camera system, additional restrictions as, e.g. bandwidth limitations and NIC settings, need to be considered. Refer to *FRAMOS Industrial Depth Camera D400e Series - Tuning System For Best Performance* [Ref-1] for tips on how to achieve best performance with multi-camera system.



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**Information:** With the D400e series multi-camera system, only the streams from the same camera model can be synchronized (D435e with D435e, D415e with D415e, D455e with D455e).

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## 2. Hardware Configuration

The FRAMOS Industrial Depth Camera D400e series is equipped with an industrial grade M8 connector used for power supply and external synchronization through the I/O interface as shown in Figure 1 and described in Table 1.

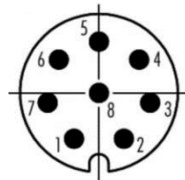


Figure 1 – Power M8 Connector, A-Coded, Male

M8 Pin	Description
1	DC Power supply, 12-24V DC (+/- 10%)
2	Opto-isolated IN
3	Opto-isolated OUT
4	GND for opto-isolated I/O
5	Not connected
6	Not connected
7	Not connected
8	GND

Table 1 – M8 Connector Pin Description

The physical input line **Opto-isolated IN** (Pin 2) is designated as opto-isolated input. The operational limits of the opto-isolated input are given in Table 2.

Description	Limits
Recommended operating voltage	+0 to +24 VDC
Voltage level representing logical 0	+0 to +1.4 VDC
Voltage level representing logical 1	> +2.2 VDC
Absolute maximum voltage	+30.0 VDC
The current draw for each input line	5 to 15 mA

Table 2 – Electrical Specification for Opto-Isolated Input



Physical output line **Opto-isolated OUT** (Pin 3) is designated as opto-isolated output. The operational limits of the opto-isolated output are given in Table 3.

Description	Limits
Recommended operating voltage	+3.3 to +24.0 VDC
Absolute maximum voltage	+30.0 VDC
Maximum output current	90 mA

Table 3 – Electrical Specification for Opto-Isolated Output



**Caution:** Exceeding the operational limits given in Table 2 and Table 3 can cause permanent damage to the device.

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## 2.1 Schemes

### 2.1.1 Opto-Isolated OUT/IN Schemes

Electrical scheme of Opto-isolated OUT is shown in Figure 2.

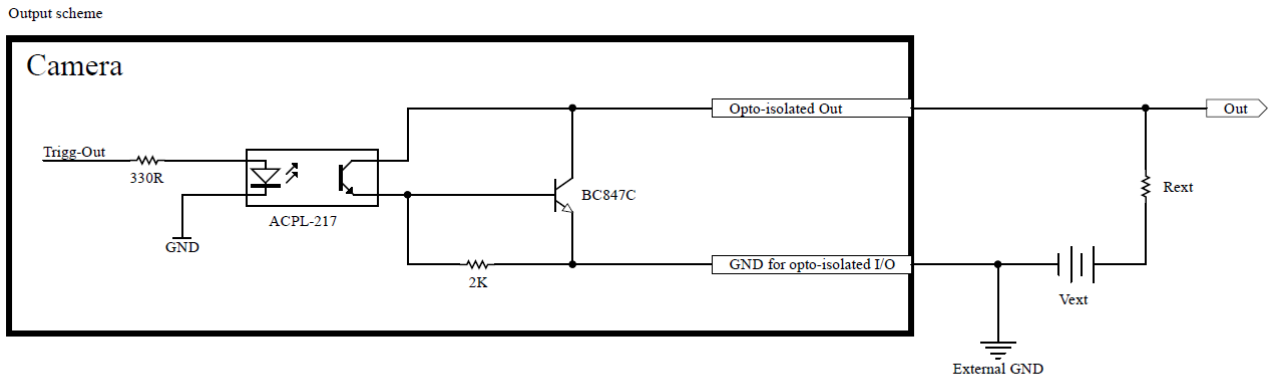


Figure 2 – Opto-Isolated OUT Scheme

Electrical scheme of Opto-isolated IN is shown in Figure 3.

