NOIV1SN016KA, NOIV1SN012KA

VITA 16/12 MegaPixels Single Foot Print CMOS Image Sensor

ON Semiconductor®

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Features

- Active Pixel Array:
  - 16K = 4096 × 4096 Active Pixels
  - 12K = 4096 × 3072 Active Pixels
- Optical Format:
  - 16K = APS−C Optical Format
  - 12K = 4/3 inch Optical Format
- 4.5 μm × 4.5 μm Square Pixels
- 32/16 Low-Voltage Differential Signaling (LVDS) High-speed Serial Outputs
- VITA 16K Frame Rate at Full Resolution, 32 LVDS Outputs
  - 80 Frames per Second normal ROT
  - 125 Frames per Second Zero ROT
- VITA 12K Frame Rate at Full Resolution, 32 LVDS Outputs
  - 110 Frames per Second normal ROT
  - 160 Frames per Second Zero ROT
- Monochrome (SN), Color (SE)
- On-chip 10-bit Analog-to-Digital Converter (ADC)
- 8-bit or 10-bit Output Mode
- 32 Random Programmable Region of Interest (ROI) readout
- Pipelined and Triggered Global Shutter, Rolling Shutter
- Serial Peripheral Interface (SPI)
- Operational Temperature Range: -40°C to +85°C
- Single 355−pin μPGA package across resolutions
- Power Dissipation: 4.1 W @ 2 Gpix/s
- These Devices are Pb−Free and are RoHS Compliant

Figure 1. VITA 16K/12K Photograph

Applications

- Machine Vision
- Motion Monitoring
- Intelligent Traffic Systems (ITS)
- Pick and Place Machines
- Inspection
- Metrology

Description

The high-resolution VITA CMOS image sensor family features global and rolling shutter mode. The on-chip programmable state machine controls the sensor array and enables high flexibility with changes in operation modes and 32 frame-to-frame configurable Regions-of-Interest (ROI). The 5T pixel on a 4.5 μm pitch enables pipelining of integration and read-out in both triggered and un-triggered global shutter mode.

A second pipeline stage provides a maximum frame rate increase by allowing the sensor to run in Zero-ROT mode. The roller shutter mode supports correlated double sampling, reducing temporal noise by approximately 3 dB. The sensor has on-chip programmable gain amplifiers and 10-bit A/D converters. The image's black level has an automatic calibration with adjustable user programmable offset. The image data interface consists of 32 or 16 LVDS channels with additional clock and synchronization channels in parallel, each running at 680 Mbps.

The high-resolution VITA family is packaged in a ceramic 355-pin PGA package and is available in a monochrome and color version.

Contact your local ON Semiconductor office for more information.

ORDERING INFORMATION

Part Number	Family	Description	Package	Product Status
NOIV1SN016KA−GDI	VITA 16K	16 MegaPixel, Monochrome, no Protective Tape	355−pin μPGA	Production
NOIV1SE016KA−GDI		16 MegaPixel, Color, no Protective Tape		
NOIV1SN016KA−GTI		16 MegaPixel, Monochrome, Protective Tape		
NOIV1SE016KA−GTI		16 MegaPixel, Color, Protective Tape		
NOIV1SN012KA−GDI	VITA 12K	12 MegaPixel, Monochrome, no Protective Tape		
NOIV1SE012KA−GDI		12 MegaPixel, Color, no Protective Tape		
NOIV1SN012KA−GTI		12 MegaPixel, Monochrome, Protective Tape		
NOIV1SE012KA−GTI		12 MegaPixel, Color, Protective Tape		

The V1 − SN/SE base part is used to reference the mono and color enhanced versions of the LVDS interface. More details on the part number coding can be found at http://www.onsemi.com/pub_link/Collateral/TND310−D.PDF

Package Mark

Side 1 near Pin 1: **NOIV1xx0RRKA−GDI**, where xx denotes mono micro lens (SN) or color micro lens (SE), RR is the resolution of the sensor in MP (16 or 12)

Side 2: **AWLYYWW,** where AWL is Production lot traceability, and YYWW is the 4−digit date code

SPECIFICATIONS

Key Specifications

Table 1. GENERAL SPECIFICATIONS

Parameter	Specification
Active pixels	4096 (H) x 4096 (V)
Pixel size	4.5 μm x 4.5 μm
Shutter type	Pipelined and triggered global shutter, rolling shutter
Master clock	340 MHz (10-bit default) 272 MHz (8-bit)
Windowing features	32 Randomly programmable windows. Normal, sub-sampled and binned readout modes
ADC resolution	10-bit, 8-bit
Number of LVDS outputs	32/16 data + 1 sync + 1 clock
Data rate	32/16 x 680 Mbps (10-bit default) 32/16 x 544 Mbps (8-bit)
Power dissipation	4.1 W @ ~2 Gpix/s (32 LVDS)
Package type	355 μPGA
Color	RGB color, mono

Table 2. ELECTRO−OPTICAL SPECIFICATIONS [1]

Parameter	Specification
Frame rate at full resolution	Refer to Table 6
Optical format	APS−C
Conversion gain	0.064 LSB10/e^- , 79.4 μV/e^-
Dark noise	34e^- in global shutter 23e^- in rolling shutter
Responsivity at 550 nm	3.1 V/lux.s
Parasitic Light Sensitivity (PLS)	<1/800 at 550 nm
Full well charge	19000 e^-
Quantum efficiency (QE) x FF	52% at 550 nm
Pixel FPN	rolling shutter: 0.7 LSB10 global shutter: 4.2 LSB10
Row FPN	rolling shutter: 0.4 LSB10 global shutter: 0.7 LSB10
Column FPN	rolling shutter: 0.4 LSB10 global shutter: 0.5 LSB10
Dynamic range	53 dB in global shutter mode 56 dB in rolling shutter mode
Signal-to-Noise Ratio (SNR)	43 dB
Dark signal	22 e^-/s, 1.3 LSB10/s at +40°C

Table 3. RECOMMENDED OPERATING RATINGS (Note 2)

Symbol	Description	Min	Max	Units
T_J	Operating temperature range	−40	+85	°C

Table 4. ABSOLUTE MAXIMUM RATINGS (Note 3)

Symbol	Parameter	Min	Max	Units
ABS (1.0 V supply)	ABS rating for 1.0 V supply	−0.5	1.2	V
ABS (1.8 V supply group)	ABS rating for 1.8 V supply group	−0.5	2.2	V
ABS (3.3 V supply group)	ABS rating for 3.3 V supply group	−0.5	4.3	V
ABS (4.2 V supply)	ABS rating for 4.2 V supply	−0.5	4.6	V
ABS (4.5 V supply)	ABS rating for 4.5 V supply	−0.5	5.0	V
T_S (Notes 3 and 4)	ABS storage temperature range	0	150	°C
	ABS storage humidity range at 85°C		85	%RH
Electrostatic discharge (ESD) (Notes 2 and 3)	Human Body Model (HBM): JS−001−2010	2000		V
	Charged Device Model (CDM): JESD22−C101	500		
LU	Latch-up: JESD−78	140		mA

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. While the ADC is 11-bit, the data is converted to 10-bit in two digital gain stages. The first digital gain stage has a fixed gain of 2/3. This may be bypassed by asserting register bit 129[11]. The second digital gain stage can be tuned by changing the value in register 205.
2. Operating ratings are conditions in which operation of the device is intended to be functional.
3. ON Semiconductor recommends that customers become familiar with, and follow the procedures in JEDEC Standard JESD625−A. Refer to Application Note AN52561. Long term exposure toward the maximum storage temperature will accelerate color filter degradation.
4. Caution needs to be taken to avoid dried stains on the underside of the glass due to condensation. The glass lid glue is permeable and can absorb moisture if the sensor is placed in a high % RH environment.

Electrical Specifications

Power Supply Ratings

Table 5. POWER SUPPLY RATINGS

Limits in bold apply for for $T_J = T_{MIN}$ to T_{MAX}, all other limits T_J = +30°C [5], [6], [7], [8]

Parameter	Description	Min	Typ	Max	Units
Power Supply Parameters					
vdda_33	Analog supply - 3.3 V domain. gnda_33 is connected to substrate	**3**	3.3	**3.6**	V
Idda_33	Current consumption from analog supply		915		mA
vddd_33	Digital supply - 3.3 V domain. gndd_33 is connected to substrate	**3**	3.3	**3.6**	V
Iddd_33	Current consumption from 3.3 V digital supply		90		mA
vdd_18	Digital supply - 1.8 V domain. gndd_18 is connected to substrate	**1.6**	1.8	**2**	V
Idd_18	Current consumption 1.8 V digital supply		370		mA
vdd_pix	Pixel array supply	**3**	3.3	**3.6**	V
Idd_pix	Current consumption from pixel supply		35		mA
vdd_resfd	Floating diffusion reset supply	3.3	4.5	4.6	V
gnd_resfd	Floating diffusion reset ground. Not connected to substrate	0	0	1.0	V
vdd_respd	Photo diode reset supply	3.3	4.2	4.6	V
gnd_respd	Photo diode reset ground. Not connected to substrate. **Note** This is a sinking power supply with 200 mA range.	0	0	1.0	V
vdd_trans	Pixel transfer supply	3.3	4.2	4.6	V
gnd_trans	Pixel transfer ground. Not connected to substrate	0	0	1.0	V
vdd_sel	Pixel select supply	3.0	3.3	3.6	V
gnd_sel	Pixel select ground. Not connected to substrate.	0	0	0	V
vdd_casc	Cascode supply	0.9	1.0	1.1	V
vref_colmux [8]	Column multiplexer reference supply	–	1.0	–	V
gnd_colbias	Column biasing ground. Dedicated ground signal for pixel biasing. Connected to substrate	–	0	–	V
gnd_colpc	Column precharge ground. Dedicated ground signal for pixel biasing. Not connected to substrate	–	0	–	V
Ptot	Total power consumption		4100		mW
Pstby1	Power consumption in standby mode, reset_n = high, clock running	–	300	–	mW
Pstby2	Power consumption in standby mode, reset_n = low, clock running	–	200	–	mW
Pstby3	Power consumption in standby mode, reset_n = low, no clock	–	30	–	mW
Popt	Power consumption at lower pixel rates		Configurable		
I/O - LVDS (EIA/TIA-644): Conforming to standard/additional specifications and deviations listed					
fserdata	Data rate on data channels in 10-bit mode DDR signaling			680	Mbps
fserdata	Data rate on data channels in 8-bit mode DDR signaling			544	Mbps
fserclock	Clock rate of output clock in 10-bit mode Clock output for mesochronous signaling			340	MHz
fserclock	Clock rate of output clock in 8-bit mode Clock output for mesochronous signaling			272	MHz
Vicm	LVDS input common mode level	0.3	1.25	2.2	V
Tccsk	Channel to channel skew (training pattern allows per-channel skew correction)			50	ps

Table 5. POWER SUPPLY RATINGS

Limits in bold apply for for $T_J = T_{MIN}$ to T_{MAX}, all other limits T_J = +30°C [5], [6], [7], [8]

Parameter	Description	Min	Typ	Max	Units
LVDS Electrical/Interface					
fin	Input clock rate for 10-bit mode			340	MHz
fin	Input clock rate for 8-bit mode			272	MHz
tidc	Input clock duty cycle	45	50	55	%
tj	Input clock jitter		20		ps
fspi	SPI clock rate			10	MHz
ratspi	10-bit: ratio: Fin/fspi	30			
	8-bit: ratio: Fin/fspi	24			

5. All parameters are characterized for DC conditions after thermal equilibrium is established.
6. This device contains circuitry to protect the inputs against damage due to high static voltages or electric fields. However, it is recommended that normal precautions be taken to avoid application of any voltages higher than the maximum rated voltages to this high−impedance circuit.
7. Minimum and maximum limits are guaranteed through test and design.
8. Vref_colmux supply should be able to source and sink current

Disclaimer: Image sensor products and specifications are subject to change without notice. Products are warranted to meet the production data sheet and acceptance criteria specifications only.

Table 6. FRAME RATE

Parameter	Description	32 LVDS Channels		Units
		Zero ROT		
		Disabled	Enabled	
fps_roi1	Xres × Yres = 4096 × 4096	80	125	fps
fps_roi2	Xres × Yres = 4096 × 3072	110	160	fps
fps_roi3	Xres × Yres = 3072 × 3072	130	215	fps
fps_roi4	Xres × Yres = 2048 × 2048	245	470	fps
fps_roi5	Xres × Yres = 1920 × 1080	470	880	fps
fps_roi6	Xres × Yres = 1024 × 1024	640	920	fps
fps_roi7	Xres × Yres = 640 × 480	1475	1860	fps
fps_roi8	Xres × Yres = 512 × 512	1450	1760	fps
fps_roi9	Xres × Yres = 256 × 256	2925	3210	fps

Power Distribution Network

A power distribution network (PDN) is designed to ensure proper power management to the VITA sensor. Table 7 provides the recommended power supplies for the VITA power management. Please refer to the AN65466 for recommended linear regulator selection, decoupling capacitor network and BOM for the power distribution network.

Table 7. RECOMMENDED POWER SUPPLIES

Category	Power Supply	Source/Sink Stage	Min Rating (V)	Typ Rating (V)	Max Rating (V)	Max DC Current (mA)	Peak Currents at Allowable pk−pk Ripples
Digital	VDDD_18	Sourcing	1.6	1.8	2	440	2 A at 200 mV
	VDDD_33	Sourcing	3	3.3	3.6	110	0.6 A at 200 mV
	VDD_sel	Sourcing	3	3.3	3.6	0	1 mA at 20 mV
Analog	VDDA_33	Sourcing	3	3.3	3.6	965	1.5 A at 50 mV
	VDD_pix	Sourcing	3	3.3	3.6	45	700 mA at 100 mV
	VDD_respd	Sourcing	3.3	4.2	4.6	7	300 mA at 20 mV
	VDD_trans	Sourcing	3.3	4.2	4.6	7	
	VDD_resfd	Sourcing	3.3	4.5	4.6	7	
	VDD_casc	Sourcing	0.9	1	1.1	0	6 mA at 300 mV
	Vref_colmux	Sourcing & Sinking		1		0	0.35 A at 0.5 mV
	gnd_respd	Sinking	0	0	1	30 mA sinking at 0.4 V	200 mA at 20 mV

9. Combining power supplies:
   - VDD_sel can be combined with either VDDD_33 or VDDA_33
   - VDD_respd and VDD_trans can be grouped together as VDD_42
   - gnd_respd is be designed to be a 7 mA sinking supply, but can be tied to ground with no impact to image quality

Color Filter Array

The VITA color sensor is processed with a Bayer RGB color pattern as shown in Figure 2. Pixel (0,0) has a red filter situated to the bottom left. Green1 and green2 have a slightly different spectral response due to (optical) cross talk from neighboring pixels. Green1 pixels are located on a green-red row, green2 pixels are located on a blue-green row.

Figure 3 depicts the spectral response for the mono and color devices. Figure 4 shows the photovoltaic response for the VITA.

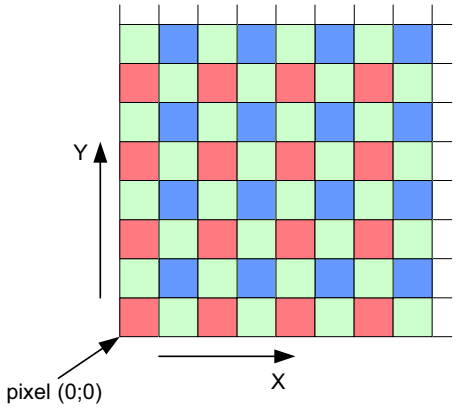


Figure 2. Color Filter Array for the Pixel Array

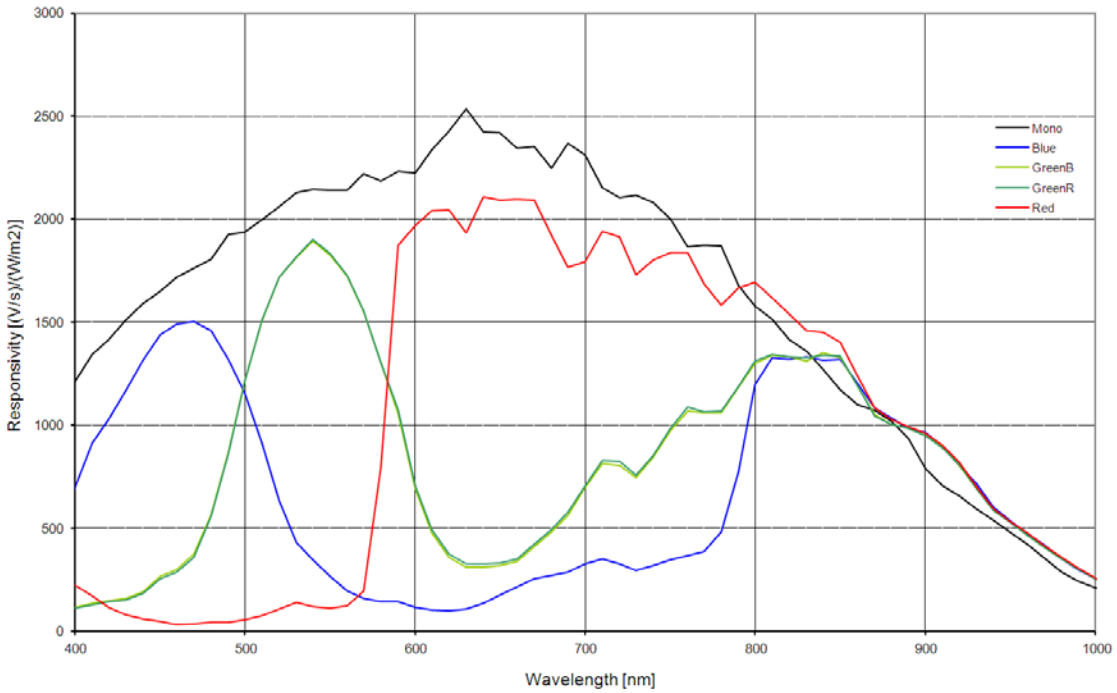


Figure 3. Mono and Color Spectral Response with Micro Lens

Note that green pixels on a Green−Red (Green 1) and Green−Blue (Green 2) row have similar responsivity to wavelength trend as is depicted by the legend “Green”.

