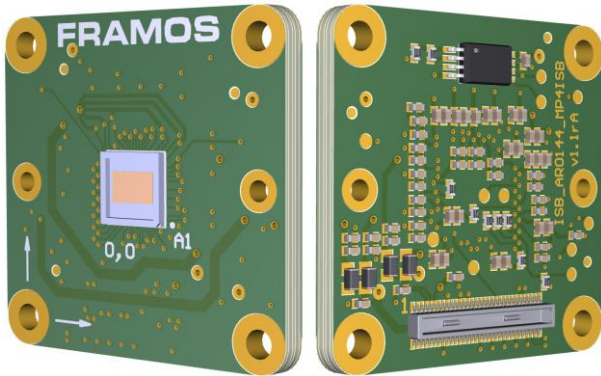




FSM-AR0144 Datasheet

ON Semiconductor AR0144CSSM / AR0144CSSC Sensor Module

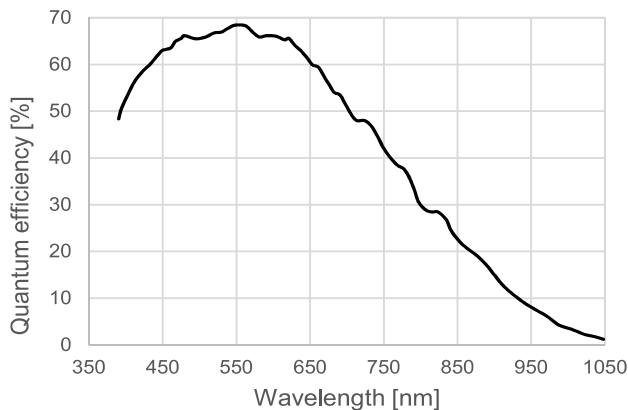
FRAMOS Sensor Module



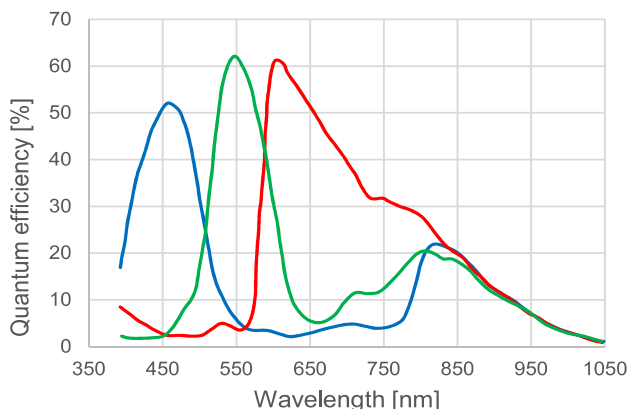
Key Benefits & Features:

- 1 Mpx ON Semiconductor CMOS Global Shutter sensor module, ready to embed!
- All FSMs are part of a rapid prototyping ecosystem, consisting of:
 - ✓ Adapters to various processing boards
 - ✓ Design sources for deep embedding
 - ✓ Various accessories and design in services

FSM-AR0144M (Monochrome):



FSM-AR0144C (Color):



Specification

| | |
|-------------------|--|
| Model Name | FSM-AR0144M / FSM-AR0144C (V1A) |
|-------------------|--|

Image Sensor

| | |
|--------------------|---|
| Vendor / Name | ON Semiconductor AR0144CSSM / AR0144CSSC |
| Shutter Type | CMOS Global Shutter |
| Technology / Grade | - / Industrial |
| Chromaticity | Color / Mono |
| Optical Format | 1/4" |
| Pixel Size | 3 x 3 μm |
| Max. Resolution | 1 Mpx / 1280 x 800 px |
| Framerate (max.) | 60.3 FPS (2-Lane) |
| Bit Depth(s) | 10 / 12 bit |

Interface

| | |
|-------------------------|----------------------------|
| Data Interface | MIPI CSI-2 (1 / 2 Lane) |
| Communication Interface | I ² C |
| Drive Frequency(s) | 6 to 48 MHz |
| Input Voltages | 1.2V, 1.8V, 2.8V |
| Interface Connector | Hirose DF40C-60DP-0.4V(51) |
| EEPROM (Sensor ID) | Yes |

Mechanical

| | |
|--------------------|-------------|
| Dimensions (HxWxD) | 26.5 x 26.5 |
|--------------------|-------------|

Environmental

| | |
|-----------------------|-------------------------------|
| Operating Temperature | -40°C to +85°C |
| Storage Temperature | -40°C to +150°C |
| Ambient Humidity | 20% to 95% RH, non condensing |

Software Support

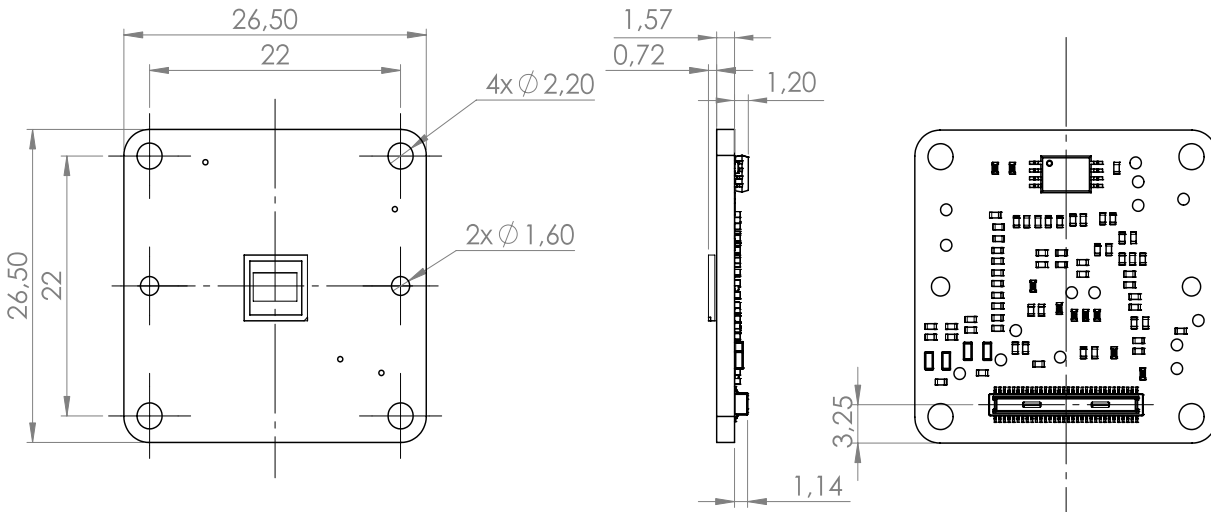
| | |
|-----------------------|--|
| Driver | V4L2 Based Device Driver Libargus / Argus Camera (ISP Tuned) Isaac ROS compliant |
| Supported Platform(s) | NVIDIA Jetson Family: AGX Xavier, Nano, TX2 (NX), Xavier NX |
| Software Version(s) | NVIDIA JP4.6 / L4T32.6.1 |