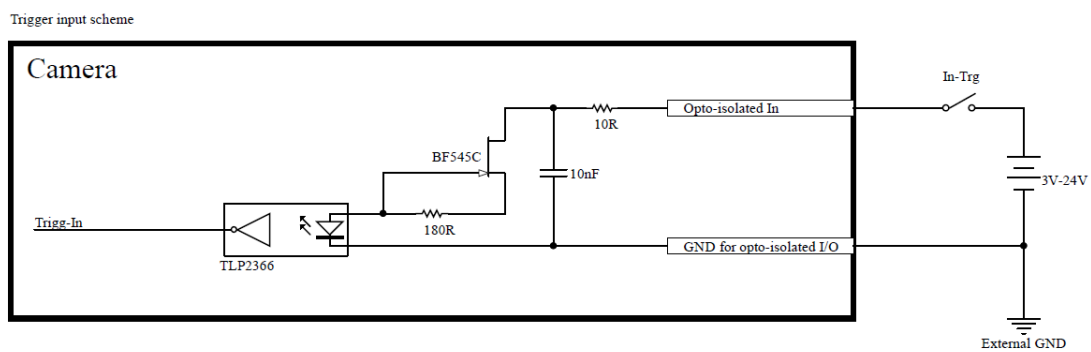


Figure 3 – Opto-Isolated IN Scheme

## 2.1.2 Synchronization Scheme

The electrical scheme of synchronization between "Master Camera" and multiple "Slave Cameras" is shown in Figure 4. The "Master Camera" black box presents simplified **Opto-isolated OUT** scheme, while the "Slave Camera" black boxes present simplified **Opto-isolated IN** schemes.

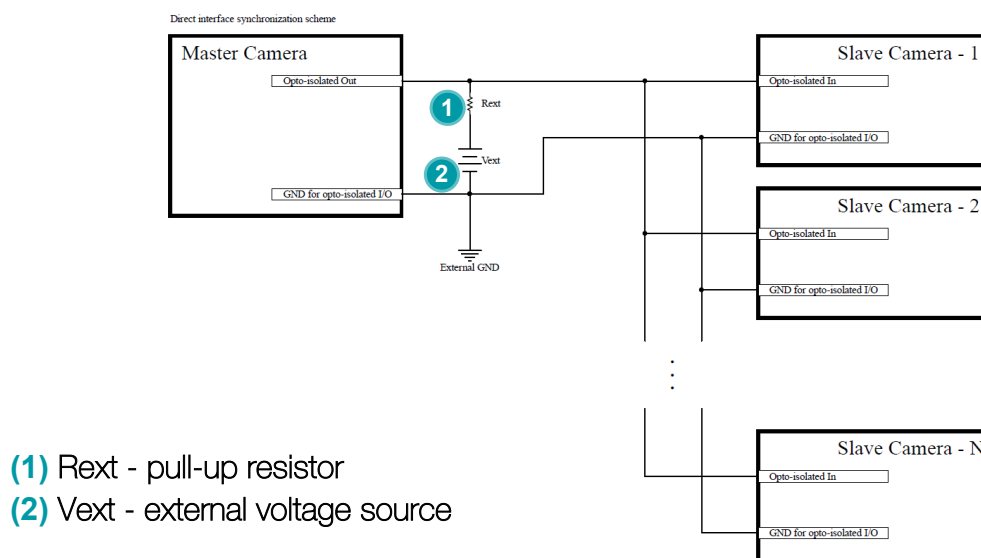


Figure 4 – Synchronization Scheme

For HW synchronization **Opto-isolated OUT** of the "Master Camera", it must be connected to **Opto-isolated IN** of multiple "Slave Cameras" as shown on Figure 4. Additionally, GND for opto-isolated I/O of all cameras is common.