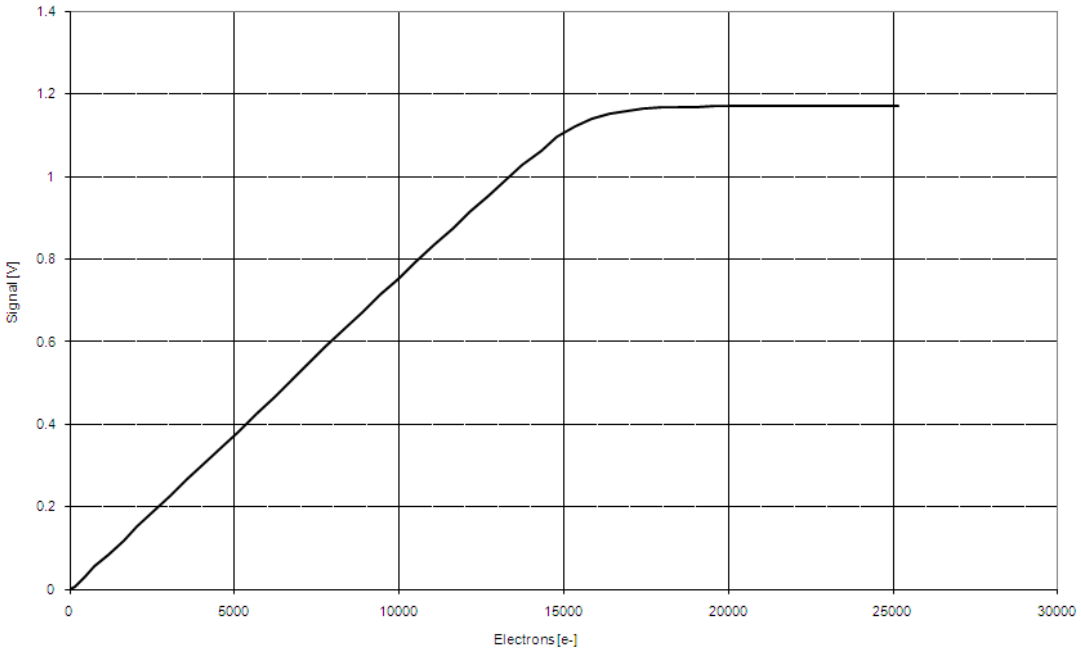


Figure 4. Typical Photovoltaic Response

OVERVIEW

Figure 5 gives an overview of all functional blocks in the image sensor. The system clock is received by the LVDS clock receiver block and distributed to other blocks. The sequencer defines the sensor timing and controls the image core. The sequencer is started either autonomously (master mode) or on assertion of an external trigger (slave mode). The image core contains all pixels and readout circuits. The column structure selects pixels for readout and performs correlated double sampling (CDS) or double sampling (DS). The data comes out sequentially and is fed into the analog front end (AFE) block. The programmable gain amplifier (PGA) of the AFE adds the offset and gain. The output is a fully differential analog signal that goes to the ADC, where the analog signal is converted to a 10-bit data stream. Depending on the operating mode, eight or ten bits are fed into the data formatting block. This block adds synchronization information to the data stream based on the frame timing. The data then goes to the low voltage serial (LVDS) interface block that sends the data out through the I/O ring.

On-chip programmability is controlled through the Serial Peripheral Interface (SPI). See Register Map on page 45 for register details. A bias block generates bias currents and voltages for all analog blocks on the chip. By controlling the bias current, the speed-versus-power of each block can be tuned. All biasing programmability is contained in the bias block.

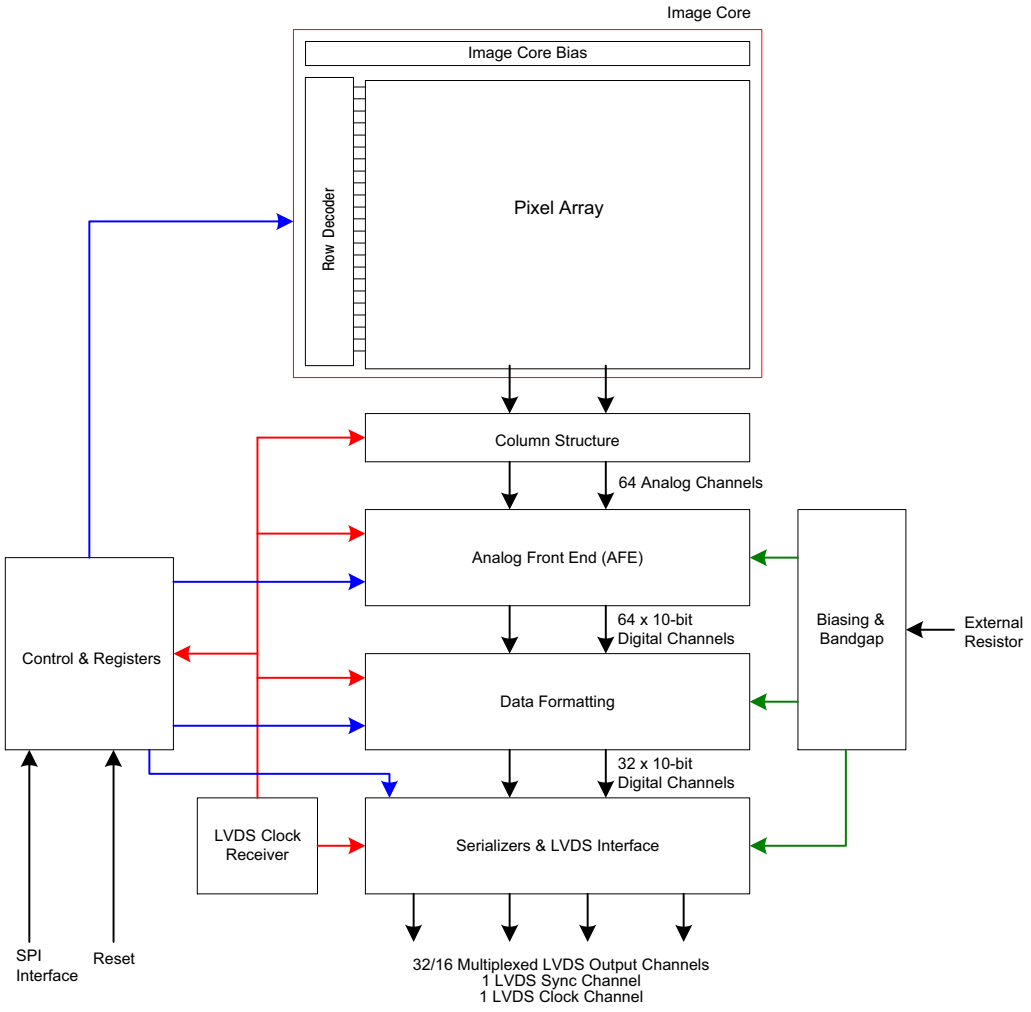


Figure 5. Block Diagram

Image Core

The image core consists of:

- Pixel array
- Address decoders and row drivers
- Pixel biasing

The VITA16K pixel array contains 4352 (H) x 4104 (V) readable pixels with a pixel pitch of 4.5 μm, inclusive of 4 pixel rows and 128 pixel columns at every side to allow for reprocessing or color reconstruction.

The VITA12K pixel array contains 4352 (H) x 3080 (V) readable pixels with a pixel pitch of 4.5 μm, inclusive of 4 pixel rows and 128 pixel columns at every side to allow for reprocessing or color reconstruction. The sensor uses a 5T pixel architecture, which makes it possible to read out the pixel array in global shutter mode with DS, or rolling shutter mode with CDS.

The function of the row drivers is to access the image array line by line, or all lines together, to reset or read the pixel data. The row drivers are controlled by the on-chip sequencer and can access the pixel array in global and rolling shutter modes.

The pixel biasing block guarantees that the data on a pixel is transferred properly to the column multiplexer when the row drivers select a pixel line for readout.

LVDS Clock Receiver

The LVDS clock receiver receives an LVDS clock signal and distributes the required clocks to the sensor.

Typical input clock frequency is 340 MHz in 10-bit mode and 272 MHz in 8-bit mode. The clock input needs to be terminated with a 100 Ω resistor.

Column Multiplexer

The 4096 pixels of one image row are stored in 4096 column sample-and-hold (S/H) stages. These stages store both the reset and integrated signal levels.

The data stored in the column S/H stages is read out through 64 parallel differential outputs operating at a frequency of 34 MHz.

At this stage, the reset signal and integrated signal values are transferred into an FPN-corrected differential signal. A programmable gain of 1x, 2x, or 4x can be applied to the signal at this stage. The column multiplexer also supports a subsampled readout mode (read-1-skip-1 for mono and read-2-skip-2 for color version). Enabling this mode can speed up the frame rate, with a decrease in resolution.

Bias Generator

The bias generator generates all required reference voltages and bias currents that the on-chip blocks use. An external resistor of 47 kΩ, connected between the pins *ibias_master* and *ibias_out* is required for the bias generator to operate properly.

Analog Front End

The AFE contains 64 channels, each containing a PGA and a 10-bit ADC. The PGA can be programmed to apply a gain of 1x, 1.39x, 1.94x, and 2.72x to the image signal. Together with the gain applied in the column multiplexer, a total signal gain of 10x can be achieved.

For each of the 64 channels, a pipelined 10-bit ADC is used to convert the analog image data into a digital signal, which is delivered to the data formatting block. A black calibration loop is implemented to ensure that the black level is mapped to match the correct ADC input level.

Data Formatting

The data block receives data from two ADCs and multiplexes this data to one LVDS block. A cyclic redundancy check (CRC) code is calculated on the passing data. For each LVDS output channel, one data block is instantiated. An extra data block is foreseen to transmit synchronization codes such as frame start, line start, frame end, and line end indications.

The data block calculates a CRC once per line for every channel. This CRC code can be used for error detection at the receiving end.

Serializer and LVDS Interface

The serializer and LVDS interface block receives the formatted (10-bit or 8-bit) data from the data formatting block. This data is serialized and transmitted by the LVDS output driver.

In 10-bit mode, the maximum output data bit rate is 680 Mbps per channel. In 8-bit mode, the maximum output data bit rate is 544 Mbps per channel.

In addition to the 32 LVDS data outputs, two extra LVDS outputs are available. One of these outputs carries the output clock, which is skew aligned to the output data channels. The second LVDS output contains frame format synchronization codes to serve system-level image reconstruction.

It is possible to use only 16 channels to grab the frame. It does reduce the maximum frame rate by 2.

Sequencer

The sequencer is responsible for the following tasks:

- Controls the image core. Starts and stops integration in rolling and global shutter modes and control pixel readout.
- Operates the sensor in master or slave mode.
- Applies the window settings. Organizes readouts so that only the configured windows are read.
- Controls the column multiplexer and analog core. Applies gain settings and subsampling modes at the correct time, without corrupting image data.
- Starts up the sensor correctly when leaving standby mode.

OPERATING MODES

This sensor supports multiple operation modes. The following list provides an overview.

- Global Shutter mode
  - ♦ Pipelined global shutter mode
    - Master mode
    - Slave mode
  - ♦ Triggered global shutter
    - Master mode
    - Slave mode
- Rolling shutter mode
- Normal and Zero ROT mode
- Multiple windowing readout
  - ♦ Flexible window configuration
  - ♦ Processing multiple windows in Global Shutter mode
- Subsampling and binning
  - ♦ Pixel binning
  - ♦ Subsampling

Global Shutter Mode

In a global shutter mode, light integration takes place on all pixels in sync, although subsequent readout is sequential, as shown in Figure 6. Figure 7 shows the integration and readout sequence for the global shutter. All pixels are light sensitive at the same time. The whole pixel core is reset simultaneously and, after the integration time, all pixel values are sampled together on the storage node inside each pixel. The pixel core is read out line by line after integration. The integration and readout can occur in parallel or sequentially.

The integration starts at a certain period, relative to the frame start.

Pipelined Global Shutter Mode

In pipelined shutter mode, the integration and readout are done in parallel. Images are continuously read and integration of frame N is ongoing during readout of the previous frame N–1. The readout of every frame starts with a frame overhead time (FOT), during which the analog value on the pixel diode is transferred to the pixel memory element. After the FOT, the sensor is read out line by line and the readout of each line is preceded by the row overhead time (ROT).

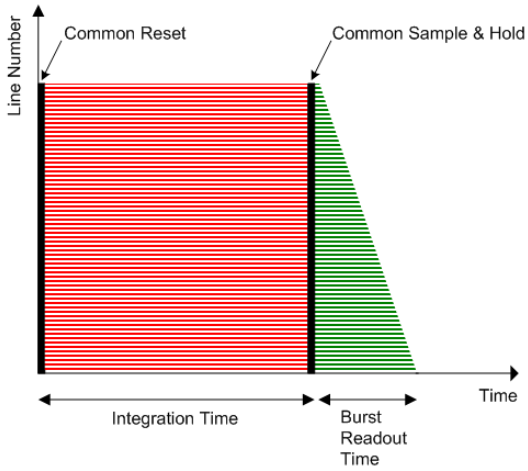


Figure 6. Global Shutter Operation

Master Mode

In this operation mode, the integration time is set through the register interface and the sensor integrates and reads out the images autonomously. The sensor acquires images without any user interaction.

Slave Mode

The slave mode adds more manual control to the sensor. The integration time registers are ignored in this mode and the integration time is instead controlled by an external pin. As soon as the control pin is asserted, the pixel array goes out of reset and integration starts. The integration continues until the user or system deasserts the external pin. Upon a falling edge of the trigger input, the image is sampled and the readout begins.

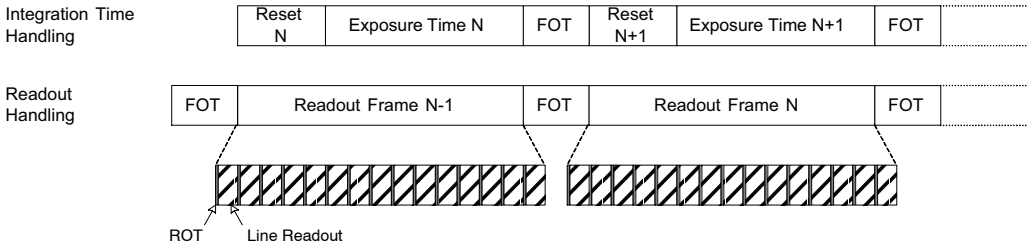


Figure 7. Integration and Readout for Pipelined Shutter

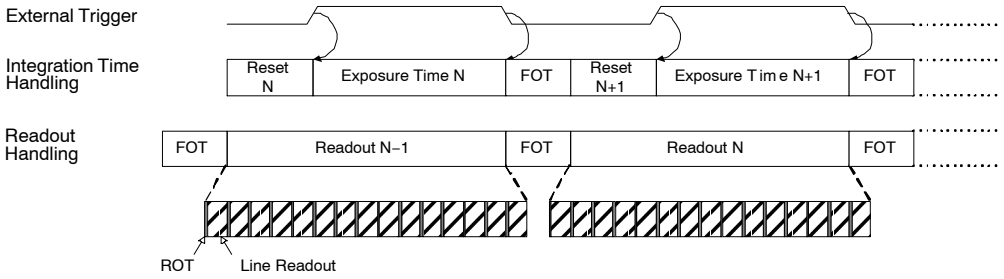


Figure 8. Pipelined Shutter Operated in Slave Mode

Triggered Global Shutter

In this mode, manual intervention is required to control both the integration time and the start of readout. After the integration time, indicated by a user controlled pin, the image core is read out. After this sequence, the sensor goes to an idle mode until a new user action is detected.

The three main differences from the pipelined shutter master mode are:

- Upon user action, a single image is read.
- Normally, integration and readout are done sequentially. However, the user can control the sensor in such a way that two consecutive batches are overlapping, that is, having concurrent integration and readout.
- Integration and readout is user-controlled through an external pin.

The triggered global mode can also be controlled in a master or in a slave mode.

Master Mode

As shown in Figure 9, in the master mode a rising edge on the synchronization pin is used to trigger the start of integration and readout. The integration time is defined by a register setting. The sensor autonomously integrates during this predefined time, after which the FOT starts and the image array is read out sequentially. A falling edge on the synchronization pin does not have any impact on the readout or integration and subsequent frames are started again for each rising edge.

Slave Mode

Integration time control is identical to the pipelined shutter slave mode, in which both integration time and readout requests are controlled by an external trigger. An external synchronization pin controls the start of integration. The moment it is deasserted, the FOT starts. At this time, the analog value on the pixel diode is transferred to the pixel memory element and the image readout can start. A request for a new frame is started when the synchronization pin is asserted again.

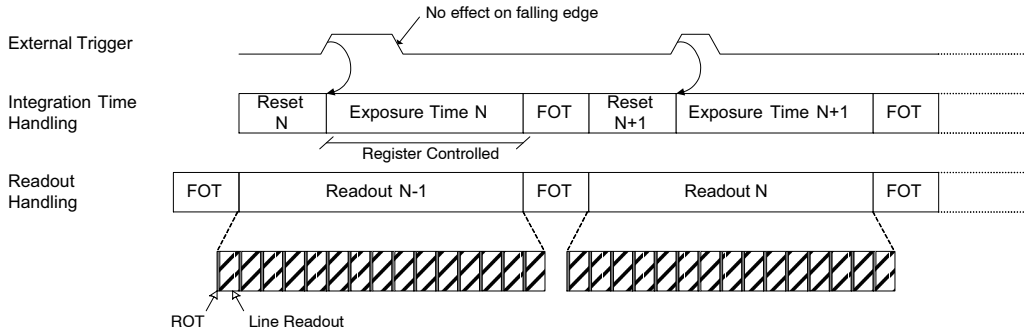


Figure 9. Triggered Shutter Operated in Master Mode

Rolling Shutter Mode

The sensor also supports the rolling shutter mode. The shutter mechanism is an electronic rolling shutter and the sensor operates in streaming mode similar to a video. This mechanism is controlled by the on-chip sequencer logic. There are two Y pointers, as indicated in Figure 10. One of them points to the row that is to be reset for rolling shutter operation and the other points to the row to be read out. Functionally, a row is reset first and selected for readout later. The time elapsed between these two operations is the exposure time.

Figure 10 schematically indicates the relative shift of the integration times of different lines during rolling shutter operation. Each row is read and reset sequentially, as described in the previous paragraph. Each row in a particular frame is integrated for the same time, but all lines in a frame ‘see’ a different stare time. Therefore, fast horizontal moving objects in the field of view give rise to motion artifacts in the image; this is an unavoidable property of a rolling shutter.

In rolling shutter mode, a second pointer indicates the rows that need to be reset for the rolling shutter mechanism. The distance between the reset pointer and the readout pointer determines the integration time.

The VITA 16K/12K supports dynamic exposure time updates without artifacts or interrupting the image data stream.

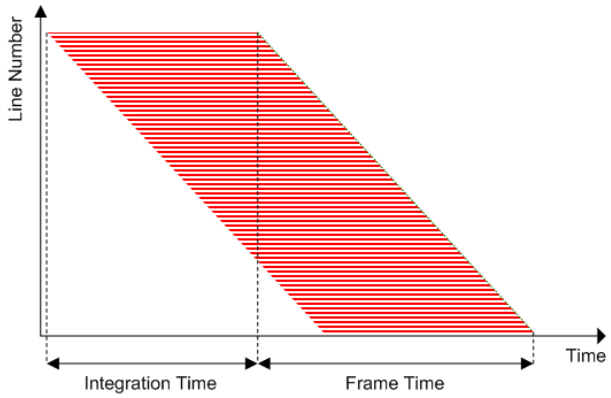


Figure 10. Rolling Shutter Operation

Normal and Zero Row Overhead Time (ROT) Modes

In pipelined global shutter mode, the integration and readout are done in parallel. Images are continuously read out and integration of frame N is ongoing during readout of the previous frame N−1. The readout of every frame starts with a Frame Overhead Time (FOT), during which the analog value of the pixel diode is transferred to the pixel memory element. After the FOT, the sensor is read out line by line and the readout of each line is preceded by a Row Overhead Time (ROT) as shown in Figure 11.

In Reduced/Zero ROT operation mode (refer to Figure 12), the row blanking and kernel readout occur in parallel. This mode is called reduced ROT as a part of the ROT is done while the image row is readout. The actual ROT can thus be longer, however the perceived ROT will be shorter (‘overhead’ spent per line is reduced).

This operation mode can be used for two reasons:

- Reduced total line time.
- Lower power due to reduced clock−rate.