Suggested Accessories & Adapters

| | |
|-----------------------|--|
| Compatible FSA Type | FSA-FT13/A |
| Recommended Devkit(s) | FSM-AR0144x/TXA_Devkit (TX2, AGX) FSM-AR0144x/NVN_Devkit (Nano, NX) |
| Lens Mounts | M12 or C/CS-Mount options |

A matrix with compatible *Sensor Adapters (FSA)* and *Processor Board Adapters (FPA)* for various setups can be found at the end of this document.

Mechanical Drawing



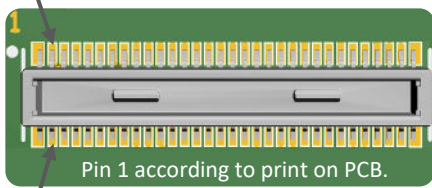
Sensor image optical center is in mechanical board center.

Connector Pinout

Type: Hirose DF40C-60DP-0.4V(51)

Mating Type: Hirose DF40HC(4.0)-60DS-0.4V(51)

| Pin | Name |
|-----|----------|
| 1 | NC |
| 3 | NC |
| 5 | 2V8 |
| 7 | 2V8 |
| 9 | 1V8 |
| 11 | GND |
| 13 | GND |
| 15 | RESETn |
| 17 | NC |
| 19 | NC |
| 21 | SCL |
| 23 | NC |
| 25 | TRIGGER |
| 27 | SDA |
| 29 | NC |
| 31 | NC |
| 33 | NC |
| 35 | SLAMODE |
| 37 | GND |
| 39 | EXTCLK |
| 41 | NC |
| 43 | GND |
| 45 | NC |
| 47 | NC |
| 49 | GND |
| 51 | CSI_DO_N |
| 53 | CSI_DO_P |
| 55 | GND |
| 57 | NC |
| 59 | NC |



| Pin | Name |
|-----|-----------|
| 2 | NC |
| 4 | NC |
| 6 | 1V2 |
| 8 | 1V2 |
| 10 | NC |
| 12 | GND |
| 14 | GND |
| 16 | NC |
| 18 | NC |
| 20 | SHUTTER |
| 22 | NC |
| 24 | NC |
| 26 | NC |
| 28 | NC |
| 30 | NC |
| 32 | FLASH |
| 34 | NC |
| 36 | NC |
| 38 | GND |
| 40 | NC |
| 42 | NC |
| 44 | GND |
| 46 | NC |
| 48 | NC |
| 50 | GND |
| 52 | CSI_D1_N |
| 54 | CSI_D1_P |
| 56 | GND |
| 58 | CSI_CLK_P |
| 60 | CSI_CLK_N |

Signals are routed directly from image sensor to connector. Details on specific signals are described in the respective image sensor datasheet.



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1 FRAMOS Sensor Module Ecosystem

The FSM Ecosystem consists of FRAMOS Sensor Modules, Adapters, Software and Sources, and provides one coherent solution supporting the whole process of integrating image sensors into embedded vision products.

During the evaluation and proof-of-concept phase, off-the-shelf sensor modules with a versatile adapter framework allow the connection of latest image sensor technology to open processing platforms, like the NVIDIA Jetson Family or the 96boards.org standard. Reference drivers and sample applications deliver images immediately after installation, supporting V4L2 and an optional derivate API providing comfortable integration. Within the development phase, electrical design references and driver sources guide with a solid and proven baseline to quickly port into individual system designs and extend scope, while decreasing risk and efforts.

To simplify and relieve the whole supply chain, all FRAMOS Sensor Modules and adapters are optimized and ready for delivery in volume and customization with pre-configured lens holder, lens and further accessories.

Off-the-Shelf Hardware

- FRAMOS Sensor Modules (FSM) from stock, ready for evaluation and optimized for initial mass production.
- Versatile adapter framework, allowing flexible testing of different modules, on different processing boards:
 - FRAMOS Sensor Adapter (FSA):
Everything the specific sensor needs for operation
 - FRAMOS Processor Adapter (FPA):
Connect up to four FSM + FSA to a specific processor board
- From lenses, mechanics and cables, all needed imaging accessories from one hand