## 2.2 Restrictions

Using the synchronization scheme presented in Figure 4, one "Master Camera" can trigger at least 7 "Slave Cameras", meaning that at least 8 cameras can be synchronized this way. The value of **Rext** resistor should be selected carefully, considering the number of cameras and external voltage source **Vext** used in the system.

Number of Devices in Multi-Camera System	Vext	Rext
2 (1 Master + 1 Slave)	24V	2K2
4 (1 Master + 3 Slaves)	24V	1K
8 (1 Master + 7 Slaves)	24V	390R

Table 4 – Recommended value for Rext resistor in different systems

Two important criteria must be satisfied when selecting the value of **Rext** resistor: the minimum value of the resistor is limited by the absolute maximum current of the opto-isolated output on the





"Master Camera"; the maximum value of the resistor is limited by the voltage level representing logical "1" of the opto-isolated input on the "Slave Camera". The recommended value of the **Rext** resistor for different systems is presented in Table 4.

Another important aspect is the resistor power rating. It is recommended to use the highest possible value of **Rext** resistor in a system, range limited by the above two criteria, to prevent excess power consumption and heating of the **Rext** resistor. For example, for a system with 8 cameras as shown in Table 4, using **Rext** 390R and **Vref** 24V, the maximum dissipation on the **Rext** resistor is  $P = 1.47W$ .



**Information:** Connecting more than 7 "Slave Cameras" in a multi-camera system as shown in Figure 4, could decrease voltage level representing logical 1 at **Opto-isolated IN** below the value given in electrical specification for opto-isolated input (see Table 2), and might lead to incorrect level recognition. It is recommended to verify that the voltage level at opto-isolated input is inside specified range with an oscilloscope.



**Caution:** The value of the **Rext** resistor should be selected carefully so that the absolute maximum current of the opto-isolated output on the "Master Camera" is not exceeded. Using a resistor with a lower value than recommended can cause permanent damage to the camera.



## 3. Software Configuration

### 3.1 Software Prerequisites

For validation purposes "LED Matrix Display" and "Intel RealSense Viewer" applications are used.

LED Matrix Display is an application which presents LEDs movement as shown in Figure 5.