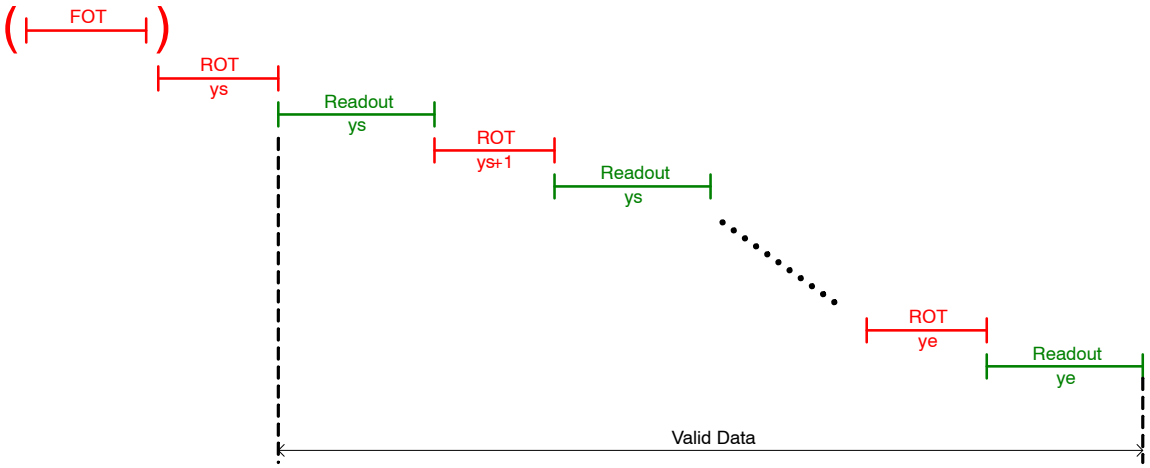


Figure 11. Integration and Readout Sequence of the Sensor Operating in Pipelined Global Shutter Mode with Normal ROT Readout.

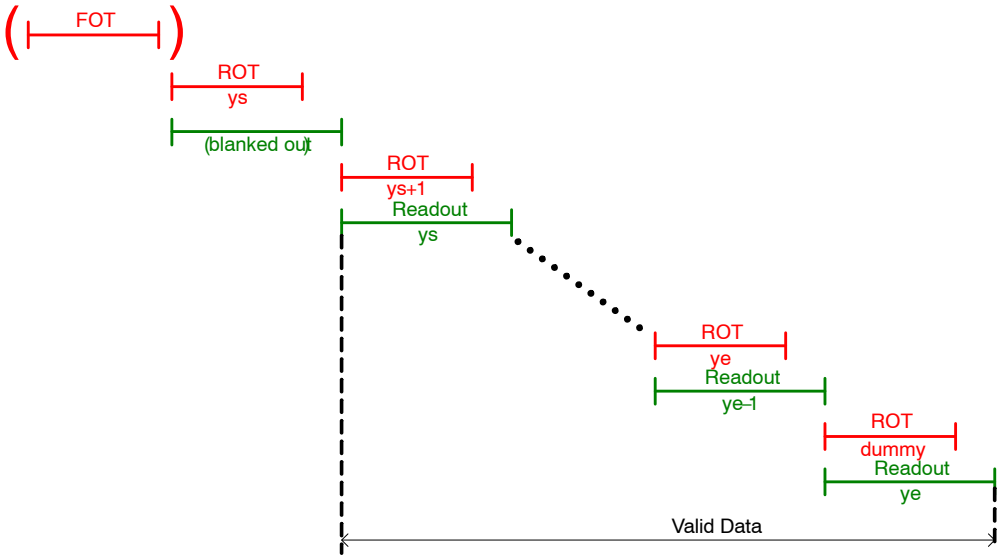


Figure 12. Integration and Readout Sequence of the Sensor operating in Pipelined Global Shutter Mode with Zero ROT Readout.

SENSOR OPERATION

Operation Flowchart

Figure 13 shows the flow chart diagram of the sensor operation. The sensor can be in five different ‘states’. Every state is indicated with the oval circle. These states are:

- Power-Off
- Standby (1)
- Standby (2)
- Idle
- Running

The states above are ordered by power dissipation. Clearly, in ‘power-off’ state the power dissipation will be minimal; in ‘running’ state the power dissipation will be maximal.

On the other hand, the lower the power consumption, the more actions (and time) are required to put the sensor in ‘running’ state and grabbing images.

This flowchart provides the trade-offs between power saving and enabling time of the sensor.

Next to the ‘states’ a set of ‘user actions’, indicated by arrows, are included in the flow chart diagram. These user actions make it possible to move from one state to another.

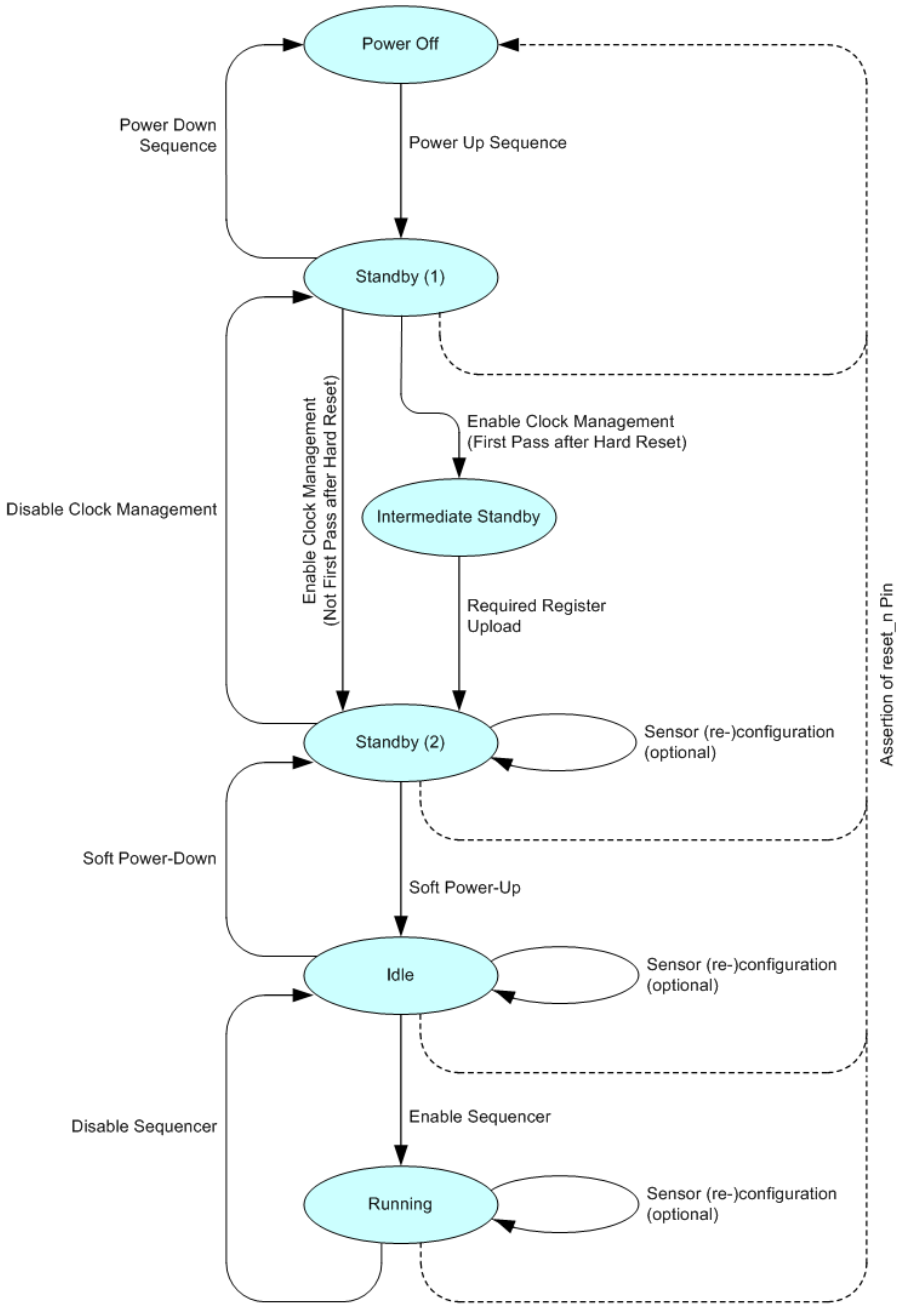


Figure 13. Sensor Operation Flow

The sensor can be in five different states:

Power-off

In this state, the sensor is inactive. All power supplies are down and the power dissipation is zero.

Standby (1)

The registers below address 40 can be configured.

Standby (2)

In this standby state all SPI registers are active, meaning that all SPI registers can be accessed for read and write operations. All other blocks are disabled.

Note: An Intermediate Standby state is traversed after a hard reset. In this state the sensor contains the default configurations. Uploads of reserved registers are required to traverse to the Standby (2) state

Idle

In the idle state, all sensor clocks are running and all blocks are enabled, except the sequencer block. The sensor is ready to start grabbing images as soon as the sequencer block is enabled.

Running

In running state, the sensor is enabled and grabbing images. The sensor can be operated in different rolling/global master/slave modes.

User Actions: Functional Mode to Power Up Sequences

To ‘travel’ between the five possible states, a set of actions is defined. Except for the power-up and power-down sequences, all actions consist of a set of SPI uploads.

The “Sensor reconfiguration actions” indicated in Figure 13 are used to reconfigure the operation modes of the sensor. The sensor state itself is not altered.

Power-up Sequence

Figure 13 shows the power-up timing of the sensor. Apply all power supplies in the order shown in the figure. It is important to comply with the described sequence. Any othyer supply ramping sequence may lead to high current peaks and, as consequence, a failure of the sensor power up

When all the supplies are stable, enable the sensor clock signal; then deassert the reset_n signal. After leaving the hard-reset mode, the sensor enters the standby (1) state. To go to the standby (2) mode, the sensor requires the reconfiguration of some registers. This reconfiguration can be applied 10 μs after the hard reset is released.

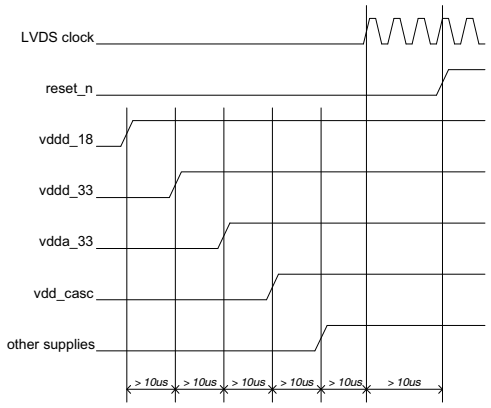


Figure 14. Power−up Procedure

NOTE: vdd_casc should come up prior to vdd_respd, vdd_resfd, and vdd_trans.

The required input clock frequency depends on the word depth mode of the sensor. This is possible in the following mode:

- 8-bit
- 10-bit

The input clock frequencies to achieve a frame rate of 58 frames/s are listed in Table 8.

Table 8. CLOCK FREQUENCY OVERVIEW

Parameter	8−bit Mode	10−bit Mode
Input Clock Frequency	272 MHz	340 MHz

Enable Clock Management

The next step consists of SPI uploads which configures the internal clock distribution. The required uploads are listed in Table 9. It is important to follow the upload sequence as listed.

Table 9. ENABLE CLOCK MANAGEMENT UPLOAD

No.	Address	Data	Description
1	2	0x0000	NOIV1SN016KA
		0x0001	NOIV1SE016KA
2	32	0x2002	Configure Clock Management
3	34	0x0001	Enable Logic Blocks

Required Register Uploads

In this phase the 'reserved' register settings are uploaded through the SPI register. Different settings are not allowed and may cause the sensor to malfunction. The required uploads are listed in Table 10.

Table 10. REQUIRED REGISTER UPLOADS

No.	Address	Data	Description
1	65	0x008B	General Biasing
2	66	0x53C8	AFE Biasing
3	67	0x8848	Mux Biasing
4	68	0x0086	LVDS Biasing
5	128	0x4520	Set desired output level to code 32 for 10-bit mode, code 8 for 8-bit mode. Set number of samples for black calibration to 2^5.
6	204	0x09E5	Configure unity gain (Normal ROT)
		0x09E6	Configure unity gain (Zero ROT)
7	224	0x3E04	Dummy rows upon integration start
8	225	0x6733	Configure internal latency
9	129[13]	0x0	10-bit Mode
		0x1	8-bit Mode
10	447	0x0BF1	Configure sequencer
11	448	0x0BC3	Configure sequencer
12	256	0x4708	Configure ROI (x)
13	257	0x0200	Configure ROI (y) – 16K res.
		0x0400	Configure ROI (y) – 12K res.
14	258	0x11FF	Configure ROI (y) – 16K res.
		0x0FFF	Configure ROI (y) – 12K res.

Soft Power Up

During the soft power-up action, the internal blocks are enabled and prepared to start processing the image data stream. This action exists of a set of SPI uploads. The soft power-up uploads are listed in Table 11.

Table 11. SOFT POWER UP REGISTER UPLOADS

No.	Address	Data	Description
1	32	0x2003	Enable Analog Clock Distribution
2	64	0x0001	Enable Biasing Block
3	40	0x0003	Enable Column Multiplexer
4	48	0x0001	Enable Analog Front-End (AFE)
5	112	0x0007	Enable LVDS Transmitters

Enable Sequencer

During the 'Enable Sequencer'-action, the frame grabbing sequencer is enabled. The sensor will start grabbing images in the configured operation mode. Refer to Operating Modes on page 10 for an overview of the possible operation modes.

The 'Enable Sequencer' action consists of a set op register uploads. The required uploads are listed in Table 12.

Table 12. ENABLE SEQUENCER REGISTER UPLOADS

No.	Address	Data (Normal ROT)	Data (Zero ROT)
1	192	0x0001	0x000D

User Actions: Functional Mode to Power Down Sequences

Disable Sequencer

During the 'Disable Sequencer'-action, the frame grabbing sequencer is stopped. The sensor will stop grabbing images and returns to the idle mode.

The 'Disable Sequencer' action consists of a set op register uploads. The required uploads are listed in Table 13.

Table 13. DISABLE SEQUENCER REGISTER UPLOADS

No.	Address	Data	Description
1	192[0]	0x0	Disable of Sequencer. NOTE: This address contains other configuration bits to select the operation mode.

Soft Power Down

During the soft power-down action, the internal blocks are disabled and the sensor is put in standby state in order to reduce the current dissipation. This action exists of a set of register uploads. The soft power-down uploads are listed in Table 14.

Table 14. SOFT POWER DOWN REGISTER UPLOADS

No.	Address	Data	Description
1	112	0x0000	Disable LVDS Transmitters
2	48	0x0000	Disable Analog Front-End (AFE)
3	40	0x0000	Disable Column Multiplexer
4	64	0x0000	Disable Biasing Block
5	32	0x2002	Disable Analog Clock Distribution

Disable Clock Management

The ‘Disable Clock Management’-action stops the internal clocking in order to further decrease the power dissipation. This action exists of a set of register uploads as listed in Table 15.

Table 15. DISABLE CLOCK MANAGEMENT UPLOADS

No.	Address	Data	Description
1	34	0x0000	Disable Logic Blocks

Power-down Sequence

The timing diagram of the advised power-down sequence is given in Figure 15. Any other sequence might cause high peak currents.

NOTE: vdd_casc should be powered down after vdd_respd, vdd_resfd, and vdd_trans.

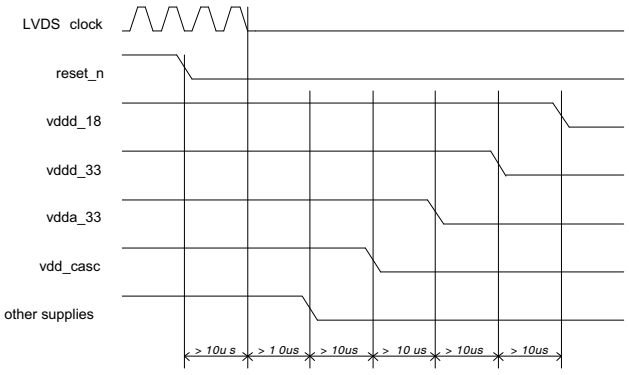


Figure 15. Power−down Sequence

Shutter and Operation Mode Reconfiguration

The VITA sensor operates in two shutter modes: global shutter and rolling shutter. The global shutter mode can be combined with a set of operation modes, as described Operation Modes on page 10.

These modes can be combined with subsampling and binning modes.

The shutter and operation modes are controlled by register 192, when the sensor is in standby or idle mode. Table 16 gives an overview of the available register settings to control the shutter and operation modes. During this action, only the fields listed in Table 16 are affected. All other settings encapsulated in register 192 must remain unchanged.

Table 16. SHUTTER/OPERATION MODE CONFIGURATION REGISTERS

Address	Default Value	Description
192 [1]	0x0	Shutter type selection 0: Global shutter 1: Rolling shutter
192 [3:2]	0x0	Normal/Zero ROT mode selection 0: Normal ROT mode 3: Zero ROT mode
192 [4]	0x0	Triggered mode selection (global shutter only) 0: Normal mode 1: Triggered mode
192 [5]	0x0	Master/Slave selection (global shutter only) 0: Master mode 1: Slave mode
192 [7]	0x0	Subsampling mode selection 0: Subsampling disabled 1: Subsampling enabled
192 [8]	0x0	Binning mode selection 0: Binning disabled 1: Binning enabled

Windowing Reconfiguration

The windowing settings can be configured during standby, idle, and running mode.

The required regions of interest (ROI) can be programmed in the roi_configuration registers (addresses 256 up to 351). Registers roi_active0 and roi_active1 are used to activate the desired ROIs.

Default window configuration (after sensor reset) is one window, full frame (window #0).

Exposure/Gain Reconfiguration

The exposure time and gain settings can be configured during standby, idle, and running mode. Refer to Signal Gain Path on page 29 for more information.

Sensor Configuration

This device contains multiple configuration registers. Some of these registers can only be configured while the sensor is not acquiring images (while register 192[0] = 0), while others can be configured while the sensor is acquiring images. For the latter category of registers, it is possible to distinguish the register set that can cause corrupted images (limited number of images containing visible artifacts) from the set of registers that are not causing corrupted images.

These three categories are described here.

Static Readout Parameters

Some registers are only modified when the sensor is not acquiring images. Reconfiguration of these registers while images are acquired can cause corrupted frames or even interrupt the image acquisition. Therefore, it is recommended to modify these static configurations while the sequencer is disabled (register 192[0] = 0). The registers shown in Table 17. Table 17 should not be reconfigured during image acquisition. A specific configuration sequence applies for these registers. Refer to the operation flow and startup description.

Table 17. STATIC READOUT PARAMETERS

Group	Addresses	Description
Clock generator	32	Configure according to recommendation
Image core	40	Configure according to recommendation
AFE	48	Configure according to recommendation
Bias	64–71	Configure according to recommendation
LVDS	112	Configure according to recommendation
Sequencer mode selection	192	• Rolling shutter enable • triggered_mode • slave_mode • nzrot_xsm_delay_enable
All reserved registers		Keep reserved registers to their default state, unless otherwise described in the recommendation

Dynamic Configuration Potentially Causing Image Artifacts

The category of registers as shown in Table 18 consists of configurations that do not interrupt the image acquisition process, but may lead to one or more corrupted images during and after the reconfiguration. A corrupted image is an image containing visible artifacts. A typical example of a corrupted image is an image which is not uniformly exposed

The effect is transient in nature and the new configuration is applied after the transient effect.

Table 18. DYNAMIC CONFIGURATION POTENTIALLY CAUSING IMAGE ARTIFACTS

Group	Addresses	Description
Black level configuration	128–129 197[8]	Reconfiguration of these registers may have an impact on the black-level calibration algorithm. The effect is a transient number of images with incorrect black level compensation.
Sync codes	129[13] 130–135	Incorrect sync codes may be generated during the frame in which these registers are modified.
Datablock test configurations	144–150	Modification of these registers may generate incorrect test patterns during a transient frame.

Dynamic Readout Parameters

It is possible to reconfigure the sensor while it is acquiring images. Frame-related parameters are internally resynchronized to frame boundaries, such that the modified parameter does not affect a frame that has already started. However, there can be restrictions to some registers as shown in Table 19.