Kickstart Software Package

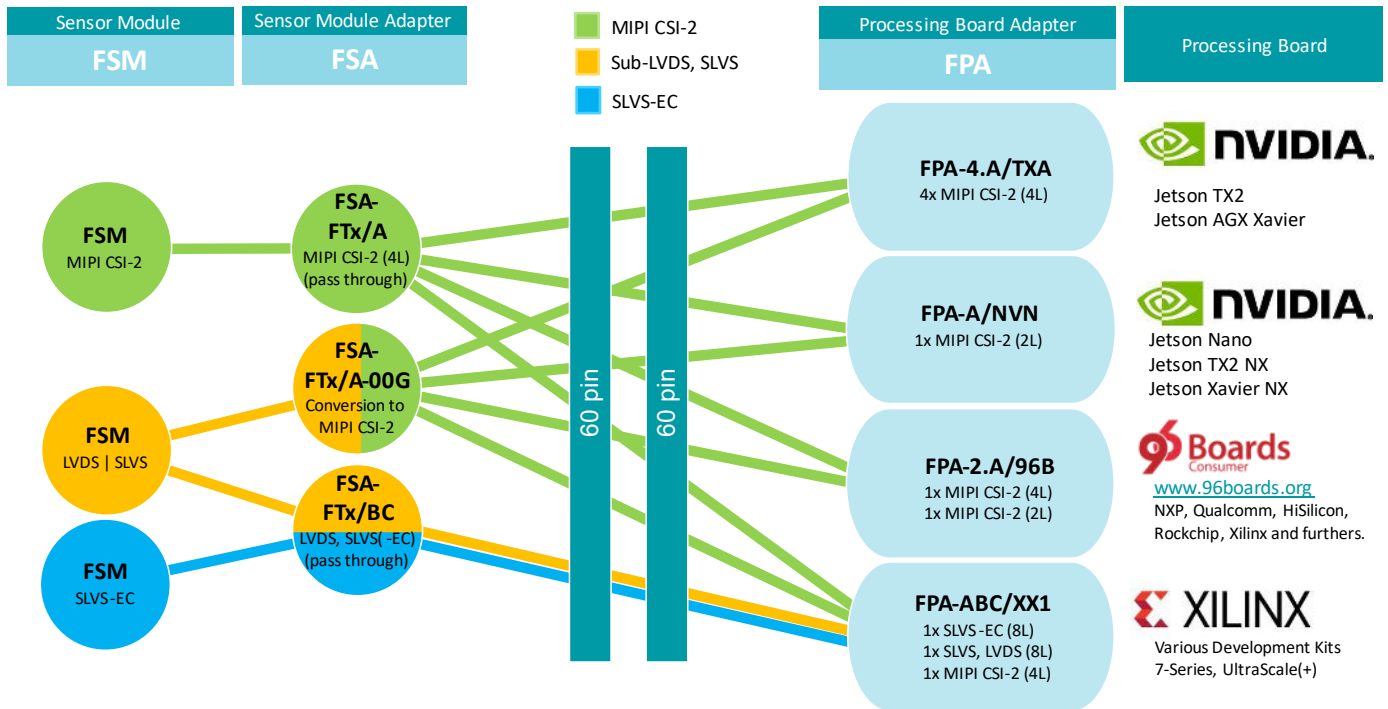
- Drivers with basic sensor integration:
 - V4L2 drivers for specific image sensors
 - Platform specific device tree overlays
- Streamlined V4L2 library (LibSV) with comfortable and generic C/C++ API
- Example applications demonstrating initialization, configuration and image acquisition

Further to the off-the-shelf hard- and software, the Ecosystem supports you on project basis with:

- Driver sources allowing the focus on application specific scope and sensor features
- Electrical references for FSA and FPA, supporting quick and optimized embedding of FSMs
- Engineering services via FRAMOS and its partners, allowing you to focus on your product's unique value

1.1 Ecosystem Overview

The figure below shows a map of compatibility with all components inside the Ecosystem. Every element (or hardware) and connection displayed in **Green** operates with native MIPI CSI-2 (D-PHY) data.



Every component and connection displayed in **Orange** or **Blue** operates with proprietary (Sub-LVDS, SLVS) or standardized (SLVS-EC) LVDS data, that requires further attention to the physical processing of the image data by either data conversion or specific FPGA IP. Users of MIPI CSI-2 based processing systems are supported by FSM specific data conversion located on dedicated FRAMOS Sensor Adapters (FSAs).

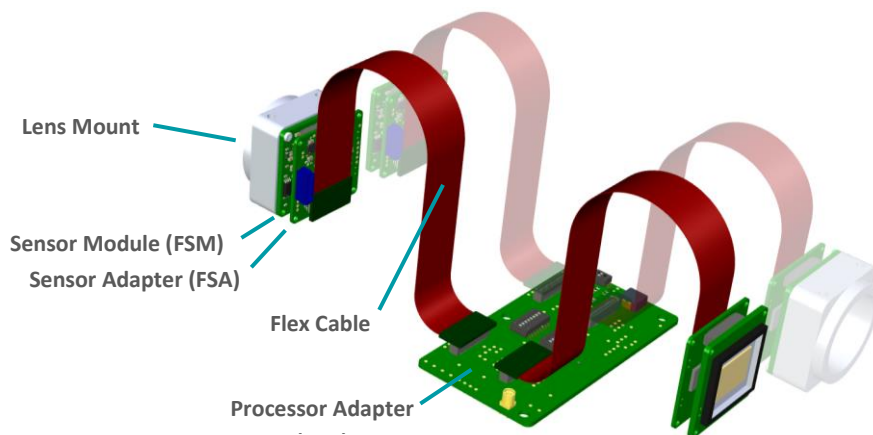


Figure 1: Assembly of a typical Sensor Module Development Kit

Specification and compatibility of all individual components are listed in the appropriate chapter of the full datasheet. Access to software and drivers is only granted with the purchase of the appropriate development kit. Electrical design sources, support and services are provided on individual basis, they are not part of the development kit or component purchase.

1.2 Materials and Services

Below you can find a list of materials and services as part of the FRAMOS Sensor Module Ecosystem.

Hardware

- FRAMOS Sensor Module Development Kits
- Individual Parts:
 - FRAMOS Sensor Modules
 - FRAMOS Sensor Adapters
 - FRAMOS Processor Adapters
 - FRAMOS Module Accessories (Cables, Mounts)

Software (part of the Development Kit)

- Software Package for NVIDIA Jetson AGX Xavier, Nano, TX2, TX2 NX and Xavier NX
- Software Package for DragonBoard 410c (96Boards)
- Xilinx FPGA reference implementation for SLVS-EC (Sony IMX421, IMX530)

Design Sources (on Project Basis)

- Software Driver Sources
- Electrical References for FSA, FPA (Schematics)

Design Services

- Off-the-shelf hardware customization including size, shape, connector and extended functionality
- Software customization and extension
 - Additional processor board support
 - Further sensor features and image (pre-)processing
- Integration of additional sensors
- Optimization for volume production
- Lens assembly and alignment
- System / solution development
- Production and integration