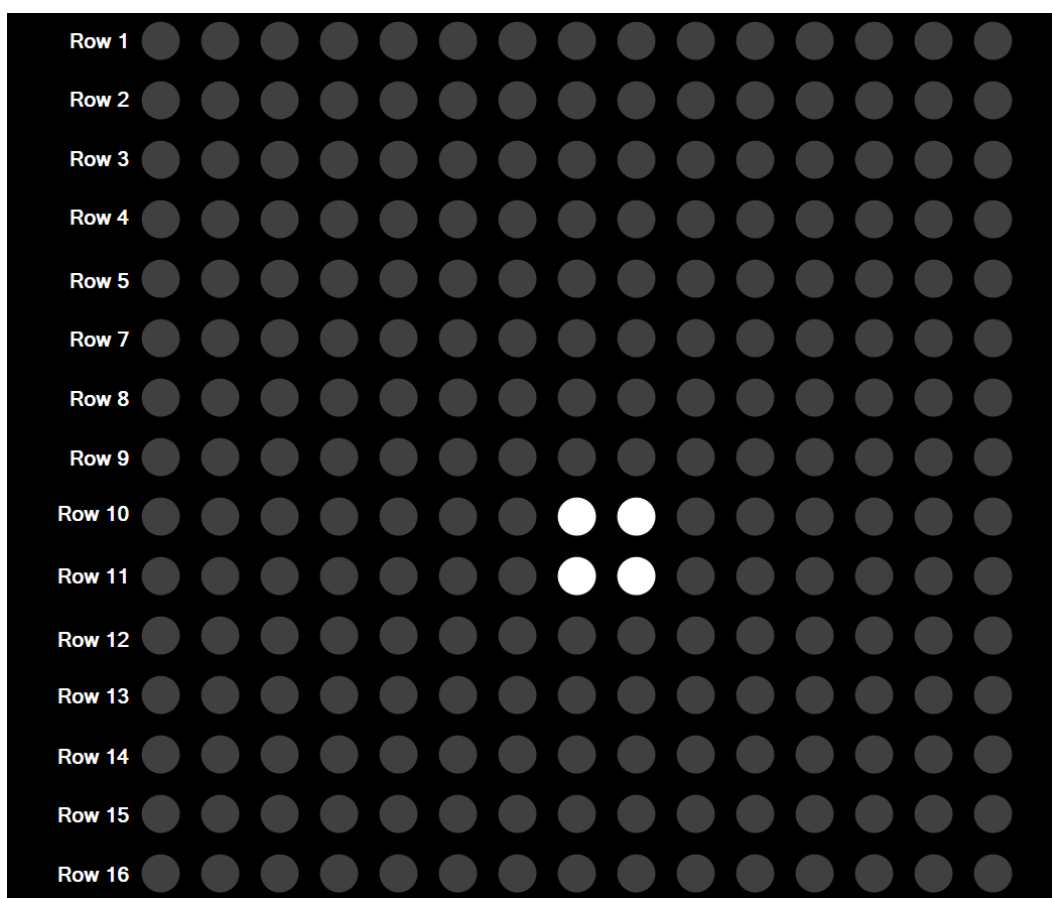


Figure 5 – LED Matrix Display Application

The LEDs are moving at the desired frequency. With setting appropriate LED moving frequency (considering the camera frame rate), it is possible to visualize if the cameras are synchronized or not.

The Intel RealSense Viewer is used for capturing infrared stream from left imager and setting required configuration on multiple FRAMOS D400e cameras.

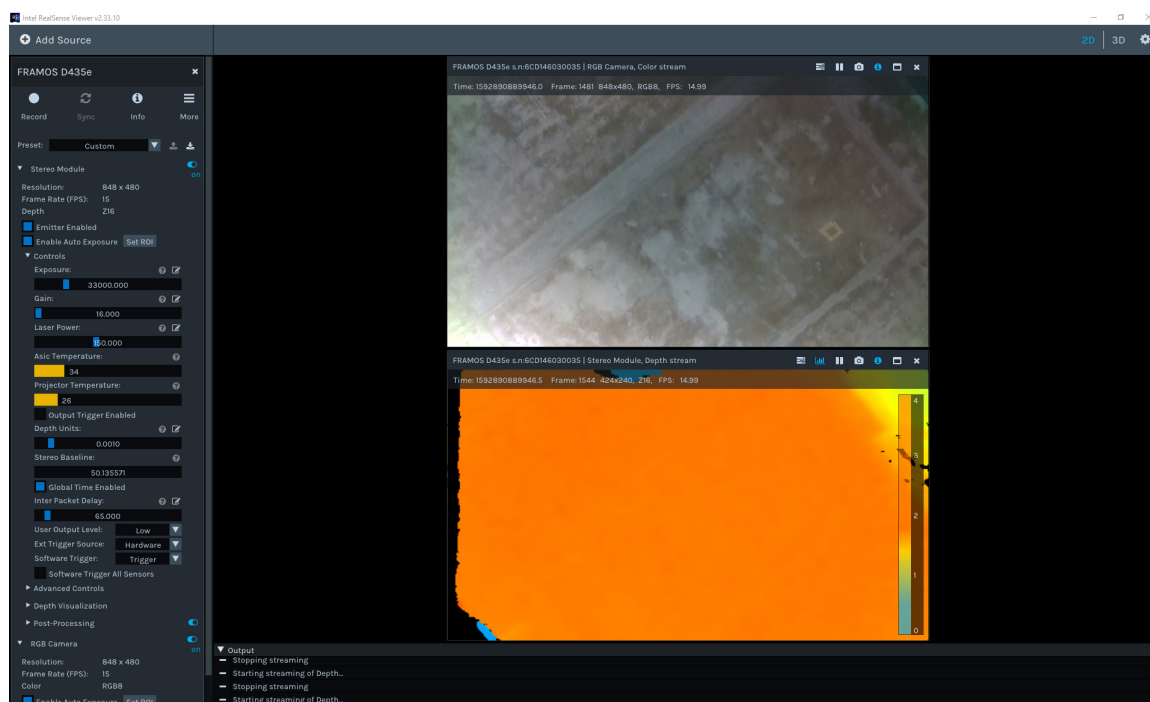


Figure 6 – FRAMOS D435e Camera streaming in Intel RealSense Viewer

## 3.2 Camera Settings

FRAMOS D400e camera series can operate in following modes:

- Default Mode
- Master Mode
- Slave Mode
- Genlock Mode
- External Event Mode

By default, camera is in "Default Mode". Considering multi-camera system, "Default Mode" means asynchronous streaming among cameras. When operating in "Master Mode", the camera outputs synchronization signal on the **Opto-isolated OUT** as long as the option "Output Trigger Enabled" is enabled. In "Slave Mode", if there is no signal on the **Opto-isolated IN**, the camera streams asynchronously in regard to other cameras in system. If there is a proper signal on **Opto-isolated IN**, the slave camera is synchronized with the master camera.

When using the FRAMOS D400e camera series in a standalone application/system, the "Default Mode" is the recommended operation mode.

If it is required to hardware synchronize cameras in multi-camera system, only one camera is set to "Master Mode", and the others to "Slave Mode". Camera that is set to "Master Mode" must have the option "Output Trigger Enabled" enabled.



### 3.2.1 Setting Operating Mode

"RS2\_OPTION\_INTER\_CAM\_SYNC\_MODE" option is used for setting camera operating mode. "RS2\_OPTION\_OUTPUT\_TRIGGER\_ENABLED" option is used for setting "Output Trigger Enabled" option.

```
// Stereo Module
enum cs_inter_cam_sync_mode
{
    CS_INTERCAM_SYNC_DEFAULT = 0,
    CS_INTERCAM_SYNC_MASTER = 1,
    CS_INTERCAM_SYNC_SLAVE = 2,
    CS_INTERCAM_SYNC_EXTERNAL = 3,
    CS_INTERCAM_SYNC_EXTERNAL_BURST = 4,
    CS_INTERCAM_SYNC_MAX = 5 //enumeration purpose only
};

// RGB Camera
enum cs_inter_cam_sync_mode_color
{
    CS_INTERCAM_SYNC_DEFAULT_COLOR = 0,
    CS_INTERCAM_SYNC_EXTERNAL_COLOR = 1,
    CS_INTERCAM_SYNC_EXTERNAL_BURST_COLOR = 2,
    CS_INTERCAM_SYNC_MAX_COLOR = 3 //enumeration purpose only
};

// Stereo Module Global Shutters (D435e)
enum cs_inter_cam_sync_mode_gs
{
    CS_INTERCAM_SYNC_DEFAULT_GS = 0,
    CS_INTERCAM_SYNC_MASTER_GS = 1,
    CS_INTERCAM_SYNC_SLAVE_GS = 2,
    CS_INTERCAM_SYNC_FULL_SLAVE_GS = 3,
    CS_INTERCAM_SYNC_EXTERNAL_GS = 259,
    CS_INTERCAM_SYNC_EXTERNAL_BURST_GS = 260,
    CS_INTERCAM_SYNC_MAX = 261 //enumeration purpose only
};
```

Example of configuring camera operation mode through Intel RealSense Viewer is shown in Figure 7.