Some reconfiguration may lead to one frame being blanked. This happens when the modification requires more than one frame to settle. The image is blanked out and training patterns are transmitted on the data and sync channels.

Table 19. DYNAMIC READOUT PARAMETERS

Group	Addresses	Description
Subsampling/binning	192[7] 192[8]	Subsampling or binning is synchronized to a new frame start.
Black lines	197	Reconfiguration of these parameters causes one frame to be blanked out in rolling shutter operation mode, as the reset pointers need to be recalculated for the new frame timing. No blanking in global shutter mode
Dummy lines	198	Reconfiguration of these parameters causes one frame to be blanked out in rolling shutter operation mode, as the reset pointers need to be recalculated for the new frame timing. N/A for global shutter mode.
ROI configuration	195-196 256–351	Optionally, it is possible to blank out one frame after reconfiguration of the active ROIs in rolling shutter mode. Therefore, register 206[8] must be asserted (blank_roi_switch configuration). An ROI switch is only detected when a new window is selected as the active window (reconfiguration of registers 195, 196, or both). Reconfiguration of the ROI dimension of the active window does not lead to a frame blank and can cause a corrupted image.
Exposure reconfiguration	199-201	Exposure reconfiguration does not cause artifact. However, a latency of one frame is observed unless reg_seq_exposure_sync_mode is set to ‘1’ in triggered global mode (master).
Gain reconfiguration	204	Gains are synchronized at the start of a new frame. Optionally, one frame latency can be incorporated to align the gain updates to the exposure updates (refer to register 204[13] - gain_lat_comp).

Freezing Active Configurations

Though the readout parameters are synchronized to frame boundaries, an update of multiple registers can still lead to a transient effect in the subsequent images, as some configurations require multiple register uploads. For example, to reconfigure the exposure time in master global mode, both the fr_length and exposure registers need to be updated. Internally, the sensor synchronizes these configurations to frame boundaries, but it is still possible that the reconfiguration of multiple registers spans over two or even more frames. To avoid inconsistent combinations, freeze the active settings while altering the SPI registers by disabling synchronization for the corresponding functionality before reconfiguration. When all registers are uploaded, re-enable the synchronization. The sensor’s sequencer then updates its active set of registers and uses them for the coming frames. The freezing of the active set of registers can be programmed in the sync_configuration registers, which can be found at the SPI address 206.

Figure 16 shows a reconfiguration that does not use the sync_configuration option. As depicted, new SPI configurations are synchronized to frame boundaries.

With sync_configuration = ‘1’. Configurations are synchronized to the frame boundaries (The registers exposure, fr_length, and mult_timer are not used in this mode)

Figure 17 shows the usage of the sync_configuration settings. Before uploading a set of registers, the corresponding sync_configuration is deasserted. After the upload is completed, the sync_configuration is asserted again and the sensor resynchronizes its set of registers to the coming frame boundaries. As seen in the figure, this ensures that the uploads performed at the end of frame N+2 and the start of frame N+3 become active in the same frame (frame N+4).

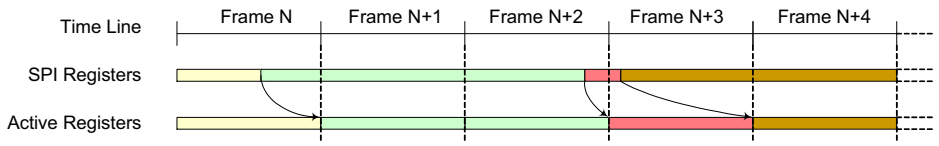


Figure 16. Frame Synchronization of Configurations (no freezing)

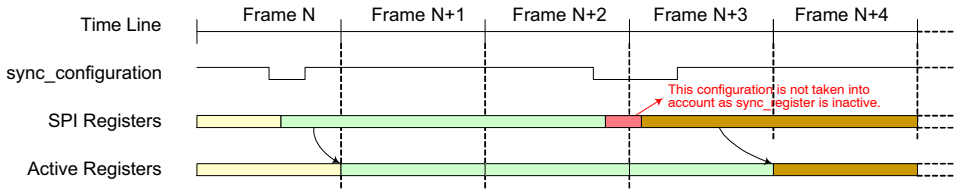


Figure 17. Reconfiguration Using Sync_configuration

NOTE: SPI updates are not taken into account while sync_configuration is inactive. The active configuration is frozen for the sensor. Table 20 lists the several sync_configuration possibilities along with the respective registers being frozen.

Table 20. ALTERNATE SYNC CONFIGURATIONS

Group	Affected Registers	Description
sync_rs_x_length	rs_x_length	Update of x-length configuration (rolling shutter only) is not synchronized at start of frame when ‘0’. The sensor continues with its previous configurations.
sync_black_lines	black_lines	Update of black line configuration is not synchronized at start of frame when ‘0’. The sensor continues with its previous configurations.
sync_dummy_lines	dummy_lines	Update of dummy line configuration is not synchronized at start of frame when ‘0’. The sensor continues with its previous configurations.
sync_exposure	mult_timer fr_length exposure	Update of exposure configurations is not synchronized at start of frame when ‘0’. The sensor continues with its previous configurations.
sync_gain	mux_gainsw afe_gain	Update of gain configurations is not synchronized at start of frame when ‘0’. The sensor continues with its previous configurations.
sync_roi	roi_active0[15:0] roi_active1[15:0] subsampling binning	Update of active ROI configurations is not synchronized at start of frame when ‘0’. The sensor continues with its previous configurations. **Note:** The window configurations themselves are not frozen. Re-configuration of active windows is not gated by this setting.

Window Configuration

Global Shutter Mode

Up to 32 windows can be defined in global shutter mode (pipelined or triggered). The windows are defined by registers 256 to 351. Each window can be activated or deactivated separately using registers 195 and 196. It is possible to reconfigure the inactive windows while acquiring images. Switching between prederfined windows is achieved by activation of the respective windows. This way a minimum number of registers need to be uploaded when it is necessary to switch between two or more sets of windows. As an example of this, scanning the scene at higher frame rates using multiple windows and switching to full frame capture when the object is tracked. Switching between the two modes only requires an upload of one (if the total number of windows is smaller than 17) or two (if more than 16 windows are defined) registers.

Rolling Shutter Mode

In rolling shutter mode it is not possible to read multiple windows. Do not activate more than one window (registers 205–206). However, it is possible to configure more than one window and dynamically switch between the different window configurations. Note that switching between two different windows might result in a corrupted frame. This is inherent in the rolling shutter mechanism, where each line must be reset sequentially before being read out. This corrupted window can be blanked out by setting register 206[8]. In this case, a dead time is noted on the LVDS interface when the window-switch occurs in the sensor. During this blank out, training patterns are sent out on the data and sync channels for the duration of one frame.

Black Calibration

The sensor automatically calibrates the black level for each frame. Therefore, the device generates a configurable number of electrical black lines at the start of each frame. The desired black level in the resulting output interface can be configured and is not necessarily targeted to ‘0’. Configuring the target to a higher level yields some information on the left side of the black level distribution, while the other end of the distribution tail is clipped to ‘0’ when setting the black level target to ‘0’.

The black level is calibrated for the 64 columns contained in one kernel. This implies 64 black level offsets are generated and applied to the corresponding columns. Configurable parameters for the black-level algorithm are listed in Table 21.

Table 21. CONFIGURABLE PARAMETERS FOR BLACK LEVEL ALGORITHM

Group	Addresses	Description
Black Line Generation		
197[7:0]	black_lines	This register configures the number of black lines that are generated at the start of a frame. At least one black line must be generated. The maximum number is 127. **Note:** When the automatic black-level calibration algorithm is enabled, make sure that this register is configured properly to produce sufficient black pixels for the black-level filtering. The number of black pixels generated per line is dependent on the operation mode and window configurations: Global Shutter - Each black line contains 80 kernels. Rolling Shutter - As the line length is fundamental for rolling shutter operation, the length of a black line is defined by the active window.
197[8]	gate_first_line	When asserting this configuration, the first black line of the frame is blanked out and is not used for black calibration. It is recommended to enable this functionality, because the first line can have a different behavior caused by boundary effects. When enabling, the number of black lines must be set to at least two in order to have valid black samples for the calibration algorithm.
Black Value Filtering		
129[0]	auto_blackcal_enable	Internal black-level calibration functionality is enabled when set to ‘1’. Required black level offset compensation is calculated on the black samples and applied to all image pixels. When set to ‘0’, the automatic black-level calibration functionality is disabled. It is possible to apply an offset compensation to the image pixels, which is defined by the registers 129[10:1]. **Note:** Black sample pixels are not compensated; the raw data is sent out to provide external statistics and, optionally, calibrations.
129[9:1]	blackcal_offset	Black calibration offset that is added or subtracted to each regular pixel value when auto_blackcal_enable is set to ‘0’. The sign of the offset is determined by register 129[10] (blackcal_offset_dec). **Note:** All channels use the same offset compensation when automatic black calibration is disabled. The calculated black calibration factors are frozen when this register is set to 0x1FF (all−‘1’) in auto calibration mode. Any value different from 0x1FF re−enables the black calibration algorithm. This freezing option can be used to prevent eventual frame to frame jitter on the black level as the correction factors are recalculated every frame. It is recommended to enable the black calibration regularly to compensate for temperature changes.
129[10]	blackcal_offset_dec	Sign of blackcal_offset. If set to ‘0’, the black calibration offset is added to each pixel. If set to ‘1’, the black calibration offset is subtracted from each pixel. This register is not used when auto_blackcal_enable is set to ‘1’.
128[10:8]	black_samples	The black samples are low-pass filtered before being used for black level calculation. The more samples are taken into account, the more accurate the calibration, but more samples require more black lines, which in turn affects the frame rate. The effective number of samples taken into account for filtering is $2^{black\_samples}$. **Note:** An error is reported by the device if more samples than available are requested (refer to registers 136 to 139).
Black Level Filtering Monitoring		
136 137 138 139	blackcal_error0 blackcal_error1 blackcal_error2 blackcal_error3	An error is reported by the device if there are requests for more samples than are available (each bit corresponding to one data path). The black level is not compensated correctly if one of the channels indicates an error. There are three possible methods to overcome this situation and to perform a correct offset compensation: • Increase the number of black lines such that enough samples are generated at the cost of increasing frame time (refer to register 197). • Relax the black calibration filtering at the cost of less accurate black level determination (refer to register 128). • Disable automatic black level calibration and provide the offset via SPI register upload. Note that the black level can drift in function of the temperature. It is thus recommended to perform the offset calibration periodically to avoid this drift.

NOTE: The maximum number of samples taken into account for black level statistics is half the number of kernels.

Serial Peripheral Interface

The sensor configuration registers are accessed through an SPI. The SPI consists of four wires:

- sck: Serial Clock
- ss_n: Active Low Slave Select
- mosi: Master Out, Slave In, or Serial Data In
- miso: Master In, Slave Out, or Serial Data Out

The SPI is synchronous to the clock provided by the master (sck) and asynchronous to the sensor's system clock. When the master wants to write or read a sensor's register, it selects the chip by pulling down the Slave Select line (ss_n). When selected, data is sent serially and synchronous to the SPI clock (sck).

Figure 18 shows the communication protocol for read and write accesses of the SPI registers. The VITA 16K/12K sensor uses 9-bit addresses and 16-bit data words

Data driven by the system is colored blue in Figure 18, while data driven by the sensor is colored yellow. The data in grey indicates high-Z periods on the miso interface. Red markers indicate sampling points for the sensor (mosi sampling); green markers indicate sampling points for the system (miso sampling during read operations).

The access sequence is:

1. Select the sensor for read or write by pulling down the ss_n line.
2. One SPI clock cycle (100 ns) after selecting the sensor, the 9-bit address is transferred, most significant bit first. The sck clock is passed through to the sensor as indicated in Figure 18. The sensor samples this data on a rising edge of the sck clock (mosi needs to be driven by the system on the falling edge of the sck clock)
3. The tenth bit sent by the master indicates the type of transfer: high for a write command, low for a read command.
4. Data transmission:
   - For write commands, the master continues sending the 16-bit data, most significant bit first.
   - For read commands, the sensor returns the requested address on the miso pin, most significant bit first. The miso pin must be sampled by the system on the falling edge of sck (assuming nominal system clock frequency and maximum 10 MHz SPI frequency).
5. When data transmission is complete, the system deselects the sensor one clock period after the last bit transmission by pulling ss_n high.

Maximum frequency for the SPI is $1/30^{th}$ (in 10-bit mode) and $1/24^{th}$ (in 8-bit mode) of the LVDS input clock frequency. For nominal input frequency (340 MHz / 272 MHz), this is 10 MHz.

Consecutive SPI commands can be issued by leaving at least two SPI clock periods between two register uploads. Deselect the chip between the SPI uploads by pulling the ss_n pin high.

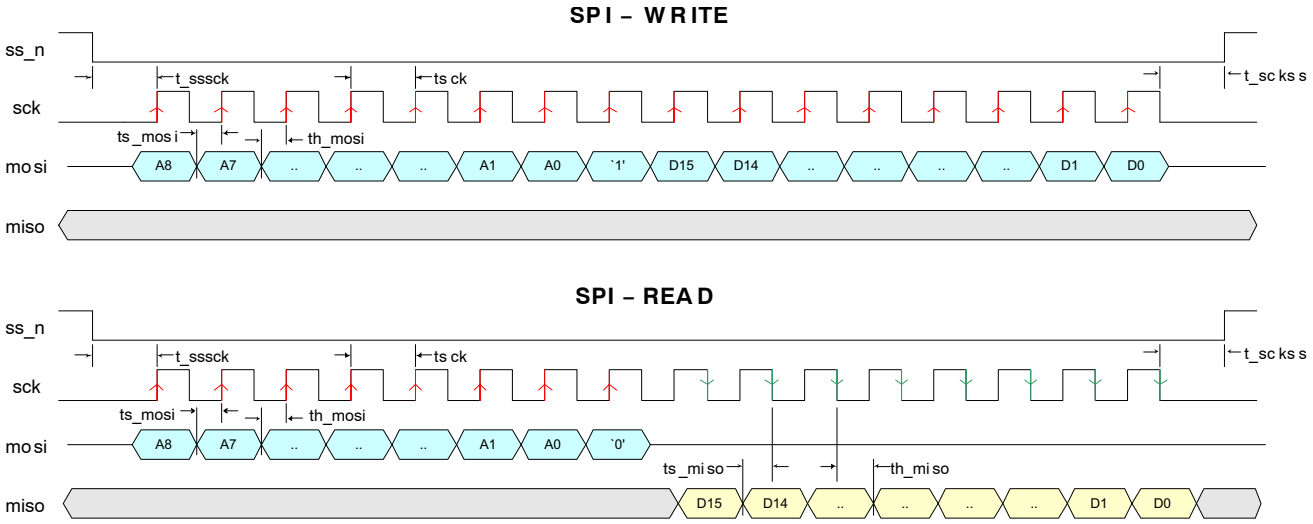


Figure 18. SPI Read and Write Timing Diagram

Table 22. SPI TIMING REQUIREMENTS

Group	Addresses	Description	Units
tsck	sck clock period	100 (*)	ns
tsssck	ss_n low to sck rising edge	tsck	ns
tsckss	sck falling edge to ss_n high	tsck	ns
ts_mosi	Required setup time for mosi	20	ns
th_mosi	Required hold time for mosi	20	ns
ts_miso	Setup time for miso	tsck/2-10	ns
th_miso	Hold time for miso	tsck/2-20	ns
tspi	Minimal time between two consecutive SPI accesses (not shown in figure)	2 x tsck	ns

*Value indicated is for nominal operation. The maximum SPI clock frequency depends on the sensor configuration (operation mode, input clock). tsck is defined as $1/f_{SPI}$. See text for more information on SPI clock frequency restrictions.

IMAGE SENSOR TIMING AND READOUT

Global Shutter Mode

Pipelined Global Mode (Master)

The sensor timing in master global shutter mode is controlled by the user by means of configuration registers. One can distinguish three parameters for the frame timing in global shutter mode:

- Image Array Reset Length
- Integration Time
- Frame Length

The relation between these parameters is:

Frame Length = Reset Length + Integration Time

The FOT time needs to be added to the frame length parameter to determine the total frame Time

Total Frame Time = FOT Time + Frame Length

Frame and integration time configuration can be controlled in two ways:

1. fr_mode = 0x0
   The reset length and integration time is configured by the user. The sensor shall calculate the frame length as the sum of both parameters.
2. fr_mode = 0x1
   The frame length and integration time is configured by the user. The reset time during which the pixels are reset, is calculated by the sensor as being the difference between the frame length and the desired integration time.

The configuration registers are exposure[15:0] and fr_length[15:0]. The latter configuration registers is either used as Reset Length configuration (fr_mode = 0x0) or as Frame Length (fr_mode = 0x'1). The granularity of both registers is defined by the mult_timer[15:0] register and is expressed in number of 68 MHz cycles (14.706 ns nominal).

Reset Length and Integration Time as Parameters

The reset time for the pixel array is controlled by the registers fr_length[15:0] and exposure[15:0]. The mult_timer configuration defines the granularity of the registers fr_length and exposure and is to be read as the number of 68 MHz cycles (14.706 ns nominal).

The exposure control for pipelined global master mode is depicted in Figure 19.

The pixel values are transferred to the storage node during the FOT, after which all photo diodes are reset. The reset state remains active for a certain time, defined by the fr_length and mult_timer registers, as shown in the figure. Meanwhile, the image array is read out line by line. After this reset period, the global photodiode reset condition is abandoned. This indicates the start of the integration or exposure time. The length of the exposure time is defined by the registers exposure and mult_timer.

NOTES:

- The start of the exposure time is synchronized to the start of a new line (during ROT) if the exposure period starts during a frame readout. Therefore, the effective time during which the image core is in a reset state is extended to the start of a new line.
- Make sure that the sum of the reset time and exposure time exceeds the time required to read out all lines. If this is not the case, the exposure time is extended until all (active) lines are read out.

Frame Length and Integration Time as Parameters

When fr_mode is configured to 0x1, one configures the frame time and exposure. The reset_length is determined by the sequencer. This configuration mode is depicted in Figure 2.

The frame length is configured in register fr_length, while the integration time is configured in register exposure. The mult_timer register defines granularity of both settings. Note that the FOT needs to be added to the configured fr_length to calculate the total frame time.

Triggered Global Shutter (Master)

In master triggered global mode, the start of integration time is controlled by a rising edge on the trigger pin. The exposure or integration time is defined by the registers exposure and mult_timer, similar to the master pipelined global mode. The fr_length configuration is not used. This operation is graphically shown in Figure 21.

NOTES:

- The falling edge on the trigger pin does not have any impact. However, the trigger must be asserted for at least 100 ns.
- The start of the exposure time is synchronized to the start of a new line (during ROT) if the exposure period starts during a frame readout. Therefore, the effective time during which the image core is in reset state is extended to the start of a new line.
- The trigger pin needs to be kept low during the FOT. The monitor pins can be used as a feedback to the FPGA/controller (eg. use monitor0, indicating the very first line when monitor_select = 0x5 – a new trigger can be initiated after a rising edge on monitor0).

If the exposure timer expires before the end of readout, the exposure time is extended until the end of the last active line.