1.2.1 Native MIPI CSI-2 Modules

Global Shutters

| Model Name | FSM-IMX297 | FSM-AR0144 | FSM-IMX296 | FSM-HDP230 | FSM-IMX565 |
|-------------------------------------|----------------------------------|------------------------------|----------------------------------|--|--|
| Shutter Type | CMOS Global Shutter | CMOS Global Shutter | CMOS Global Shutter | CMOS Global Shutter | CMOS Global Shutter |
| Technology | Pregius (Gen2)(Bin) | - | Pregius (Gen2) | - | Pregius S (Gen4) |
| Resolution [MP] | 0.4 | 1 | 1.6 | 2.3 | 12.3 |
| Resolution [HxV] | 728 x 544 | 1280 x 800 | 1456 x 1088 | 1944 x 1204 | 4128 x 3008 |
| Max. Framerate [FPS] | 120.9 FPS (1-Lane) | 60.3 FPS (2-Lane) | 60.4 FPS (1-Lane) | 59.9 FPS (4-Lane) 59.9 FPS (2-Lane) | 42.6 FPS (4-Lane) 22.3 FPS (2-Lane) |
| Mono / Color | Mono | Color / Mono | Mono | Color / Mono | Color / Mono |
| Sensor Manufacturer | Sony | ON Semiconductor | Sony | Pyxalis | Sony |
| Sensor Name | IMX297LLR / IMX297LQR | AR0144CSSM / AR0144CSCC | IMX296LLR / IMX296LQR | HDPYX 230-G Mono / HDPYX 230-G RGB | IMX565AAMJ-C / IMX565AAQJ-C |
| Application / Grade | Sensing | Industrial | Sensing | Automotive | Industrial |
| Optical Format [inch] | 1/2.9 | 1/4 | 1/2.9 | 1/2.5 | 1/1.1 |
| Pixel Size [µm] | 6.9 x 6.9 | 3 x 3 | 3.45 x 3.45 | 3.2 x 3.2 | 2.74 x 2.74 |
| Pixel Bitdepth [bit] | 10 bit | 10 / 12 bit | 10 bit | 8 / 10 / 12 / 14 / 16 bit | 8 / 10 / 12 bit |
| Data Interface [Type] | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 |
| Data Interface [# Lanes] | 1 | 1 / 2 | 1 | 2 / 4 | 2 / 4 |
| Communication Interface | I ² C (4-wire serial) | I ² C | I ² C (4-wire serial) | I ² C | I ² C |
| Drive Frequency [MHz] | 37.125 / 74.25 / 54 | 6 to 48 | 37.125 / 74.25 / 54 | 6 to 27 | 37.125 / 54 / 74.25 MHz |
| Input Voltages | 1.2V, 1.8V, 3.3V | 1.2V, 1.8V, 2.8V | 1.2V, 1.8V, 3.3V | 1.2V, 1.8V, 2.8V | 1.1V, 1.8V, 2.9V, 3.3V |
| Supported Lens Mounts | M12 or C/CS-Mount options | M12 or C/CS-Mount options | M12 or C/CS-Mount options | M12 or C/CS-Mount options | C/CS-Mount option |
| Board Dimensions [mm ²] | 26.5 mm x 26.5 mm | 26.5 mm x 26.5 mm | 26.5 mm x 26.5 mm | 26.5 mm x 26.5 mm | 26.5 mm x 26.5 mm |



Rolling Shutters (Part 1/3) – up to 5 MP

| Model Name | FSM-IMX327 | FSM-IMX290 | FSM-IMX462 | FSM-IMX464 | FSM-IMX335 | FSM-AR0521 |
|-------------------------------------|------------------------------------|-------------------------------------|-------------------------------------|------------------------------------|------------------------------------|------------------------------------|
| Shutter Type | CMOS Rolling Shutter | CMOS Rolling Shutter | CMOS Rolling Shutter | CMOS Rolling Shutter | CMOS Rolling Shutter | CMOS Rolling Shutter |
| Technology | Starvis + NIR | Starvis + NIR | Starvis | Starvis + NIR | Starvis | - |
| Resolution [MP] | 2.1 | 2.1 | 2.1 | 4.2 | 5 | 5 |
| Resolution [HxV] | 1920 x 1080 | 1920 x 1080 | 1920 x 1080 | 2712 x 1538 | 2616 x 1964 | 2592 x 1944 |
| Max. Framerate [FPS] | 60 FPS (4-Lane) 60 FPS (2-Lane) | 120 FPS (4-Lane) 60 FPS (2-Lane) | 120 FPS (4-Lane) 60 FPS (2-Lane) | 90 FPS (4-Lane) 30 FPS (2-Lane) | 60 FPS (4-Lane) 30 FPS (2-Lane) | 69 FPS (4-Lane) 34 FPS (2-Lane) |
| Mono / Color | Color | Color | Mono | Color / Mono | Color / Mono | Color / Mono |
| Sensor Manufacturer | Sony | Sony | Sony | Sony | Sony | ON Semiconductor |
| Sensor Name | IMX327LQR1 | IMX462LQR-C | IMX290LLR / IMX290LQR | IMX464LQR-C | IMX335LLN / IMX335LQN | AR0521SR2M / AR0521SR2C |
| Application / Grade | Security | Security | Security | Security | Security | |
| Optical Format [inch] | 1/2.8 | 1/2.8 | 1/2.8 | 1/1.8 | 1/2.8 | 1/2.5 |
| Pixel Size [µm] | 2.9 x 2.9 | 2.9 x 2.9 | 2.9 x 2.9 | 2.9 x 2.9 | 2 x 2 | 2.2 x 2.2 |
| Pixel Bitdepth [bit] | 10 / 12 bit | 10 / 12 bit | 10 / 12 bit | 10 / 12 bit | 10 / 12 bit | 8 / 10 / 12 bit |
| Data Interface [Type] | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 |
| Data Interface [# Lanes] | 2 / 4 | 2 / 4 | 2 / 4 | 2 / 4 | 2 / 4 | 2 / 4 |
| Communication Interface | I ² C (4-wire serial) | I ² C | I ² C (4-wire serial) | I ² C | I ² C | I ² C |
| Drive Frequency [MHz] | 37.125 / 74.25 | 37.125 / 74.25 | 37.125 / 74.25 | 6 to 27 / 37.125 / 74.25 | 6 - 27 / 37.125 / 74.25 | 10 to 48 |
| Input Voltages | 1.2V, 1.8V, 2.9V | 1.2V, 1.8V, 2.9V | 1.2V, 1.8V, 2.9V | 1.2V, 1.8V, 2.9V | 1.2V, 1.8V, 2.9V | 1.2V, 1.8V, 2.7V |
| Supported Lens Mounts | M12 or C/CS-Mount options | M12 or C/CS-Mount options | M12 or C/CS-Mount options | M12 or C/CS-Mount options | M12 or C/CS-Mount options | M12 or C/CS-Mount options |
| Board Dimensions [mm ²] | 26.5 x 26.5 | 26.5 x 26.5 | 26.5 x 26.5 | 26.5 x 26.5 | 26.5 x 26.5 | 26.5 x 26.5 |