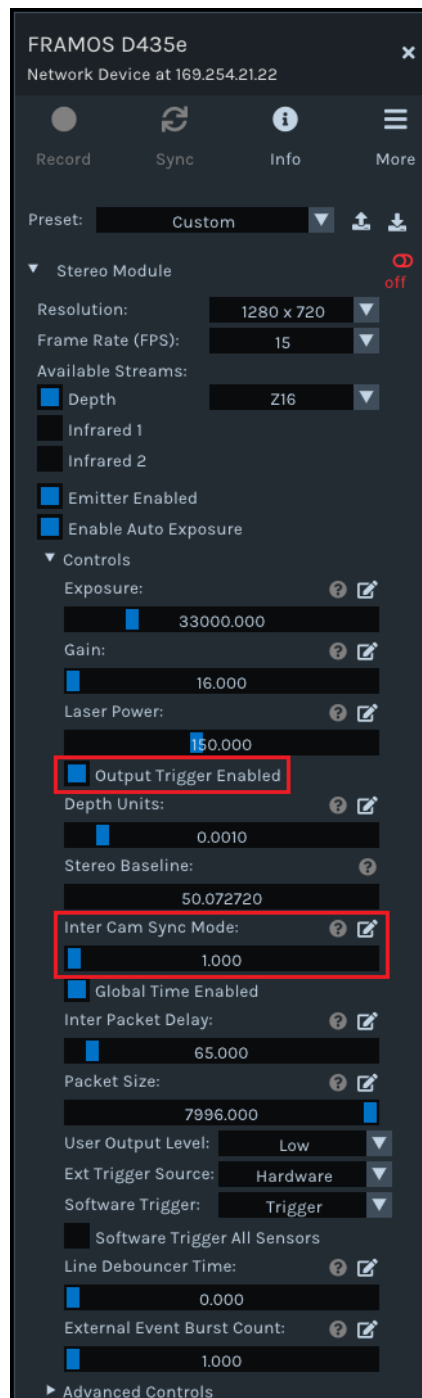


Figure 7 – Setting camera operating mode to master mode

To set the operating mode in code, call the "set\_option" function with option name and requested value as shown below.

```
// To set an option to a different value, call set_option with a new value
sensor.set_option(RS2_OPTION_INTER_CAM_SYNC_MODE, requested_value);
```



### 3.2.2 Additional remarks

In a multi-camera system, where multiple cameras are streaming to one network card on a PC, FRAMOS D400e cameras and network settings must be tuned to achieve best performance. Following recommendations given in *FRAMOS Industrial Depth Camera D400e - Tuning System For Best Performance*, **Inter Packet Delay** and **Packet Size** options need to be adjusted, considering the configured **Resolution** and **Frame Rate** options.

For example, in a system with two FRAMOS D400e cameras connected to one network card and a streaming configuration as follows:

- Resolution: 1280x720
- Frame Rate: 15
- Packet Size: 1500,

the recommended value for Inter Packet Delay is:

- Inter Packet Delay: 50



## 4. Hardware Validation

Multi-camera synchronization validation is performed using two FRAMOS D435e cameras pointing at the LED Matrix Display Application running on a Desktop PC. Capturing the fast-moving LEDs with both cameras simultaneously provides visual verification if the cameras are capturing images at the same time and frame rate.

With the remarks given in Chapter 3.2, one camera is configured to master operating mode, and the other to slave operating mode, as shown in Figure 8:

- (1) Master Camera.
- (2) Slave Camera.

Additionally, the Emitter and Auto Exposure are disabled, with Exposure and Gain slightly modified for better visualization.