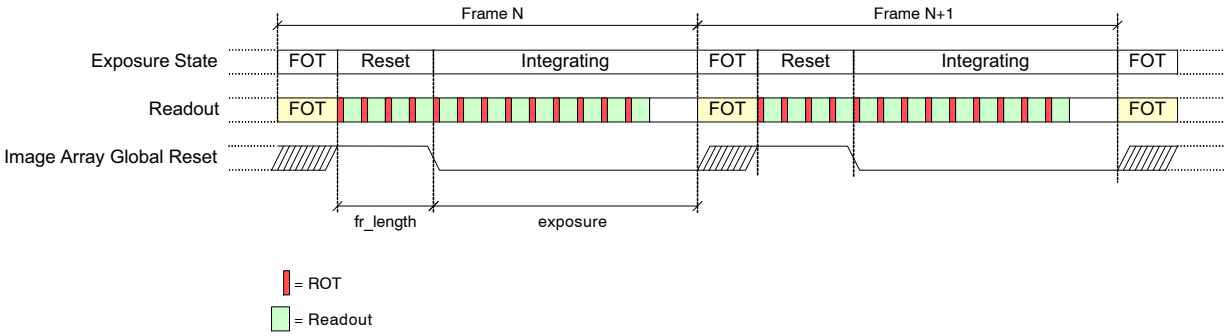


Figure 19. Integration Control for Pipelined Global Shutter Mode (Master, fr_mode = 0x0)

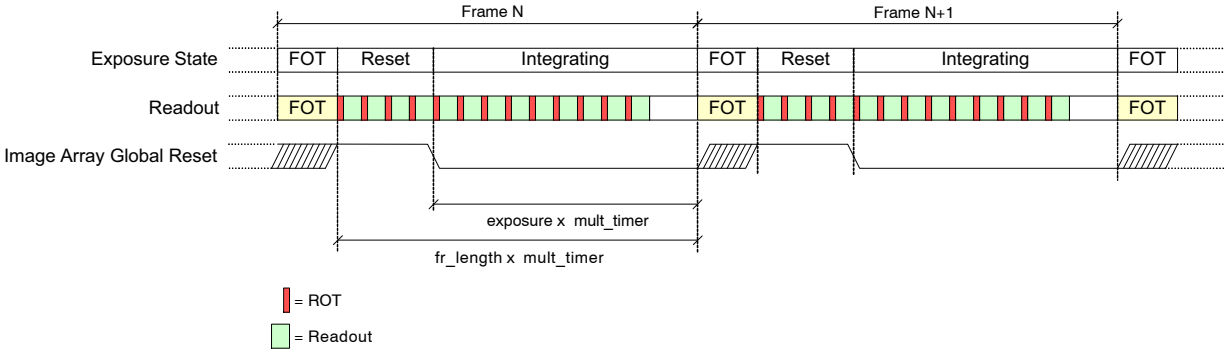


Figure 20. Integration Control for Pipelined Global Shutter Mode (Master, fr_mode = 0x1)

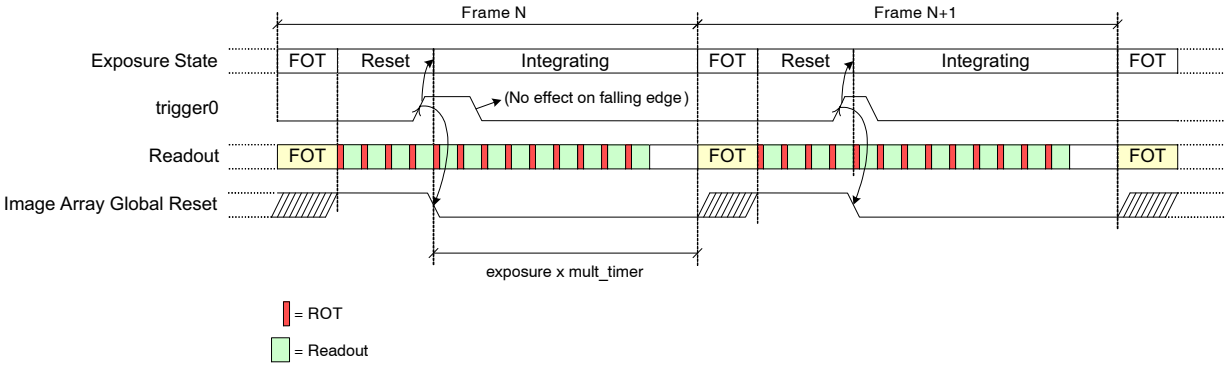


Figure 21. Exposure Time Control in Triggered Global Mode (Master)

Triggered Global Shutter (Slave)

Exposure or integration time is fully controlled by means of the trigger pin in slave mode. The register's fr_length, exposure, and mult_timer are ignored by the sensor.

A rising edge on the trigger pin indicates the start of the exposure time, while a falling edge initiates the transfer and readout of the image array. In other words, the high time of the trigger pin indicates the integration time, the period of the trigger pin indicates the frame time.

The use of the trigger during slave mode is shown in Figure 22.

NOTES:

- The start of the exposure time is synchronized to the start of a new line (during ROT) if the exposure period starts during a frame readout. Therefore, the effective time during which the image core is in a reset state is extended to the start of a new line.
- If the trigger is deasserted before the end of readout, the exposure time is extended until the end of the last active line. Consequently the FOT and start of frame readout is postponed accordingly.
- The trigger pin needs to be kept low during the FOT. The monitor pins can be used as a feedback to the FPGA/controller (eg. use monitor0, indicating the very first line when monitor_select = 0x5 – a new trigger can be initiated after a rising edge on monitor0).

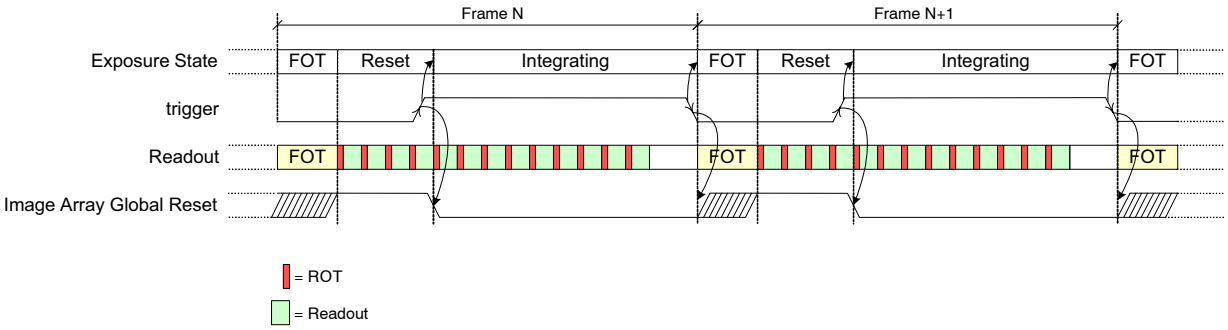


Figure 22. Exposure Time Control in Global−Slave Mode

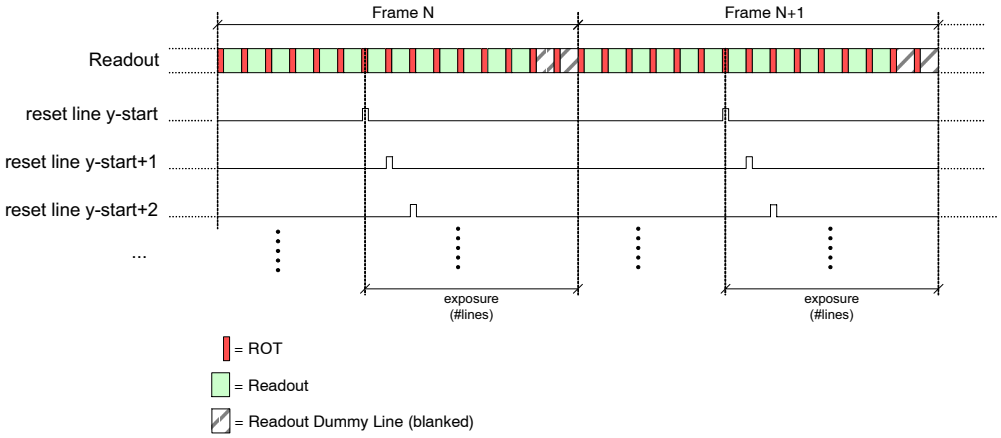
Rolling Shutter Mode

The exposure time during rolling shutter mode is always an integer multiple of line-times. The exposure time is defined by the register exposure and expressed in number of lines. The register fr_length and mult_timer are not used in this mode.

The maximum exposure time is limited by the frame time. It is possible to increase the exposure time at the cost of the frame rate by adding so called dummy lines. A dummy line lasts for the same time as a regular line, but no pixel data is transferred to the system. The number of dummy lines is controlled by the register dummy_lines.

The rolling shutter exposure mechanism is graphically shown in Figure 23.

The duration of one line is the sum of ROT and the time required to read out one line (depending on the number of active kernels in the window). Optionally, this readout time can be extended by the configuration rs_x_length. This register, expressed in number of periods of the logic clock (16.129 ns nominal), determines the length of the x-readout. However, the minimum length is governed by the window size (x-size).



NOTE: This figure illustrates a short frame with a few dummy lines.

Figure 23. Integration Control in Rolling Shutter Mode

ADDITIONAL FEATURES

Multiple Window Readout

The sequencer supports multiple window readout. This means that small ROIs, which are read out sequentially, can be defined in the full image array. Therefore, the sequencer scans all requested kernels line by line.

Window Configuration

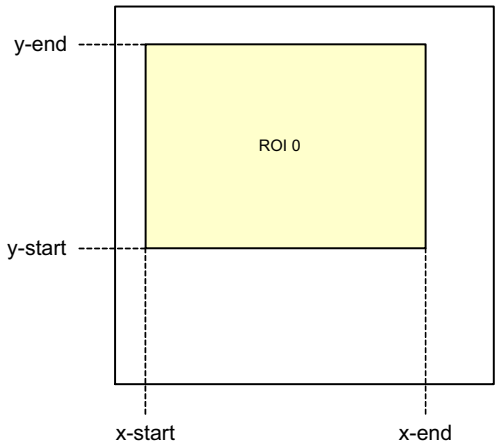


Figure 24. Region of Interest Configuration

Figure 24 shows the four parameters defining a region of interest (ROI). These parameters are explained here.

- x-start[6:0]

x-start defines the x-starting point of the desired window. The sensor reads out 64 pixels in a single clock cycle. Therefore, the granularity for configuring the x-start position is also 64 pixels. To find the corresponding column in the pixel array, multiply the value in the x-start register by 64.

- x-end[6:0]

This register defines the window end point on the x-axis. As for x-start, the granularity for this configuration is one kernel. x-end must be larger than x-start. The minimal window width is two kernels.

- y-start[12:0]

This is the start line of the readout window. The granularity of this setting is one line.

- y-end[12:0]

This is the end line of the readout window. y-end must be configured larger than y-start. This setting has the same granularity as the y-start configuration.

The configuration width of the required settings is mentioned between brackets. Seven bits are required for the x boundaries, 13 bits for the y boundaries.

Up to 32 windows can be defined, possibly (partially) overlapping. Figure 25 illustrates the use of overlapping windows. Note that pixel (0,0) is located in the left bottom corner.

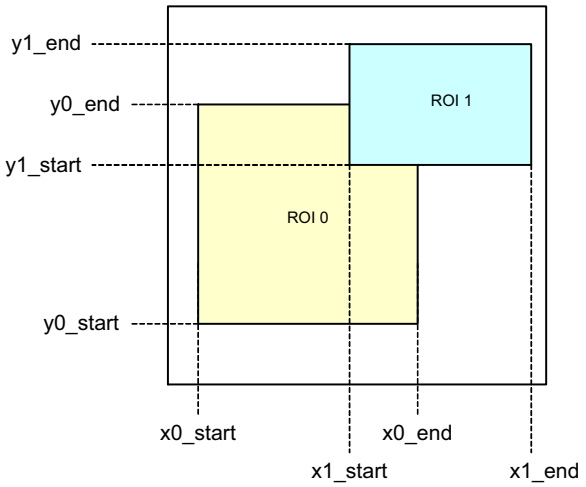


Figure 25. Overlapping Multiple Window Configuration

For each line to be scanned, the sequencer control block analyzes which windows must be read out, from left to right. The following restrictions apply to the window configurations (they must be valid for each line):

- For each line, the windows are ordered from left to right, based on their x-start address:
  x_start_roi(i) & x_start_roi(j) where j > i
- Overlapping in the x-direction is restricted to simple window overlapping schemes. When a new window is started, it needs to continue at least until the end of the previous window. In other words, it is not possible to start a window M, overlap with a window M+1, and at the end of window M+1, re-enter window M. The end of window M+1 must coincide or be larger than the end of window M:
  x_end_roi(i) & x_end_roi(j) where j > i
- For subsampling and binning modes, the start addresses are restricted to even addresses; the end addresses are restricted to even addresses for subsampling and odd addresses for binning. Erroneous start and end addresses are corrected by the sensor logic.
- The x−start, x−end, y−start and y−end addresses should be limited to the following ranges:

Table 23. WINDOW OFFSETS

	Data	
	NOIV1Sx016KA	NOIV1Sx012KA
x−start	0x06	0x06
x−end	0x49	0x49
y−start	0x01FC	0x03FC
y−end	0x1203	0x1003

Processing Multiple Windows

Global Shutter

The multiple windowing mechanism described in this section is only valid for the global shutter operation mode.

The sequencer control block houses two sets of counters to construct the image frame. As previously described, the y-counter indicates the line that needs to be read out and is incremented at the end of each line. For the start of the frame, the y-counter is initialized to the y-start address of the first window. It runs until the y-end address of the last window to be read out. Note that the last window is configured by the configuration registers and is not necessarily window #31.

The x-counter starts counting from the x-start address of the window with the lowest ID that is active on the addressed line. Only windows in which the current y-address is enclosed are taken into account for scanning. Other windows are skipped.

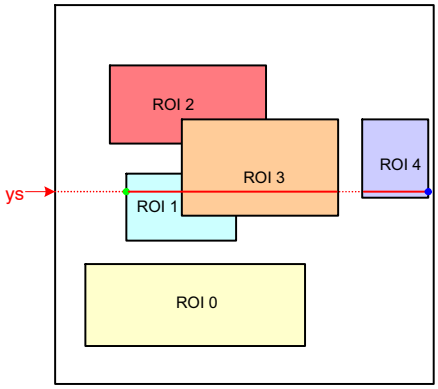


Figure 26. Scanning the Image Array with Five Subwindows

Figure 26 illustrates a practical example of a configuration with five windows. The current position of the read pointer (ys) is indicated by a red line crossing the image array. For this position, three windows need to be read out. The initial start position for the x-kernel pointer is the x-start configuration of ROI1. Kernels are scanned up to the ROI3 x-end position. From there, the x-pointer jumps to the next window, which is ROI4 in this illustration. When reaching ROI4's x-end position, the read pointer is incremented to the next line and xs is reinitialized to the starting position of ROI1.

NOTES:

- The initial starting point for the readout pointer at the start of a frame is the y-start position of the first active window.
- The read pointer is not necessarily incremented by one, but depending on the configuration, it can jump in y-direction. For Figure 26, this is the case when reaching the end of ROI0 where the read pointer jumps to the y-start position of ROI1.
- The x-pointer starting position is equal to the x-start configuration of the first active window on the current line addressed. This window is not necessarily window #0.
- The x-pointer is not necessarily incremented by one each cycle. At the end of a window it can jump to the start of the next window.

Rolling Shutter

Multiple windowing is not supported in rolling shutter mode. Only single-window readout is possible. The active window can be selected among the 32 windows in the configuration. Dynamic window reconfiguration (or dynamic selection of a different window configuration) is supported. Eventual corrupted images due to transients are blanked out in the sensor.

Subsampling and Binning

Pixel binning and subsampling methods are used as way of decimating the image. The number of pixel samples is reduced by a factor of four, while the optical area is maintained.

Pixel Binning

Pixel binning is a technique in which different pixels belonging to a rectangular bin are averaged in the analog domain. Two-by-two pixel binning is implemented such that two adjacent pixels are averaged both in column and row. Binning is configurable using a register setting. Pixel binning is not supported on the color option.

Note: register 194[9] needs to be configured to 0x1 for 2x2 pixel binning. When configuring to 0x0, 2x1 binning is obtained (binning in x only).

Subsampling

Subsampling is obtained by adapting the readout sequence. In subsampling mode, both lines and pixels are read in a read-N-skip-N mode. This reduces the number of lines in a frame and the number of pixels in a line. Overall frame time is reduced by a factor 4.

The monochrome sensor is read out in a read-one-skip-one pattern for both the rows and the columns, while the color version supports a read-two-skip-two subsampling scheme. This mode is selectable through register configuration. Figure 27 shows which pixels are read and which ones are skipped for monochrome and color sensors respectively. Readout direction is indicated as an x and y arrow.

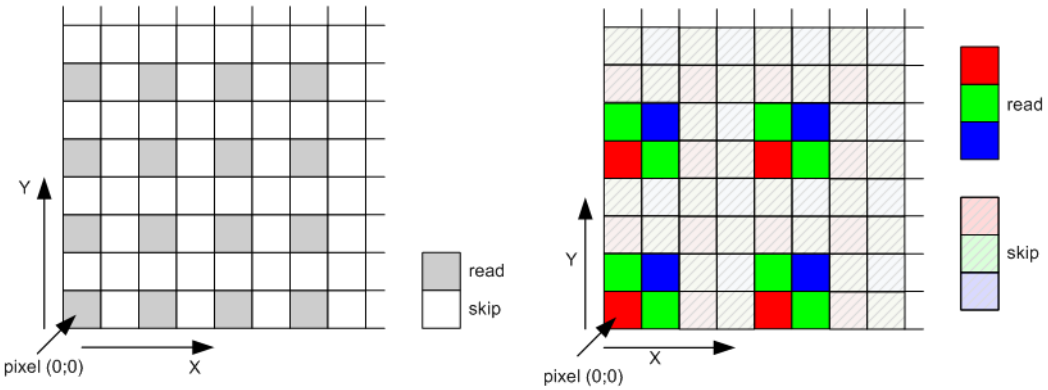


Figure 27. Subsampling Scheme

Signal Gain Path

Table 24 and Table 25 show the available registers (fields) to program the desired exposure time and gain settings. Settings 199[1:0] and 199[15:14] should remain unchanged.

Table 24. EXPOSURE TIME CONFIGURATION REGISTERS

Address	Default Value	Description
201	0x0000	Exposure time Rolling shutter: granularity = lines Global shutter: granularity defined by 'Mult Timer' (register 199).
199	0x0001	Mult Timer (global shutter only) Defines granularity of exposure and reset length. unit = 1/68 MHz for normal ROT mode
200	0x0000	Reset length or Frame Length (global shutter only) Granularity defined by 'Mult Timer' (register 199)

Table 25. GAIN CONFIGURATION REGISTERS

Address	Unity Gain Config-uration	Description
204 [4:0]	0x05	Column gain setting (Normal ROT) 0x07: column gain = 2/3x 0x05: column gain = 1x 0x09: column gain = 2x 0x13: column gain = 4x Other settings are not supported.
	0x06	Column gain setting (Zero ROT) 0x06: column gain = 1x 0x10: column gain = 2x 0x14: column gain = 4x Other settings are not supported.
204 [12:5]	0x4F	AFE gain setting 0x4F: AFE gain = 1.00x 0x33: AFE gain = 1.39x 0x36: AFE gain = 1.94x 0x66: AFE gain = 2.72x Other settings are not supported.
204 [13]		Postpone gain update by one frame when '1' to compensate for exposure time updates latency.
205[11:0]	0x080	Digital Gain, 5.7 unsigned representation (5 bits before decimal point, 7 bits for fractional part). Maximum gain is 31.992

Mode Changes and Frame Blanking

Dynamically reconfiguring the sensor may lead to corrupted or non-uniformilly exposed frames. For some reconfigurations, the sensor automatically blanks out the image data during one frame. Frame blanking is summarized in the following table for the sensor's image related modes.