Rolling Shutters (Part 2/3) – 8 MP

| Model Name | FSM-IMX334 | FSM-IMX485 | FSM-IMX585 | FSM-IMX678 | FSM-IMX415 | FSM-IMX715 |
|-------------------------------------|-------------------------------|------------------------------------|--------------------------------------|------------------------------------|------------------------------------|------------------------------------|
| Shutter Type | CMOS Rolling Shutter | CMOS Rolling Shutter | CMOS Rolling Shutter | CMOS Rolling Shutter | CMOS Rolling Shutter | CMOS Rolling Shutter |
| Technology | Starvis | Starvis + NIR | Starvis2 | Starvis2 | Starvis + NIR | Starvis + NIR |
| Resolution [MP] | 8.3 | 8.3 | 8.3 | 8.3 | 8.4 | 8.4 |
| Resolution [HxV] | 3864 x 2180 | 3864 x 2180 | 3856 x 2180 | 3856 x 2180 | 3864 x 2192 | 3864 x 2192 |
| Max. Framerate [FPS] | 60 FPS (4-Lane) | 72 FPS (4-Lane) 38 FPS (2-Lane) | 90.1 FPS (4-Lane) 30 FPS (2-Lane) | 72 FPS (4-Lane) 30 FPS (2-Lane) | 90 FPS (4-Lane) 44 FPS (2-Lane) | 90 FPS (4-Lane) 44 FPS (2-Lane) |
| Mono / Color | Color / Mono | Color | Color | Color / Mono | Color | Color |
| Sensor Manufacturer | Sony | Sony | Sony | Sony | Sony | Sony |
| Sensor Name | IMX334LLR / IMX334LQR | IMX485LQJ | IMX585AAQJ1-C | IMX678AAQR1 | IMX415-AAQR | IMX715AAQR1 |
| Application / Grade | Security | Security | Security | Security | Security | Security |
| Optical Format [inch] | 1/1.8 | 1/1.2 | 1/1.2 | 1/1.8 | 1/2.8 | 1/2.8 |
| Pixel Size [µm] | 2 x 2 | 2.9 x 2.9 | 2.9 x 2.9 | 2 x 2 | 1.45 x 1.45 | 1.45 x 1.45 |
| Pixel Bitdepth [bit] | 10 / 12 bit | 10 / 12 bit | 10 / 12 bit | 10 / 12 bit | 10 / 12 bit | 10 / 12 bit |
| Data Interface [Type] | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 |
| Data Interface [# Lanes] | 4 | 2 / 4 | 2 / 4 | 2 / 4 | 2 / 4 | 2 / 4 |
| Communication Interface | I ² C | I ² C | I ² C | I ² C | I ² C | I ² C |
| Drive Frequency [MHz] | 6 - 27 / 37.125 / 74.25 | 6 to 27 / 37.125 / 74.25 | 6 to 27 / 37.125 / 72 / 74.25 | 6 - 27 / 37.125 / 74.25 | 24 / 27 / 37.125 / 72 / 74.25 | 24 / 27 / 37.125 / 72 / 74.25 |
| Input Voltages | 1.2V, 1.8V, 2.9V | 1.2V, 1.8V, 2.9V | 1.1V, 1.8V, 3.3V | 1.1V, 1.8V, 3.3V | 1.1V, 1.8V, 2.9V | 1.1V, 1.8V, 2.9V |
| Supported Lens Mounts | M12 or C/CS- Mount options | C/CS-Mount option | C/CS-Mount option | M12 or C/CS- Mount options | M12 or C/CS- Mount options | M12 or C/CS- Mount options |
| Board Dimensions [mm ²] | 26.5 x 26.5 | 26.5 x 26.5 | 26.5 x 26.5 | 26.5 x 26.5 | 26.5 x 26.5 | 26.5 x 26.5 |