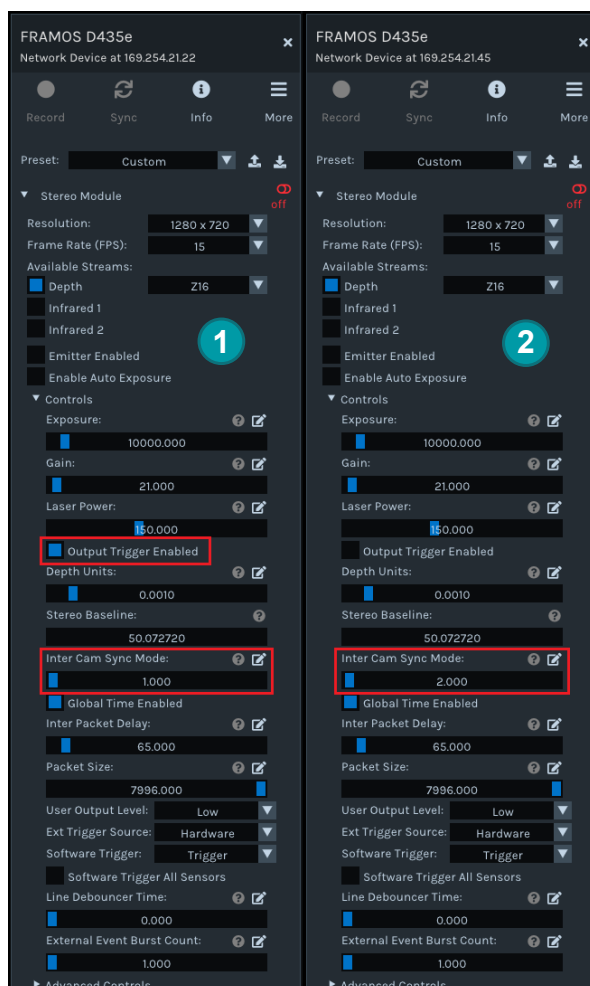


Figure 8 – Master and Slave FRAMOS D435e cameras



## 4.1 Results

As mentioned in Chapter 3.2, if not configured otherwise, the cameras are operating in "Default Mode" after power-up.

As shown in Figure 9, when cameras are working in "Default Mode", captured images show misalignment in the bright LEDs position, confirming asynchronous streams: the first camera captures LEDs starting in row 8 while the other camera captures LEDs starting in row 9.

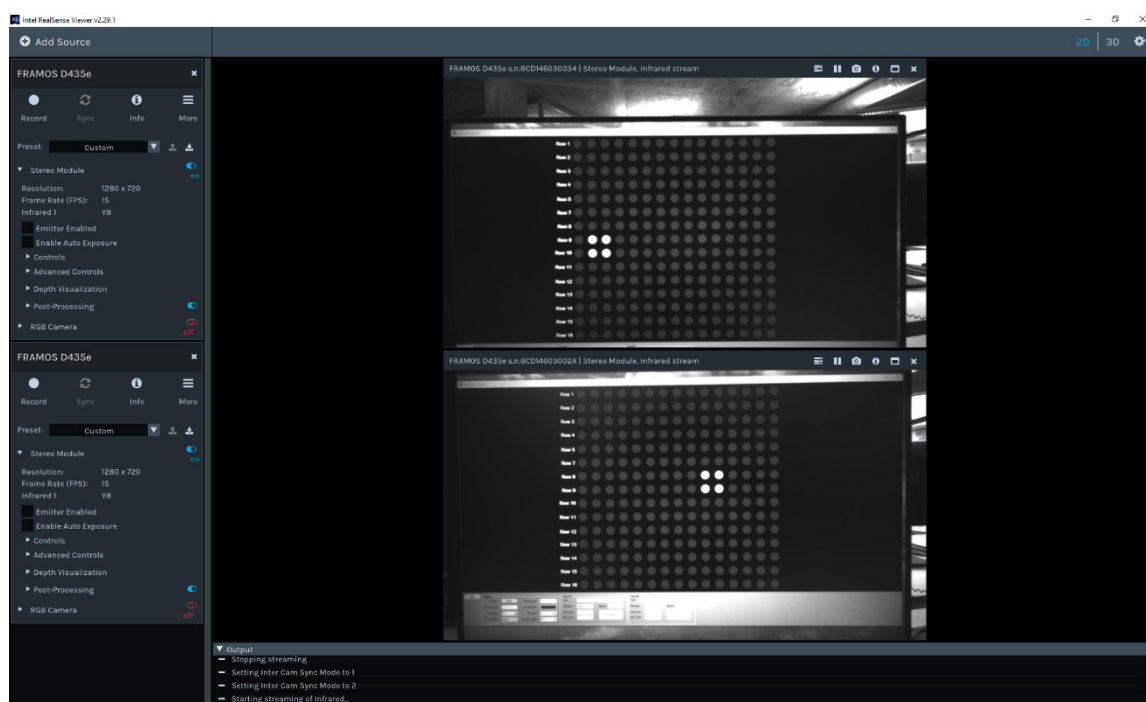


Figure 9 – Asynchronous Streams from two FRAMOS D435e Cameras

Synchronous streams from two different cameras are presented in Figure 10. With one camera configured as a master, and one as a slave, the captured images show bright LEDs at the same position: starting in row 10, column 2.