NOTE: Major mode switching (i.e. switching between rolling and global shutter modes, master, triggered, slave modes) must be performed while the sequencer is disabled (reg_seq_enable = 0x0).

Table 26. DYNAMIC SENSOR RECONFIGURATION AND FRAME BLANKING

Configuration	Global Shutter		Rolling Shutter		Notes
	Corrupted Frame	Blanked Out Frame	Corrupted Frame	Blanked Out Frame	
Shutter Mode and Operation					
rolling_shutter_enable	Do not reconfigure while the sensor is acquiring images. Disable image acquisition by setting reg_seq_enable = 0x0.				
triggered_mode	Do not reconfigure while the sensor is acquiring images. Disable image acquisition by setting reg_seq_enable = 0x0.				
slave_mode	Do not reconfigure while the sensor is acquiring images. Disable image acquisition by setting reg_seq_enable = 0x0.				
zero_rot_enable	Do not reconfigure while the sensor is acquiring images. Disable image acquisition by setting reg_seq_enable = 0x0.				
subsampling	Enabling: No Disabling: Yes	Configurable	No	Yes	For global shutter mode: configurable with blank_subsampling_ss register. For rolling shutter mode: frame is always blanked out.
binning	No	Configurable	No	Yes	For global shutter mode: configurable with blank_subsampling_ss register For rolling shutter mode: frame is always blanked out.
Frame Timing					
rs_x_length	No	No	No	No	
black_lines	No	No	No	No	
dummy_lines	N/A	N/A	No	No	
Exposure Control					
mult_timer	No	No	N/A	N/A	Latency is 1 frame
fr_length	No	No	N/A	N/A	Latency is 1 frame
exposure	No	No	No	No	Latency is 1 frame
Gain					
mux_gainsw	No	No	No	No	Latency configurable by means of gain_lat_comp register
afe_gain	No	No	No	No	Latency configurable by means of gain_lat_comp register.
db_gain	No	No	No	No	Latency configurable by means of gain_lat_comp register.
Window/ROI					
roi_active	See Note	No	No	Configurable	For Global shutter mode: Windows containing lines previously not read out may lead to corrupted frames. For Rolling shutter mode: Frame blanking when blank_roi_switch is asserted (recommended).

Table 26. DYNAMIC SENSOR RECONFIGURATION AND FRAME BLANKING

Configuration	Global Shutter		Rolling Shutter		Notes
	Corrupted Frame	Blanked Out Frame	Corrupted Frame	Blanked Out Frame	
roi_configuration	See Note	No	Yes	No	Reconfiguring the windows by means of roi*_configuration* may lead to corrupted frames when configured close to frame boundaries. It is recommended to (re)configure an inactive window and switch the roi_active register. See Notes on roi_active.
Black Calibration					
black_samples	No	No	No	No	If configured within range of configured black lines
auto_blackal_enable	See Note	No	See Note	No	Manual correction factors become instantly active when auto_blackcal_enable is deasserted during operation.
blackcal_offset	See Note	No	See Note	No	Manual blackcal_offset updates are instantly active.
CRC Calculation					
crc_seed	No	No	No	No	Impacts the transmitted CRC
Sync Channel					
bl	No	No	No	No	Impacts the Sync channel information, not the Data channels.
img	No	No	No	No	Impacts the Sync channel information, not the Data channels.
crc	No	No	No	No	Impacts the Sync channel information, not the Data channels.
tr	No	No	No	No	Impacts the Sync channel information, not the Data channels.

Sensor Status

The currently used exposure and gain parameters are reported by the sensor in registers 208 to 214. These status registers are updated at the start of the frame in which these parameters become active.

Temperature Diode

The temperature diode allows the monitoring of the sensor die temperature during operation. The diode can be connected through the pins td_anode and td_cathode.

The die temperature (Tdie), as a function of the measured forward threshold voltage of the diode, with a known bias current (Vdiode at bias 40 μA), is determined according to the following formula:

T_{die} = (0.77–Vdiode at bias 40 μA)/0.00158°C

Monitor Pins

The sensor features three logic monitor output pins. These pins can provide internal state and synchronization information to the outside system. These status pins can be used during system setup or for system frame synchronization.

The pins are named monitor0, monitor1, and monitor2. The information provided on these pins is configured with the register monitor_select (register 192[13:11]).

NOTE: Monitor indications are generated in the sequencer. These signals lead the image and synchronization data on the LVDS channels.

Table 27. MONITOR SELECT

Monitor Select	Monitor Output	Description
0x0	monitor0: ‘0’	No information is provided on the output pins. All outputs are driven to logic ‘0’
	monitor1: ‘0’	
	monitor2: ‘0’	
0x1	monitor0: Integration time indication	High during integration
	monitor1: ROT indication	High when ROT is active, low outside ROT
	monitor2: Dummy line indication	High during dummy lines, low during all other lines
0x2	monitor0: Integration time indication	High during integration
	monitor1: N/A	N/A
	monitor2: N/A	N/A
0x3	monitor0: Start of X-readout	Pulse indicating the start of x-readout
	monitor1: Black line indication	High during black lines, low during all other lines
	monitor2: Dummy line indication	High during dummy lines, low during all other lines
0x4	monitor0: Frame start	Pulse indicating the start of a new frame
	monitor1: Start of ROT	Pulse indicating the start of ROT
	monitor2: Start of X-readout	Pulse indicating the start of x-readout
0x5	monitor0: First line indication	High during the first line of each frame, low for all others
	monitor1: Start of ROT indication	Pulse indicating the start of ROT
	monitor2: ROT inactive indication	Low during ROT, high outside ROT
0x6	monitor0: ROT indication	High when ROT is active, low outside ROT
	monitor1: Start of X-readout	Pulse indicating the start of X-readout
	monitor2: X-readout inactive indication	Low during X-readout, high outside X-readout
0x7	monitor0: Start of X-readout for black lines	Pulse indicating the start of X-readout for black lines
	monitor1: Start of X-readout for image lines	Pulse indicating the start of X-readout for image lines
	monitor2: Start of X-readout for dummy lines	Pulse indicating the start of X-readout for dummy lines

DATA OUTPUT FORMAT

LVDS Output Channels

The image data output occurs through 32 or 16 LVDS data channels, operating at 680 Mbps in 10-bit mode and 544 Mbps in 8-bit mode. A synchronization LVDS channel and an LVDS output clock signal synchronizes the data.

The data channels are used to output the image data only. The sync channel transmits information about data sent over these data channels (includes codes indicating black pixels, normal pixels, and CRC).

To perform word synchronization on the output data stream, a predefined training pattern is sent after startup of the sensor and during idle times (during FOT, ROT, and in between frames and lines). This data is used to perform word alignment on the receiving side.

To decrease the data bit rate at the outputs (and reduce the power consumption), the sensor can operate in 8-bit mode.

In 10-bit mode, the words on data and sync channels have a 10-bit length. The words are serialized most significant bit first. The output data rate is 680 Mbps max.

In 8-bit mode, the words on data and sync channels have an 8-bit length. The words are serialized most significant bit first. The output data rate is 544 Mbps max.

This decreases the data bit rate on the LVDS data channels. Power consumption is reduced by reconfiguring the internal bias currents. LVDS channels run at 272 MHz (DDR) in 8-bit mode.

Table 28. LVDS OUTPUT CHANNELS CONFIGURATION

Configuration			Description	Output Data Rate Channel [Mbps]	Number of data channels
MUX mode (pin F25)	ADC mode (pin H22)	8-bit_mode (register 129[13])			
0	0	0	10−bit mode	680	32
1	0	0	10−bit mode	680	16
0	1	1	8−bit mode	544	32
1	1	1	8−bit mode	544	16
X	0	1	Not supported	N/A	N/A
X	1	0	Not supported	N/A	N/A

The 8-bit mode is selected using the adc_mode pin. The datablock sync channel is configured accordingly (8-bit_mode configuration). In 8-bit mode, the eight most significant bits of the ADC data words are transmitted over the data channels.

Sync channel encoding is similar to the 10-bit mode. The two least significant bits of the (configured) sync codes are omitted and the window ID is transmitted after each frame synchronization word (the two LSBs are to be ignored).

NOTE: The 8-bit mode can only be used to reduce the data rate at the cost of image data resolution. Operating the sensor in 8-bit mode at a higher clock frequency to achieve higher frame rates is not supported.

LVDS Channel Multiplexing with the MUX Mode Pin

The MUX mode pin (F25) enables the reduction of the number of used data channels at the expense of maximum frame rate. When asserted, the sensor will multiplex down the 32 data channels to use only the 16 even-numbered data channels. The image data from even and odd channels will be interleaved on the even−numbered channels, while the synchronization channel will show two repeated synchronization codes. The unused data channels are powered down and will not send any data. Note that the sensor needs to be reset after change of multiplexing mode.

Serial Link Interface Operation

This sensor's serial link interface is based on a mesochronous clocking system. This means that all data and control links operate at the same frequency, but their phase may be different due to skew. The host provides an LVDS clock as input to the sensor. To compensate for possible large on-chip delays, the sensor retransmits this clock with the same delay as that seen by the data channels and synchronization channel. The receiver end (generally an FPGA-based system) performs per-interface skew compensation.

The data on high-speed serial links can drift due to various reasons such as skew, jitter, PCB trace delays, process, voltage, and temperature variations. The receiver performs per-LVDS interface skew compensation using bit and word alignment techniques.

To support per-interface skew compensation, the sensor provides a training mode that allows the system to perform bit and word alignment on all interfaces.

During idle moments (when the sensor is not capturing images or during frame and line overhead), the image sensor transmits training patterns. These patterns are configurable by means of a register upload and should be chosen such that these can easily be detected by reducing the risk of mimicking in the regular data stream.

Bit Alignment

Bit alignment procedures position the sampling edge of the clock at the center of the data eye window by adding delay to the data path (using delay taps).

Word Alignment

Word alignment procedures ensure that the reconstructed parallel data bits are in correct order at the output of the deserializer. Word alignment is done by looking for well known training patterns.

All major FPGA vendors provide bit and word alignment methods for their FPGAs. Refer to the FPGA vendor's application for more information on the use of these functionalities.

When the host succeeds in a lock for bit and word alignment procedures, the system enables the sensor for image acquisition. Specific frame alignment patterns are transmitted for image frame synchronization purposes.

Frame Format

The frame format is explained by example of the readout of two (overlapping) windows, as shown in Figure 28 (a).

The readout of a frame occurs on a line-by-line basis. In this representation, the read pointer goes from left to right, bottom to top.

Figure 28 indicates that, after the FOT is complete, a number of lines which only include information of 'ROI 0' are sent out, starting at position y0_start. When the line at position y1_start is reached, a number of lines containing data of 'ROI 0' and 'ROI 1' are sent out, until the line position of y0_end is reached. From there on, only data of 'ROI 1' appears on the data output channels until line position y1_end is reached.

NOTE: Only frame start and frame end sync words are indicated in (b). CRC codes are also omitted from Figure 28.

During readout of image data over the data channels, the sync channel sends out frame synchronization codes, which provide information related to the image data being sent over the data channels.

Each line of a window starts with a line start (LS) indication and ends with a line end (LE) indication. The line start of the first line is replaced by a frame start; the line end of the last line is replaced with a frame end indication. Each such frame synchronization code is followed by a window ID (range 0 to 31).

The data channels contain valid pixel data during FS/FE/LS/LE and window ID synchronization codes.

NOTE: For overlapping windows, the line synchronization codes of the overlapping windows with lower IDs are not sent out. As shown in the illustration, no LE is transmitted for the overlapping part of window 0.

Black lines are read out at the start of a frame. These lines are enclosed by LS and LE indications (no frame start/end). The window ID for the black lines must be ignored.

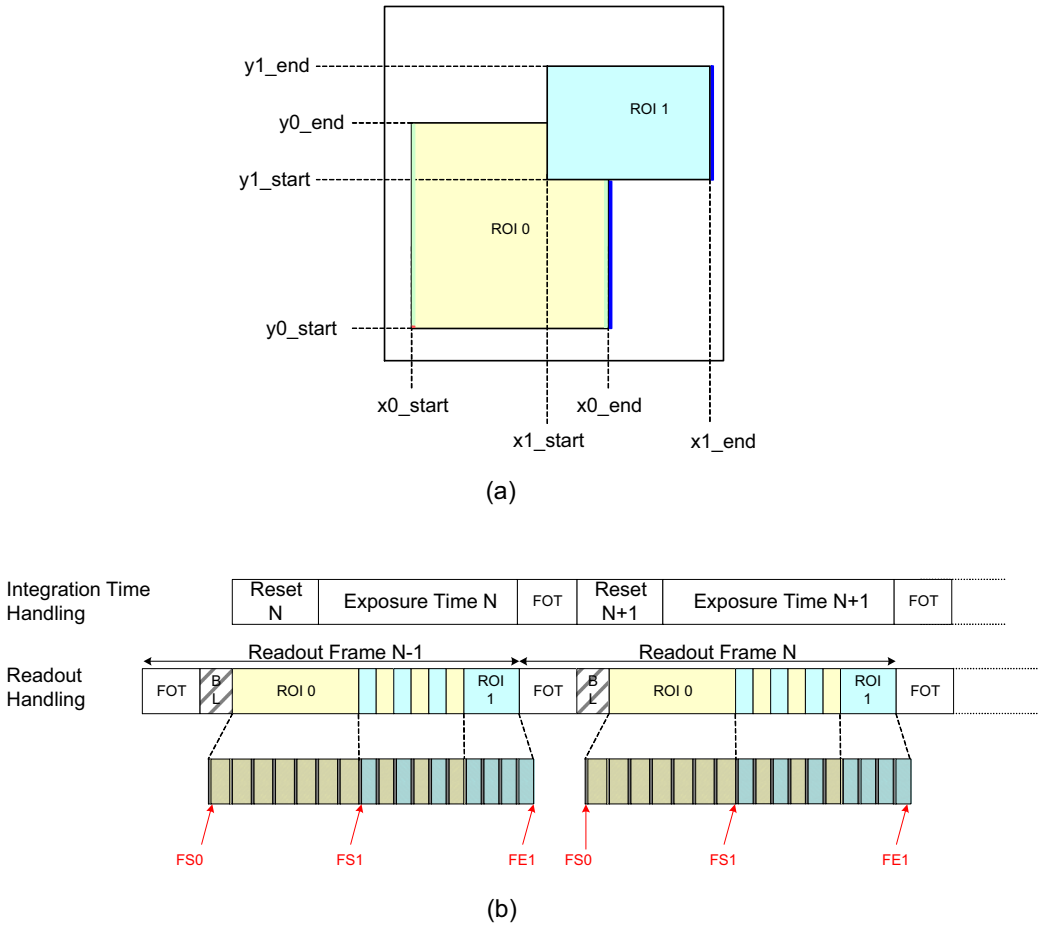


Figure 28. Frame Sync Codes

Figure 29 and Figure 30 show the details of the readout of a number of lines for single window readout, at the beginning of the frame.

Figure 31 shows the details of the readout of a number of lines for two overlapping windows.

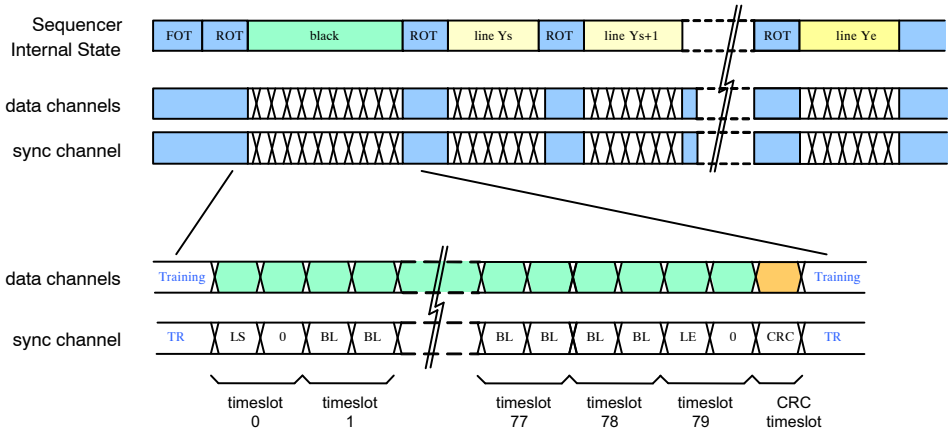


Figure 29. Timeline Showing Readout of Black Line for Global Shutter

NOTE: For rolling shutter, the number of black pixels on one line is reduced to the selected window's length. The sequence shown is repeated if more than one black line is generated.

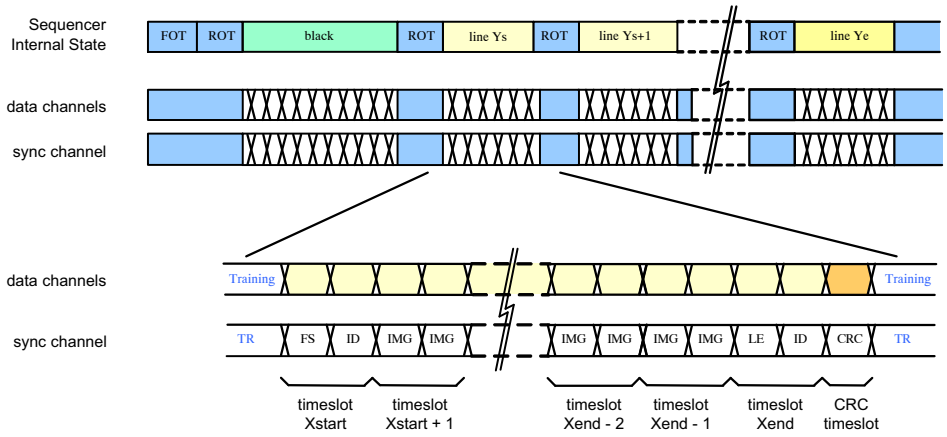


Figure 30. Timeline for Single Window Readout

NOTE: In the figure, the second image line is shown in more detail. The LS code is replaced by FS for the first line and the LE code is replaced by FE for the last line in the window.

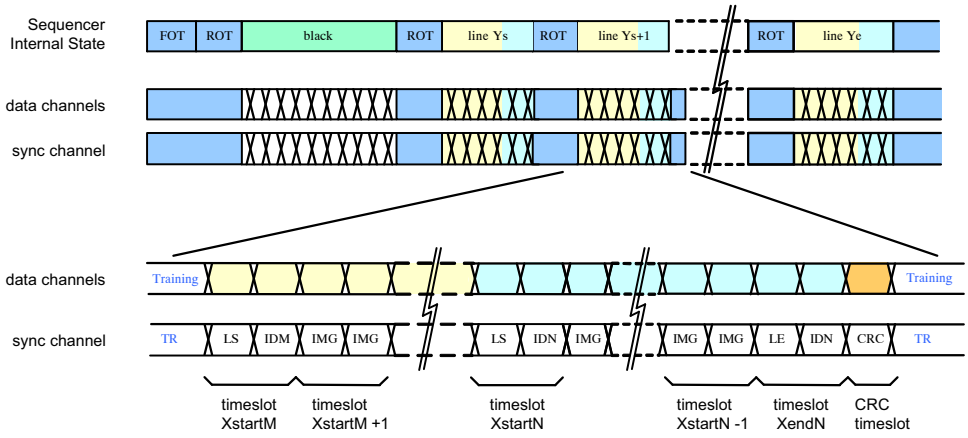


Figure 31. Timeline Showing Readout of Two Overlapping Windows

Frame Format in 8−bit Mode

The frame format is identical to the 10-bit mode. Sync and data word depth is reduced to eight bits. Synchronization Words

Frame Synchronization for 10-Bit Mode

Table 29 shows the structure of the frame synchronization code. Note that the table shows the default data word (configurable) for 10-bit mode. If more than one window is active at the same time, the sync channel transmits the frame synchronization codes of the window with highest index only.