Rolling Shutters (Part 3/3) – equal or higher than 12 MP

| Model Name | FSM-IMX412 | FSM-IMX577 | FSM-IMX477 | FSM-AR1335 | FSM-IMX283 |
|-------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|----------------------|
| Shutter Type | CMOS Rolling Shutter | CMOS Rolling Shutter | CMOS Rolling Shutter | CMOS Rolling Shutter | CMOS Rolling Shutter |
| Technology | Starvis | Starvis | Starvis | - | Starvis |
| Resolution [MP] | 12.3 | 12.3 | 12.3 | 13.1 | 20.2 |
| Resolution [HxV] | 4056 x 3040 | 4056 x 3040 | 4056 x 3040 | 4208 x 3120 | 5496 x 3694 |
| Max. Framerate [FPS] | 59.9 FPS (4-Lane) 30 FPS (2-Lane) | 59.9 FPS (4-Lane) 30 FPS (2-Lane) | 59.9 FPS (4-Lane) 30 FPS (2-Lane) | 27.2 FPS (4-Lane) 13 FPS (2-Lane) | 24.7 FPS (4-Lane) |
| Mono / Color | Color | Color | Color | Color | Color |
| Sensor Manufacturer | Sony | Sony | Sony | ON Semiconductor | Sony |
| Sensor Name | IMX412-AACK | IMX477-AAPK | IMX577-AACK | AR1335CSSM / AR1335CSSC | IMX283CQJ |
| Application / Grade | Security | Security | Security | Industrial | Audio/Video |
| Optical Format [inch] | 1/2.3 | 1/2.3 | 1/2.3 | 1/3.2 | 1 |
| Pixel Size [µm] | 1.55 x 1.55 | 1.55 x 1.55 | 1.55 x 1.55 | 1.1 x 1.1 | 2.4 x 2.4 |
| Pixel Bitdepth [bit] | 10 / 12 bit | 8 / 10 / 12 bit | 8 / 10 / 12 bit | 8 / 10 bit | 10 / 12 bit |
| Data Interface [Type] | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 | MIPI CSI-2 |
| Data Interface [# Lanes] | 2 / 4 | 2 / 4 | 2 / 4 | 2 / 4 | 4 |
| Communication Interface | I ² C (CCI) | I ² C (CCI) | I ² C (CCI) | I ² C | I ² C |
| Drive Frequency [MHz] | 6 / 12 / 18 / 27 | 6 to 27 | 6 to 27 | 6 to 48 | 6 to 27 |
| Input Voltages | 1.05V, 1.8V, 2.75V | 1.05V, 1.8V, 2.8V | 1.05V, 1.8V, 2.8V | 1.2V, 1.8V, 2.7V | 1.2V, 1.8V, 2.9V |
| Supported Lens Mounts | M12 or C/CS-Mount options | M12 or C/CS-Mount options | M12 or C/CS-Mount options | M12 or C/CS-Mount options | C/CS-Mount option |
| Board Dimensions [mm ²] | 26.5 x 26.5 | 26.5 x 26.5 | 26.5 x 26.5 | 26.5 x 26.5 | 26.5 x 26.5 |

1.2.2 Sub-LVDS, SLVS and SLVS-EC Modules

| Model Name | FSM-IMX264 | FSM-IMX304 | FSM-IMX530 |
|-------------------------------------|----------------------------------|----------------------------------|---|
| Shutter Type | CMOS Global Shutter | CMOS Global Shutter | CMOS Global Shutter |
| Technology | Pregius (Gen2) | Pregius (Gen2) | Pregius S (Gen4) |
| Resolution [MP] | 5.1 | 12.4 | 24.5 |
| Resolution [HxV] | 2464 x 2056 | 4112 x 3008 | 5328 x 4608 |
| Max. Framerate [FPS] | CSI-2: 35.7 FPS (4-Lane) | CSI-2: 23.4 FPS (4-Lane) | SLVS-EC: 106.9 FPS (8-Lane) CSI-2: 30 FPS (4-Lane) |
| Mono / Color | Color / Mono | Color / Mono | Color / Mono |
| Sensor Manufacturer | Sony | Sony | Sony |
| Sensor Name | IMX264LLR / IMX264LQR | IMX304LLR / IMX304LQR | IMX530-AAMJ / IMX530-AAQJ |
| Application / Grade | Industrial | Industrial | Industrial |
| Optical Format [inch] | 2/3 | 1.1 | 1.2 |
| Pixel Size [µm] | 3.45 x 3.45 | 3.45 x 3.45 | 2.74 x 2.74 |
| Pixel Bitdepth [bit] | 12 bit | 12 bit | 8 / 10 / 12 bit |
| Data Interface [Type] | SubLVDS | SubLVDS | SLVS, SLVS-EC |
| Data Interface [# Lanes] | 4 | 4 / 8 | 1 / 2 / 4 / 8 |
| Communication Interface | I ² C (4-wire serial) | I ² C (4-wire serial) | I ² C (4-wire serial) |
| Drive Frequency [MHz] | 37.125 / 54 / 74.25 | 37.125 / 54 / 74.25 | 37.125 / 54 / 74.25 |
| Input Voltages | 1.2V, 1.8V, 3.3V | 1.2V, 1.8V, 3.3V | 1.1V, 1.8V, 2.9V, 3.3V |
| Supported Lens Mounts | C/CS-Mount option | C/CS-Mount option | C/CS-Mount option |
| Board Dimensions [mm ²] | 28 x 28 | 28 x 28 | 28 x 28 |

2 Software Package and Drivers

As FRAMOS we know that the getting started with a new technology is the biggest challenge. The idea behind the Software Package is to enable embedded software engineers to get quickly to a streaming system and provide at the same time all tools that are needed to extend and adapt it according the individual needs of the application.

What the software package and driver are:

- A reference for a custom sensor implementation
- Demonstrating how to use the required interfaces
- Demonstrating how to communicate with the image sensor
- Demonstrating how to generally initialize and configure the image sensor
- Provide initial image streaming output to the user space
- Demonstrating how to run basic image processing on pixel data

Supported Processor Platforms

The table below shows which platforms are supported by the standard driver package, and how many FSMs can at maximum be operated in parallel.

| Sensor Module | NVIDIA Jetson TX2 | NVIDIA AGX Xavier | NVIDIA Jetson Nano, TX2 NX, Xavier NX | DragonBoard 410c | 96Boards Consumer Edition | Xilinx Development Boards | |
|---------------|-------------------|-------------------|---------------------------------------|------------------|---|---------------------------|----------------|
| FSM-AR0144 | | 4 | 2 | | HW only, driver development on project basis. | | |
| FSM-AR0521 | | 4 | 2 | 2 | | | |
| FSM-AR1335 | | 4 | 2 | | | | |
| FSM-HDP230 | 4 | 4 | 2 | | | | |
| FSM-IMX264 | 2 | 4 | - | | | | |
| FSM-IMX283 | 2 | 4 | - | | | | |
| FSM-IMX290 | | 4 | 2 | 2 | | | |
| FSM-IMX296 | | 4 | 2 | 2 | | | |
| FSM-IMX297 | | 4 | 2 | | | | |
| FSM-IMX304 | 2 | 4 | - | | | | |
| FSM-IMX327 | | 4 | 2 | 2 | | | |
| FSM-IMX334 | 2 | 4 | - | | | | |
| FSM-IMX335 | | 4 | 2 | | | | |
| FSM-IMX412 | | 4 | 2 | 2 | | | |
| FSM-IMX415 | | 4 | 2 | | | | |
| FSM-IMX462 | | 4 | 2 | | | | |
| FSM-IMX464 | | 4 | 2 | | | | |
| FSM-IMX477 | | 4 | 2 | | | | |
| FSM-IMX485 | | 4 | 2 | | | | |
| FSM-IMX565 | | 4 | 2 | | | | |
| FSM-IMX577 | | 4 | 2 | | | | |
| FSM-IMX585 | | 4 | 2 | | | | |
| FSM-IMX678 | | 4 | 2 | | | | |
| FSM-IMX715 | | 4 | 2 | | | | |
| FSM-IMX530 | 2 | 4 | - | | | | 1 ¹ |

Table 1: Ecosystem Software Package - Supported number of FSMs per processing board

¹ SLVS-EC based FPGA reference implementation as part of the SLVS-EC RX IP Core offering.