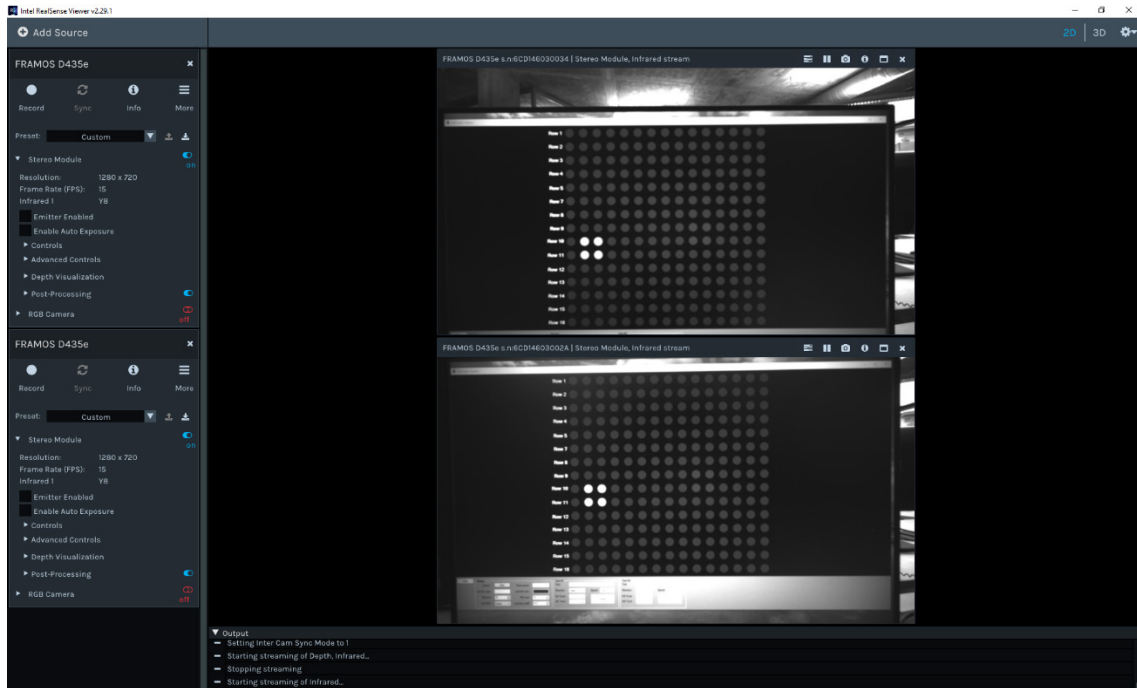


Figure 10 – Synchronous Streams from two FRAMOS D435e Cameras



## 5. References

1. [FRAMOS Industrial Depth Camera D400e Series - Tuning System For Best Performance, FRAMOS GmbH.](#)
2. [Using the Intel® RealSense™ Depth cameras D4xx in Multi-Camera Configurations v1.1, Intel Corporation.](#)



## 6. Revision History

Date	Version	Changes
2020-06-30	1.0.0	Initial release
2021-07-15	1.1.0	Updated chapter "Hardware Configuration"; Updated "References"
2021-10-15	1.2.0	Updated chapter "Setting Operating Mode"; Updated chapter "Hardware Validation"

Table 5 – Revision History

NOTE: *This document replaces and supersedes the application note "FRAMOS Industrial Depth Camera D435e - Multi-Camera Synchronization" v1.0.0.*