Table 29. FRAME SYNCHRONIZATION CODE DETAILS FOR 10-BIT MODE

Sync Word Bit Position	Register Address	Default Value	Description
9:7	N/A	0x5	Frame start indication
9:7	N/A	0x6	Frame end indication
9:7	N/A	0x1	Line start indication
9:7	N/A	0x2	Line end indication
6:0	131[6:0]	0x2A	These bits indicate that the received sync word is a frame synchronization code. The value is programmable by a register setting

Window Identification

Frame synchronization codes are always followed by a 5-bit window identification (bits 4:0). This is an integer number, ranging from 0 to 31, indicating the active window. If more than one window is active for the current cycle, the highest window ID is transmitted.

Data Classification Codes

For the remaining cycles, the sync channel indicates the type of data sent through the data links: black pixel data (BL), image data (IMG), or training pattern (TR). These codes are programmable by a register setting. The default values are listed in Table 30.

Table 30. SYNCHRONIZATION CHANNEL DEFAULT IDENTIFICATION CODE VALUES FOR 10-BIT MODE

Sync Word Bit Position	Register Address	Default Value	Description
9:0	132 [9:0]	0x015	Black pixel data (BL). This data is not part of the image. The black pixel data is used internally to correct channel offsets.
9:0	133 [9:0]	0x035	Valid pixel data (IMG). The data on the data output channels is valid pixel data (part of the image).
9:0	134 [9:0]	0x059	CRC value. The data on the data output channels is the CRC code of the finished image data line.
9:0	135 [9:0]	0x3A6	Training pattern (TR). The sync channel sends out the training pattern which can be programmed by a register setting.

Frame Synchronization in 8-bit Mode

The frame synchronization words are configured using the same registers as in 10-bit mode. The two least significant bits of these configuration registers are ignored and not sent out. Table 31 shows the structure of the frame synchronization code, together with the default value, as specified in SPI registers. The same restriction for overlapping windows applies in 8-bit mode.

Table 31. FRAME SYNCHRONIZATION CODE DETAILS FOR 8-BIT MODE

Sync Word Bit Position	Register Address	Default Value	Description
7:5	N/A	0x5	Frame start (FS) indication
7:5	N/A	0x6	Frame end (FE) indication
7:5	N/A	0x1	Line start (LS) indication
7:5	N/A	0x2	Line end (LE) indication
4:0	[6:2]	0x0A	These bits indicate that the received sync word is a frame synchronization code. The value is programmable by a register setting.

Window Identification

Similar to 10-bit operation mode, the frame synchronization codes are followed by a window identification. The window ID is located in bits 6:2 (all other bit positions are ‘0’). The same restriction for overlapping windows applies in 8-bit mode.

Data Classification Codes

BL, IMG, CRC, and TR codes are defined by the same registers as in 10-bit mode. Bits 9:2 of the respective configuration registers are used as classification code. The default values are listed in Table 32.

Table 32. SYNCHRONIZATION CHANNEL DEFAULT IDENTIFICATION CODE VALUES FOR 8-BIT MODE

Sync Word Bit Position	Register Address	Default Value	Description
7:0	132 [9:2]	0x05	Black pixel data (BL). This data is not part of the image. The black pixel data is used internally to correct channel offsets.
7:0	133 [9:2]	0x0D	Valid pixel data (IMG). The data on the data output channels is valid pixel data (part of the image).
7:0	134 [9:2]	0x16	CRC value. The data on the data output channels is the CRC code of the finished image data line.
7:0	135 [9:2]	0xE9	Training Pattern (TR). The sync channel sends out the training pattern which can be programmed by a register setting.

Training Patterns on Data Channels

In 10-bit mode, during idle periods, the data channels transmit training patterns, indicated on the sync channel by a TR code. These training patterns are configurable independent of the training code on the sync channel as shown in Table 33. In 8-bit mode, the training pattern for the data channels is defined by the same register as in 8-bit mode, where the lower two bits are omitted; see Table 34.

Table 33. TRAINING CODE ON SYNC CHANNEL IN 10-BIT MODE

Sync Word Bit Position	Register Address	Default Value	Description
[9:0]	130 [9:0]	0x3A6	Data channel training pattern. The data output channels send out the training pattern, which can be programmed by a register setting. The default value of the training pattern is 0x3A6, which is identical to the training pattern indication code on the sync channel.

Table 34. TRAINING PATTERN ON DATA CHANNEL IN 8-BIT MODE

Data Word Bit Position	Register Address	Default Value	Description
[7:0]	130 [9:2]	0xE9	Data Channel Training Pattern (Training pattern).

Cyclic Redundancy Code

At the end of each line, a CRC code is calculated to allow error detection at the receiving end. Each data channel transmits a CRC code to protect the data words sent during the previous cycles. Idle and training patterns are not included in the calculation.

The sync channel is not protected. A special character (CRC indication) is transmitted whenever the data channels send their respective CRC code.

The polynomial in 10-bit operation mode is $x^{10}+x^9+x^6+x^3+x^2+x+1$. The CRC encoder is seeded at the start of a new line and updated for every (valid) data word received. The CRC seed is configurable usign the crc_seed register. When ‘0’, the CRC is seeded by all-‘0’; when ‘1’ it is seeded with all-‘1’.

In 8-bit mode, the plynomial is $x^8+x^6+x^3+x^2+1$. The CRC seed is configured by means of the crc_seed register.

NOTE: Note The CRC is calculated for every line. This implies that the CRC code can protect lines from multiple windows.

Black Reference

The sensor reads out one or more black lines at the start of every new frame. The number of black lines to be generated is programmable and is at a minimum, equal to 1. The length of the black lines depends on the operation mode. For rolling shutter mode, it is equal to the line length configured in the active window. For global shutter mode, the sensor always reads out the entire line (80 kernels), independent of window configurations.

The black references are used to perform black calibration and offset compensation in the data channels. The raw black pixel data is transmitted over the usual LVDS channels, while the regular image data is compensated (can be bypassed).

On the output interface, black lines can be seen as a separate window, without frame start and ends (only line start and ends). The window ID is to be ignored and data is indicated by a BL code. In 8-bit mode, the configuration of the black level calibration block automatically scales to 8-bit mode. No reconfiguration is required.

Example Using Multiple Windowing

Figure 32 shows an example of the synchronization codes sent when reading out multiple windows.

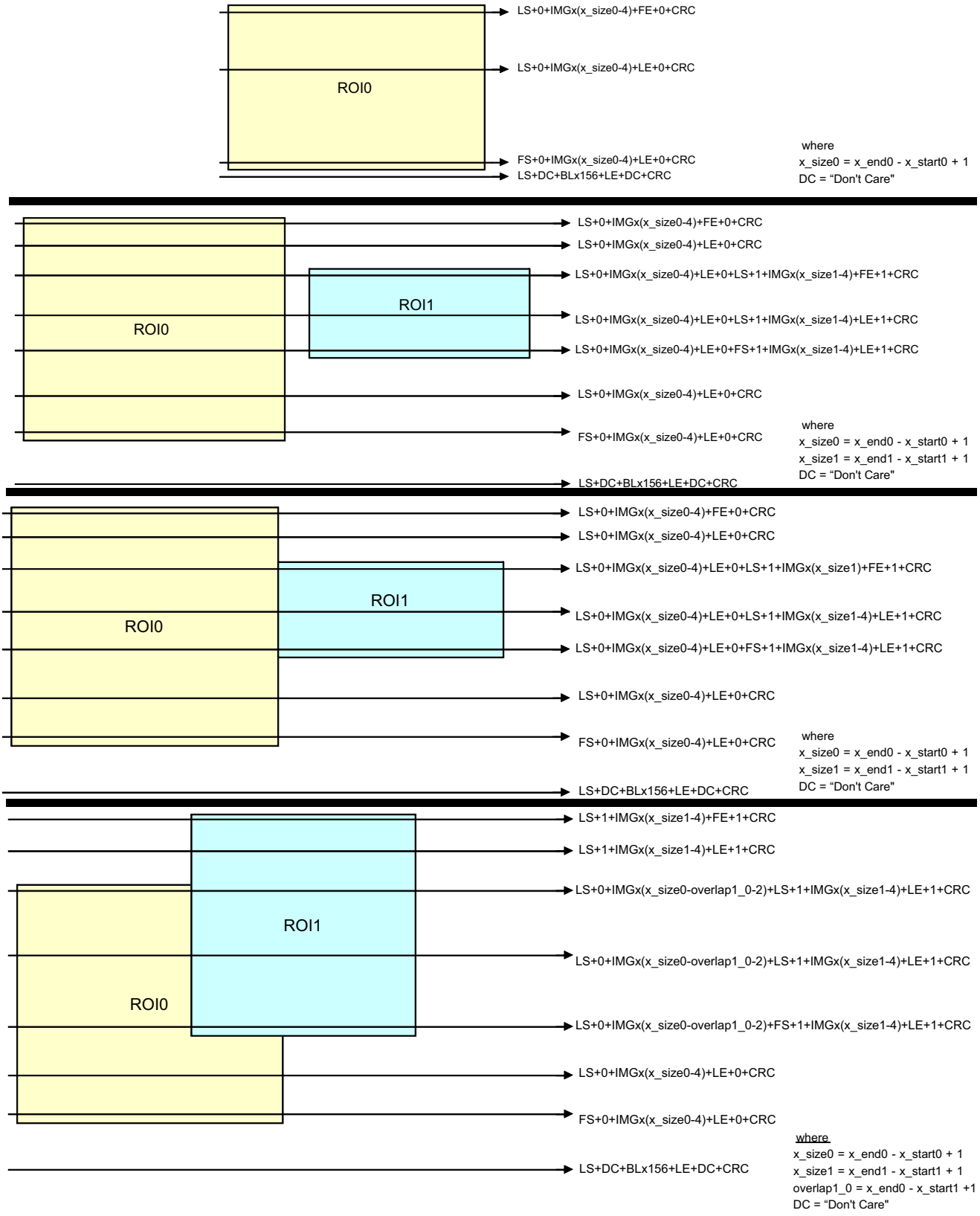


Figure 32. Synchronization Codes for Multiple Windows (applicable for Global Shutter only)

Data Order

To read out the image data through the output channels, the pixel array is organized in kernels. The kernel size is 64 pixels in x-direction by one pixel in y-direction.

The data order in 8-bit mode is identical to the 10-bit mode. Figure 33 indicates how the kernels are organized. The data order of this image data on the data output channels depends on the subsampling mode.

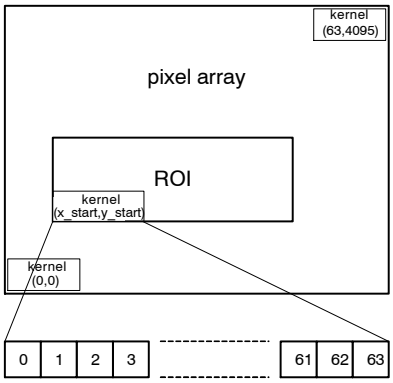


Figure 33. Kernel Organization in Pixel Array

- P1−SE/SN: Subsampling Disabled
  - ♦ 32 LVDS Output Channels

The image data is read out in kernels of 64 pixels in x-direction by one pixel in y-direction. One data channel output delivers two pixel values of one kernel sequentially.

Figure 34 shows how a kernel is read out over the 32 output channels. For even positioned kernels, the kernels are read out ascending, and for odd positioned kernels the data order is reversed (descending).

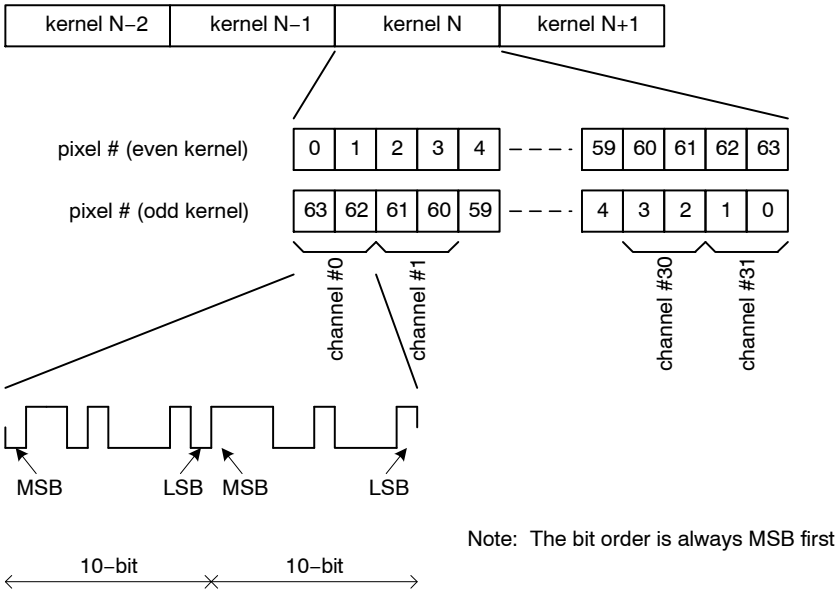


Figure 34. 32 LVDS Data Output Order when Subsampling is Disabled

  - ♦ 16 LVDS Output Channels

Figure 35 shows how a kernel is read out over the 16 output channels. Each pair of adjacent channels is multiplexed into one channel. For even positioned kernels, the kernels are read out ascending but in pair of even and odd pixels, while for odd positioned kernles the data order is reversed (descending) but in pair of even and odd pixels.

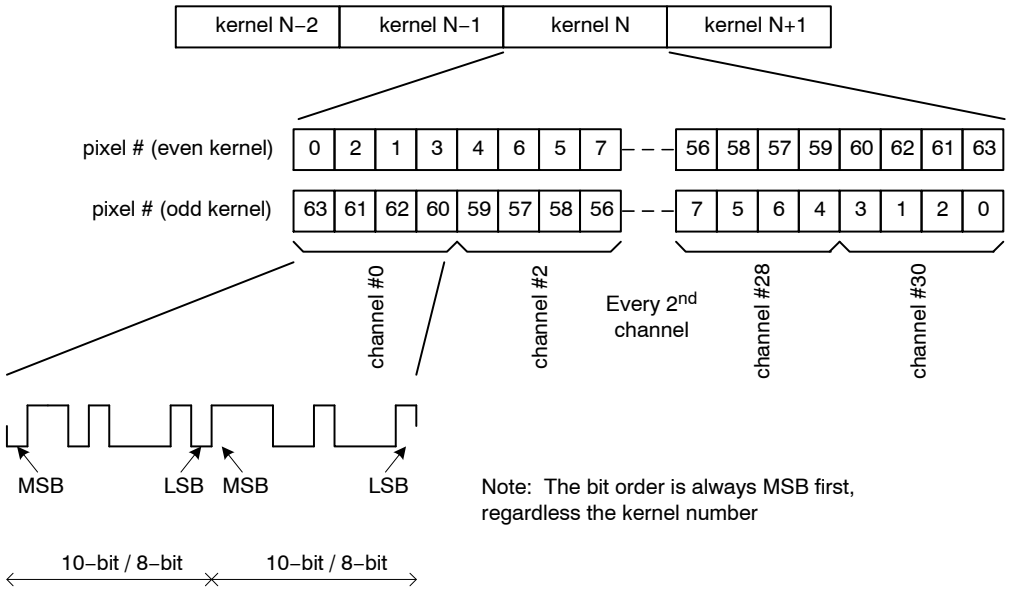


Figure 35. Data Output Order for 16 LVDS Outputs when Subsampling is Disabled

- Subsampling on Monochrome Sensors

During subsampling, every other pixel is read out and the lines are read in a read-1-skip-1 manner. To read out the image data with subsampling enabled, two neighboring kernels are combined to a single kernel of 128 pixels in the x-direction and one pixel in the y-direction.

Note that there is no difference in data order for even and odd kernel numbers. This is opposed to the ‘no-subsampling’ readout described earlier.

♦ 32 LVDS Output Channels

Figure 36 shows the data order for 32 LVDS output channels.

Note that there is no difference in data order for even/odd kernel numbers, as opposed to the ‘no−subsampling’ readout described in section 0.

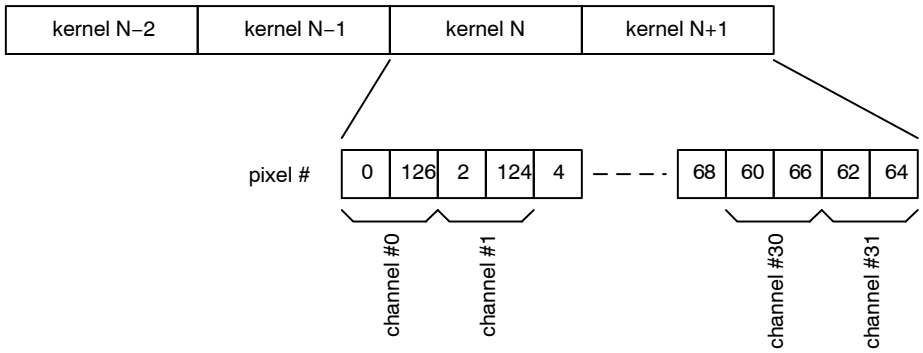


Figure 36. Data Output Order for 32 LVDS Output Channels in Subsampling Mode on a Monochrome Sensor

♦ 16 LVDS Output Channels

Figure 37 shows the data order for 16 LVDS output channels.

Note that there is no difference in data order for even/odd kernel numbers, as opposed to the ‘no−subsampling’ readout described in section 0.

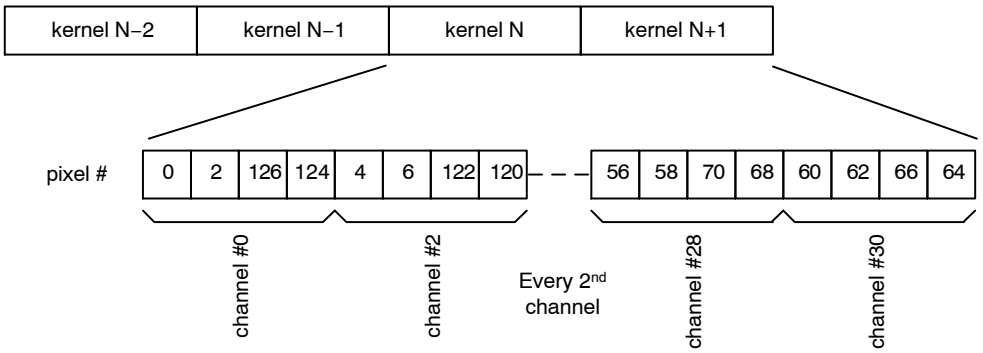


Figure 37. Data Output Order for 16 LVDS Output Channels in Subsampling Mode on a Monochrome Sensor

- Binning Mode

The output order in binning mode is identical to the subsampled mode.

- Subsampling on Color Sensor

To read out the image data with subsampling enabled on a color sensor, two neighboring kernels are combined to a single kernel of 128 pixels in the x-direction and 1 pixel in the y-direction. Only the pixels 0, 1, 4, 5, 8, 9, 12, 13 to 124, and 125 are read out. There is no difference in data order for even/odd kernel numbers, as opposed to the ‘no-subsampling’ readout described in section.

♦ 32 LVDS Output Channels

Figure 38 shows the data order for 32 LVDS output channels.