2.1 Reference Software: NVIDIA Jetson Family

The software package provided with the Development Kits of the FRAMOS Sensor Module Ecosystem provided for NVIDIA Jetson platforms provides a reference implementation of sensor and device drivers for MIPI CSI-2. It contains a minimum feature set demonstrating how to utilize the platform specific data interface and communication implementation, as well as the initialization of the image sensor and implementation of basic features.

Package Content:

- Platform and device drivers with Linux for Tegra Support
- V4L2 based subdevice drivers (low-level C API)
- Streamlined V4L2 library (LibSV) providing generic C/C++ API
- Display Examples:
 - OpenCV (Software)
 - LibArgus (Hardware)

Supported Devices:

- NVIDIA Jetson Nano Developer Kit (B01)
- NVIDIA Jetson TX2 Developer Kit
- NVIDIA Jetson TX2 NX Developer Kit
- NVIDIA Jetson Xavier NX Developer Kit
- NVIDIA Jetson AGX Xavier Developer Kit

2.1.1 Platform and Sensor Device Drivers

The driver divides into two main parts that are configured in separate ways – the Image Modes and the General Features of the image sensor.

Image Modes

These are major attributes that have impact to the image data stream formatting. They require a static pre-configuration within the device tree (DT):

- Image / streaming resolution
- Pixel format / bit depth
- Data rate / lane configuration

Each driver provides access to 3 – 5 pre-built configurations, reflecting the main operation modes of the imager. Beside the full resolution, that is always available, they allow to receive image streams in common video resolutions like VGA, Full HD and UHD as they are supported or make sense by the imagers, and utilize sensor features like ROI and binning.

They act as an example for implementation and usage and are available as source. Due to the size limitation of the device tree, it is not possible to integrate an extensive set of options.

General Features

These are attributes of the image sensor that do not manipulate the data stream formatting. The drivers provided with the Software Pack integrate the sensor features as shown in the table below.

| Pre-Implemented Features per Model | Gain (Analog / Digital) | Frame Rate | Exposure Time | Flip / Mirror | IS Mode (Master / Slave) | Sensor Mode ID | Test Pattern Output | Black Level | HDR Output | Broadcast | Data Rate | Synchronizing Master |
|------------------------------------|-------------------------|------------|---------------|---------------|--------------------------|----------------|---------------------|-------------|------------|-----------|-----------|----------------------|
| FSM-AR0144 | Green | Green | Green | Green | Green | Green | Green | Green | Red | Red | Red | Red |
| FSM-AR0521 | Green | Green | Green | Green | Green | Green | Green | Green | Red | Red | Red | Red |
| FSM-AR1335 | Green | Green | Green | Green | Green | Green | Green | Green | Red | Red | Red | Red |
| FSM-HDP230 | Green | Green | Green | Green | Green | Green | Green | Green | Green | Red | Red | Red |
| FSM-IMX264 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Red | Red | Red |
| FSM-IMX283 | Green | Green | Green | Red | Red | Green | Green | Green | Red | Red | Red | Red |
| FSM-IMX290 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Red | Green | Red |
| FSM-IMX296 | Green | Green | Green | Red | Green | Red | Green | Green | Red | Red | Red | Red |
| FSM-IMX297 | Green | Green | Green | Red | Green | Red | Green | Green | Red | Red | Red | Red |
| FSM-IMX304 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Red | Red | Red |
| FSM-IMX327 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Red | Green | Red |
| FSM-IMX334 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Green | Green | Green |
| FSM-IMX335 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Red | Red | Red |
| FSM-IMX412 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Green | Red | Red |
| FSM-IMX415 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Green | Green | Green |
| FSM-IMX462 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Red | Green | Red |
| FSM-IMX464 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Green | Green | Green |
| FSM-IMX477 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Red | Red | Red |
| FSM-IMX485 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Green | Green | Green |
| FSM-IMX530 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Red | Red | Red |
| FSM-IMX565 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Red | Red | Red |
| FSM-IMX577 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Green | Red | Red |
| FSM-IMX565 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Red | Green | Red |
| FSM-IMX585 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Green | Green | Green |
| FSM-IMX678 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Green | Green | Green |
| FSM-IMX715 | Green | Green | Green | Red | Green | Green | Green | Green | Red | Green | Green | Green |

- V4L (libsv) and libargus
- V4L (libsv)
- Not Supported/Implemented

Table 2: Supported sensor features on NVIDIA Jetson Family

Further features, as they are supported by the image sensor, can be integrated into the driver sources using the image sensor datasheet.

2.1.2 Image Pre-Processing Examples

The provided image processing examples show the general mechanisms of data handling for an image processing using 3rd-party libraries. The OpenCV example provides data that is raw (mono) or demosaiced (color) and not further optimized for visual experience, while the LibArgus examples leverages the discrete ISP (Image Signal Processor) inside the Jetson SoC to optimize image reproduction.

Argus Camera Example:

- Using hard ISP in NVIDIA Jetson SoCs, most performant option for image preprocessing
- Only applicable for color sensors (color processing can't be disabled)
- Most performant option
- Utilizing libArgus closed source library, support and tuning on individual basis through FRAMOS
- Example Implementation: Shows Demo Tuning per FSM Devkit

| | Xavier (AGX, NX) | Tegra X2 (TX2, TX2 NX) | Tegra X1 (TX1, Nano) |
|-------------------------------|---------------------|---------------------------|-------------------------|
| Performance | | | |
| Max. # of streams through ISP | 16 | 12 | 6 |
| Pixel Bandwidth (max.) | 2 Gpix/s | 1.4 Gpix/s | 1.4 Gpix/s |
| Image Resolution (max.) | 64 MP | 24 MP | 24 MP |
| Image Width (max.) | 6144 px | 6144 px | 6144 px |

Table 3: ISP capabilities / limitations of NVIDIA Jetson Family

The software package provided with our FSM Devkits contains a functionally and performance limited example configuration for the Jetson ISP. The configuration is sensor and lens related and demonstrates the combination of our standard kit in environments that are illuminated with fluorescent light, like in office or laboratory.

| Supported Features in Default Configuration | |
|---|--------------------------------------|
| Lens Considered (Type) | Yes (Devkit Lens) |
| IR Cut Filter (Type) | Yes (650nm/50%) |
| Sensor Configuration | Driver Default |
| Demosaic | Yes ² |
| Black Level Compensation | Yes (Calibrated) |
| Bad Pixel Correction | Yes (Calibrated) |
| Color Correction | Yes (Calibrated) |
| Auto White Balance (A, TL84, D65) | Limited (Calibrated for TL84 only) |
| Manual White Balancing | Limited (Not Calibrated) |
| Lens Shading / Falloff Correction | Limited (Calibrated for Devkit lens) |
| Noise Reduction | Limited (Not Calibrated) |
| Sharpening | Limited (Not Calibrated) |
| Auto Exposure, Gain, Gamma, Color/Tone, Contrast Tuning | Requires Application Specific Tuning |

Table 4: Default tuning of NVIDIA Jetson, supplied with FSM Devkits

² Demosaicing is always active and can't be disabled. For monochrome sensors refer to libSV to bypass the ISP.



To archive best performance and stable results also in variable lighting conditions, a fully featured calibration will be required. As NVIDIA camera partner, FRAMOS provides full ISP configurations for standard setups on request. Further, full custom calibration services considering lens and application specific requirements for sophisticated applications are provided on per project basis.

OpenCV Example:

- Open software library
- Easy to use and large feature set
- Very resource hungry (CPU)
- Not recommended for pre-processing
- Example Implementation: Demosaicing, Displaying

Due to limited performance and extreme resource utilization, the image processing support utilizing the CPU will not be further enhanced.

3 Ecosystem Compatibility Matrix

3.1 Hardware Support

The following matrix shows the compatibility of FSMs, FSAs and FPAs to each other. The FSAs differentiate to each other by supplied voltages, power up sequence, generated clock (oscillator) and physical attributes.

Sensor Modules with MIPI CSI-2 (D-PHY) Output

| Item | FSM-IMX412 FSM-IMX477 FSM-IMX577 | FSM-IMX290 FSM-IMX327 FSM-IMX334 FSM-IMX335 FSM-IMX462 FSM-IMX464 FSM-IMX485 | FSM-IMX296 FSM-IMX297 | FSM-AR0521 FSM-AR1335 | FSM-IMX415 FSM-IMX715 | FSM-IMX283 | FSM-AR0144 | FSM-HDP230 | FSM-IMX565 FSM-IMX585 FSM-IMX678 |
|------------|---|--|---|---|---|--|---|---|---|
| FSA-FT1/A | FPA-4.A/TXA FPA-A/NVN FPA-2.A/96B FPA-ABC/XX1 ³ | | | | | | | | |
| FSA-FT3/A | | FPA-4.A/TXA FPA-A/NVN ⁴ FPA-2.A/96B FPA-ABC/XX1 ³ | | | | | | | |
| FSA-FT6/A | | | FPA-4.A/TXA FPA-A/NVN FPA-2.A/96B FPA-ABC/XX1 ³ | | | | | | |
| FSA-FT7/A | | | | FPA-4.A/TXA FPA-A/NVN FPA-2.A/96B FPA-ABC/XX1 ³ | | | | | |
| FSA-FT11/A | | | | | FPA-4.A/TXA FPA-A/NVN FPA-2.A/96B FPA-ABC/XX1 ³ | | | | |
| FSA-FT12/A | | | | | | FPA-4.A/TXA FPA-2.A/96B FPA-ABC/XX1 ³ | | | |
| FSA-FT13/A | | | | | | | FPA-4.A/TXA FPA-A/NVN FPA-2.A/96B FPA-ABC/XX1 ³ | | |
| FSA-FT19/A | | | | | | | | FPA-4.A/TXA FPA-A/NVN FPA-2.A/96B FPA-ABC/XX1 ³ | |
| FSA-FT26/A | | | | | | | | | FPA-4.A/TXA FPA-A/NVN FPA-2.A/96B FPA-ABC/XX1 ³ |

Table 5: Ecosystem Compatibility Matrix – Native CSI-2 (D-PHY) FSMs

³ Not verified, Xilinx Development Board with hard MIPI CSI-2 / D-PHY interface.

⁴ FSM-IMX334 is not supported due to the sensor requiring 4-lanes MIPI.

Sensor Modules with (Sub-) LVDS and SLVS Output

| Item | Data Output (FSA) | FSM-IMX264 | FSM-IMX304 | FSM-IMX421 | FSM-IMX530 |
|----------------|-------------------|--|--|-------------|--|
| FSA-FT14/A-00G | MIPI CSI-2 | FPA-4.A/TXA FPA-2.A/96B FPA-ABC/XX1 ³ | | | |
| FSA-FT15/A-00G | MIPI CSI-2 | | FPA-4.A/TXA FPA-2.A/96B FPA-ABC/XX1 ³ | | |
| FSA-FT18/A-00G | MIPI CSI-2 | | | | FPA-4.A/TXA FPA-2.A/96B FPA-ABC/XX1 ³ |
| FSA-FT18/BC | SLVS, SLVS-EC | | | | FPA-ABC/XX1 FPA-C/AGX |
| FSA-FT20/BC | SLVS-EC | | | FPA-ABC/XX1 | |

Table 6: Ecosystem Compatibility Matrix – Sub-LVDS, SLVS and SLVS-EC FSMs