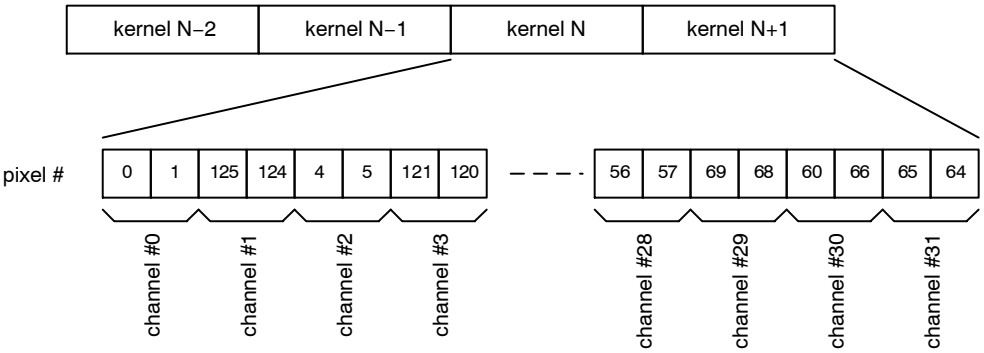


Figure 38. Data Output Order for 32 LVDS Output Channels in Subsampling Mode on a Color Sensor

♦ 16 LVDS Output Channels

Figure 39 shows the data order for 16 LVDS output channels.

Note that there is no difference in data order for even/odd kernel numbers, as opposed to the ‘no−subsampling’ readout described in section 0.

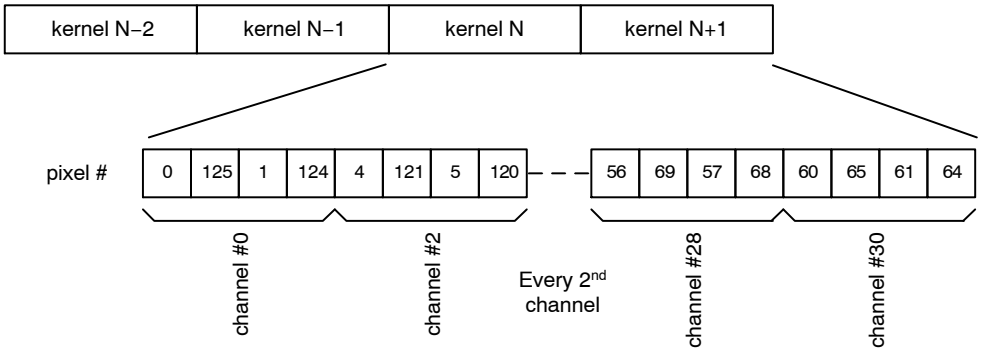


Figure 39. Data Output Order for 16 LVDS Output Channels in Subsampling Mode on a Color Sensor

Frame Rate

Frame rate for subsampling and binning mode is compared to the normal mode. Assume the y-resolution is the programmed number of lines to read out.

Normal Readout

The frame time in normal readout mode is shown by the following formula:

Frame Time = t_{FOT} + (y-resolution) x (t_{ROT} + $t_{readout}$)

The frame rate is equal to 1/FrameTime. Nominal frame rate for full frame readout is 80 fps.

Subsampling Mode

The frame time for subsampled readout is shown by the following formula:

Frame Time = t_{FOT} + (y-resolution / 2) x (t_{ROT} + $t_{readout}$ / 2),

where t_{ROT} represents the equivalent ROT time for a normal readout of the same frame. Analogous readout represents the equivalent readout time for normal readout.

Binning Mode

The frame time for subsampled readout is given by the following formula:

Frame Time = t_{FOT} + (y-resolution / 2) x (t_{ROT} x 2+ $t_{readout}$ / 2),

where t_{ROT} represents the equivalent ROT time for a normal readout of the same frame. Analogous readout represents the equivalent readout time for normal readout.

Test Pattern Generation

The data block provides several test pattern generation capabilities. Figure 40 shows the functional diagram for the data channels. It is possible to inject synthesized test patterns at various points. Refer to the Register Map on page 45 for the test mode configuration registers (registers 144 to 150).

In 8-bit mode, test patterns are generated as in 10-bit mode, however the two least significant bits of the resulting data are not transmitted.

The test pattern modes are summarized in Table 35. Note that these modes only exist for the data channel. The sync and clock channels do not provide this functionality.

For each test mode, the user can select whether the generated data is framed. When the register frame_testpattern is asserted, the test data simply replaces the ADC data. This means that the test data is only sent between frame/line start and frame/line end indications. Outside these windows, regular training patterns are sent, as during normal operation. CRC is calculated and inserted as for normal data for the fixed and incrementing test pattern generation.

Table 35. TEST MODE SUMMARY

Register Configuration			Description
prbs_en	testpattern_en	testpattern	
0	0	X	Normal operation mode
0	1	0	Fixed pattern generation. Pattern is defined by testpattern register
0	1	1	Incrementing pattern generation. Initial value is determined by *testpattern*.
1	X	X	PRBS data generation. The testpattern register determines the seed for the PRBS generator.

When *frame_testpattern* is deasserted, the output is constantly replaced by the generated test data. No training patterns are generated.

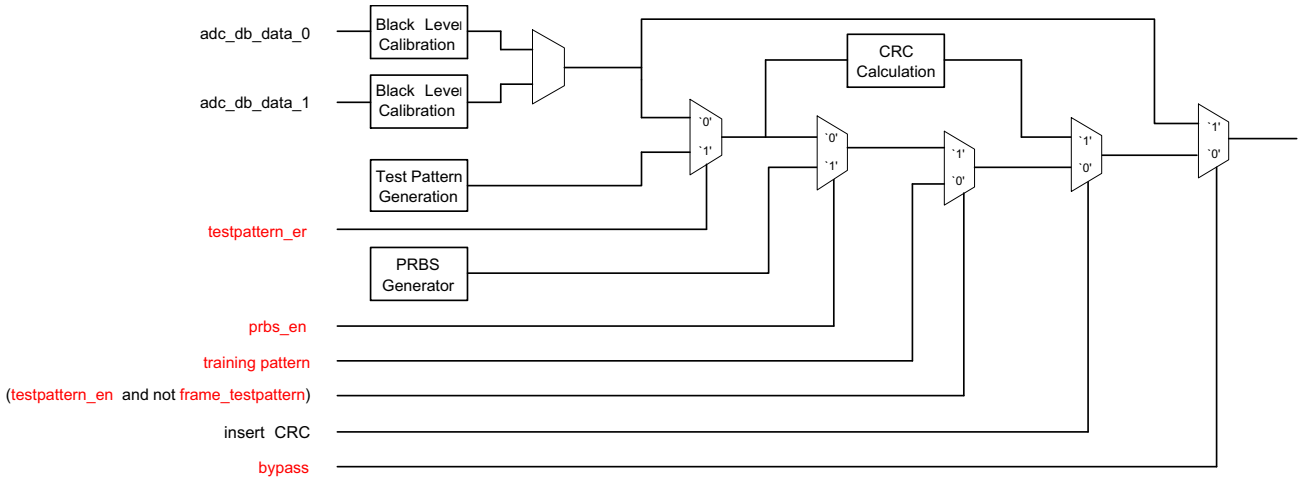


Figure 40. Functional Block Diagrams for the Data Channels

NOTE: In the figure, register configurations are indicated in red.

The sync channel continues to send regular frame timing information when the sequencer is enabled (independently of the test pattern configurations).

The synthesized test patterns are injected directly into the data channels. Therefore, no data demultiplexing is required at the receiving end (as opposed to regular image data capture).

Fixed Pattern

A configured word can be continuously repeated on the output. This word is configurable for each data channel separately (testpattern). The testpattern is inserted when testpattern_en is asserted.

Incrementing Test Pattern

In each cycle, the test pattern word is incremented by one, when inc_testpattern is asserted. After reaching the maximum value, the incrementer is reset to its start value (testpattern). When the testdata is framed, the incrementer is also reset to the testpattern value at each line start.

To enable this mode, enable the digital testpattern mode (assert testpattern_en) and assert inc_testpattern.

Pseudo Random Bit Sequence Generation

In this test mode, the output channels are sourced with pseudo random bit sequence (PRBS) pattern. The PRBS seed can be configured for each data channel using the testpattern register. For the other test pattern generation mode, the datastream is not interrupted when frame_testpattern is deasserted.

NOTES:

- The CRC generator is not functional in this mode, and no real CRC can be calculated. Instead, the CRC slot is used to send one more PRBS word.
- A PRBS generator does not generate random data when the seed is all zero. Therefore, it is advisable to configure the testpattern registers to a value different from ‘0’. Using different seeds for each channel results in different sequences for each data channel.

E−grey and E−black Settings for Automatically Provided Correction Data

The uploads in Table 36 and Table 37 may be used to generate e−grey and e−black images for collecting image data to be used in correction algorithms without obscuring or illuminating the sensor.

Table 36. UPLOADS FOR E−BLACK IMAGE

Register	Value
219	0x3E3E
220	0x6767

Table 37. UPLOADS FOR E−GREY IMAGE

Register	Value
219	0x3E2D
220	0x674F
429	0x0100
430	0x0BF1
431	0x0BC3
432	0x0BC2
435	0x2143
436	0x2142
463	0x0100
464	0x0FE4
465	0x0BC2
472	0x0B46
475	0x2143
476	0x2142

REGISTER MAP

Each functional entity has a dedicated address space, starting at a block offset. The register address is obtained by adding the address offset to the block offset. This address must be used to perform SPI uploads and is shown in the Address column of the register map table.

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
Chip ID [Block Offset: 0]							
0	0		chip_id	0x56FA	22266		RO
		[15:0]	id	0x56FA	22266	ON Semiconductor Chip ID	
1	1		revision	0x0002	2		RO
		[3:0]	rev	0x2	2	Chip Revision Numbering	
2	2		chip_configuration	0x0000	0		RW
		[0]	color	0x0	0	Configure according to part number: Mono: 0x0 Color: 0x1	
Clock Generator [Block Offset: 32]							
0	32		config	0x0004	4		RW
		[0]	enable	0x0	0	Enable analogue clocks ‘0’ = disabled, ‘1’ = enabled	
		[14:1]	reserved	0x0002	2	Reserved	
General Logic [Block Offset: 34]							
0	34		config	0x0000	0		RW
		[0]	enable	0x0	0	Logic General Enable Configuration ‘0’ = Disable ‘1’ = Enable	
Image Core [Block Offset: 40]							
0	40		image_core_config	0x0000	0		RW
		[0]	reserved	0x0	0	Reserved	
		[1]	mux_pwd_n	0x0	0	Column Multiplexer Power Down ‘0’ = powered down, ‘1’ = powered up	
		[2]	reserved	0x0	0	Reserved	
1	41		image_core_config	0x0B5A	2906		RW
		[12:0]	reserved	0xB5A	2906	Reserved	
		[13]	testpattern	0x0	0	Testpattern generation in the columns	
		[14]	injectlevel	0x0	0	Inject level for testpattern generation	
		[15]	reserved	0x0	0	Reserved	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
AFE [Block Offset: 48]							
0	48		power_down	0x0000	0		RW
		[0]	pwd_n	0x0	0	Power down for AFE's (64 columns) '0' = powered down, '1' = powered up	
Bias Generator [Block Offset: 64]							
0	64		power_down	0x0000	0		RW
		[0]	pwd_n	0x0	0	Power down bandgap '0' = powered down, '1' = powered up	
1	65		configuration	0x888B	34955		RW
		[0]	extres	0x1	1	External Resistor Selection '0' = internal resistor, '1' = external resistor	
		[3:1]	bgrtrim	0x5	5	Bandgap Trim	
		[7:4]	imc_colpc_ibias	0x8	8	Column Precharge ibias Configuration	
		[11:8]	imc_colbias_ibias	0x8	8	Column Bias ibias Configuration	
		[15:12]	reserved	0x8	8	Reserved	
2	66		afe_bias	0x53C8	21448		RW
		[3:0]	afe_ibias	0x8	8	AFE ibias Configuration	
		[7:4]	afe_adc_iref	0xC	12	ADC iref Configuration	
		[14:8]	afe_pga_iref	0x53	83	PGA iref Configuration	
3	67		mux_bias	0x8888	34952		RW
		[3:0]	mux_25u_stage1	0x8	8	Column Multiplexer Stage 1 Bias Configuration	
		[7:4]	mux_25u_stage2	0x8	8	Column Multiplexer Stage 2 Bias Configuration	
		[11:8]	mux_25u_delay	0x8	8	Column Multiplexer Delay Bias Configuration	
		[15:12]	mux_25u_vcmbuff	0x8	8	Column Multiplexer Vcm Bias Configuration	
4	68		lvds_bias	0x0088	136		RW
		[3:0]	lvds_ibias	0x8	8	LVDS Ibias	
		[7:4]	lvds_iref	0x8	8	LVDS Iref	
6	70		reserved	0x8888	34952		RW
		[15:0]	reserved	0x8888	34952	Reserved	
Test [Block Offset: 80]							
0	80		reserved	0x0000	0		RW
		[9:0]	reserved	0x0	0	Reserved	
1	81		reserved	0x0000	0		RW
		[15:0]	reserved	0x0000	0	Reserved	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
16	96		reserved	0x0000	0		RW
		[5:0]	reserved	0x0	0	Reserved	
17	97		reserved	0x0000	0		RO
		[7:0]	reserved	0x00	0	Reserved	
Ser/lvds/io [Block Offset: 112]							
0	112		power_down	0x0000	0		RW
		[0]	clock_out_pwd_n	0x0	0	Power down for Clock Output. '0' =powered down, '1' = powered up	
		[1]	sync_pwd_n	0x0	0	Power down for Sync channel '0' = powered down, '1' = powered up	
		[2]	data_pwd_n	0x0	0	Power down for data channels (4 channels) '0' = powered down, '1' = powered up	
Data Block [Block Offset: 128]							
0	128		blackcal	0x4008	16392		RW
		[7:0]	black_offset	0x08	8	Desired black level at output	
		[10:8]	black_samples	0x0	0	Black pixels taken into account for black calibration. Total samples = 2**black_samples	
		[14:11]	reserved	0x8	8	Reserved	
		[15]	crc_seed	0x0	0	CRC Seed '0' = All-0 '1' = All-1	
1	129		general_configuration	0xC001	49153		RW
		[0]	auto_blackcal_enable	0x1	1	Automatic blackcalibration is enabled when 1, bypassed when 0	
		[9:1]	blackcal_offset	0x00	0	Black Calibration offset used when auto_black_cal_en = '0'.	
		[10]	blackcal_offset_dec	0x0	0	blackcal_offset is added when 0, subtracted when 1	
		[11]	reserved	0x0	0	Reserved	
		[12]	reserved	0x0	0	Reserved	
		[13]	8bit_mode	0x0	0	Shifts window ID indications by 4 cycles. '0' = 10-bit mode, '1' = 8-bit mode	
		[15:14]	reserved	0x3	3	Reserved	
2	130		trainingpattern	0x03A6	934		RW
		[9:0]	trainingpattern	0x3A6	934	Training pattern sent on Data channels during idle mode. This data is used to perform word alignment on the LVDS data channels.	
		[10]	reserved	0x0	0	Reserved	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
3	131		sync_code0	0x002A	42		RW
		[6:0]	frame_sync	0x02A	42	Frame Sync LSBs Note: The three MSBs of the resulting 10-bit Frame sync word is not configurable. The tenth bit indicates frame/line sync code, ninth bit indicates start, eighth bit indicates end.	
4	132		sync_code1	0x0015	21		RW
		[9:0]	bl	0x015	21	Black Pixel Identification Sync Code	
5	133		sync_code2	0x0035	53		RW
		[9:0]	img	0x035	53	Valid Pixel Identification Sync Code	
6	134		sync_code3	0x0059	89		RW
		[9:0]	crc	0x059	89	CRC Value Identification Sync Code	
7	135		sync_code4	0x03A6	934		RW
		[9:0]	tr	0x3A6	934	Training Value Identification Sync Code	
8	136		blackcal_error0	0x0000	0		RO
		[15:0]	blackcal_error[15:0]	0x0000	0	Black Calibration Error. This flag is set when not enough black samples are availlable. Black Calibration shall not be valid. Channels 0-15	
9	137		blackcal_error1	0x0000	0		RO
		[15:0]	blackcal_error[31:16]	0x0000	0	Black Calibration Error. This flag is set when not enough black samples are availlable. Black Calibration shall not be valid. Channels 16-31	
10	138		blackcal_error2	0x0000	0		RO
		[15:0]	blackcal_error[47:32]	0x0000	0	Black Calibration Error. This flag is set when not enough black samples are availlable. Black Calibration shall not be valid. Channels 32-47	
11	139		blackcal_error3	0x0000	0		RO
		[15:0]	blackcal_error[63:48]	0x0000	0	Black Calibration Error. This flag is set when not enough black samples are availlable. Black Calibration shall not be valid. Channels 48-63	
12	140		reserved	0x0000	0		RW
		[15:0]	reserved	0x0000	0	Reserved	
13	141		reserved	0xFFFF	65535		RW
		[15:0]	reserved	0xFFFF	65535	Reserved	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
(Datablock - Test)							
16	144		test_configuration	0x0000	0		RW
		[0]	testpattern_en	0x0	0	Insert synthesized testpattern when ‘1’, normal operation when ‘0’.	
		[1]	inc_testpattern	0x0	0	Incrementing testpattern when ‘1’, constant testpattern when ‘0’	
		[2]	prbs_en	0x0	0	Incrementing tstpattern when ‘1’. constant testpattern when ‘0’. Lower bound is defined by testpattern*, upper bound is 1023. After reaching 1023, the counter is reloaded with configured start data.	
		[3]	frame_testpattern	0x0	0	Frame test patterns when ’1’, unframed testpatterns when ’0’	
		[4]	reserved	0x0	0	Reserved	
17	145		reserved	0x0000	0		RW
		[15:0]	reserved		0	Reserved	
18	146		test_configuration0	0x0100	256		RW
		[7:0]	testpattern0_lsb	0x00	0	Testpattern (LSBs) used on datapath #0, #8, #16, #24 when testpattern_en = ‘1’. Note: Most significant bits are configured in register 150.	
		[15:8]	testpattern1_lsb	0x01	1	Testpattern (LSBs) used on datapath #1, #9, #17, # 25 when testpattern_en = ‘1’. Note: Most significant bits are configured in register 150.	
19	147		test_configuration1	0x0302	770		RW
		[7:0]	testpattern2_lsb	0x02	2	Testpattern (LSBs) used on datapath #2, #10, #18, #26 when testpattern_en = ‘1’. Note: Most significant bits are configured in register 150.	
		[15:8]	testpattern3_lsb	0x03	3	Testpattern (LSBs) used on datapath #3, #11, #19, #27 when testpattern_en = ‘1’. Note: Most significant bits are configured in register 150.	
20	148		test_configuration2	0x0504	1284		RW
		[7:0]	testpattern4_lsb	0x04	4	Testpattern (LSBs) used on datapath #4, #12, #20, #28 when testpattern_en = ‘1’. Note: Most significant bits are configured in register 150.	
		[15:8]	testpattern5_lsb	0x05	5	Testpattern (LSBs) used on datapath #5, #13, #21, #29 when testpattern_en = ‘1’. Note: Most significant bits are configured in register 150.	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
21	149		test_configuration3	0x0706	1798		RW
		[7:0]	testpattern6_lsb	0x06	6	Testpattern (LSBs) used on datapath #6, #14, #22, #30 when testpattern_en = '1'. Note: Most significant bits are configured in register 150.	
		[15:8]	testpattern7_lsb	0x07	7	Testpattern (LSBs) used on datapath #7, #15, #23, #31 when testpattern_en = '1'. Note: Most significant bits are configured in register 150.	
22	150		test_configuration16	0x0000	0		RW
		[1:0]	testpattern0_msb	0x0	0	Testpattern (LSBs) used on datapath #0, #8, #16, #24 when testpattern_en = '1'. Note: Least significant bits are configured in register 146.	
		[3:2]	testpattern1_msb	0x0	0	Testpattern (MSBs) used on datapath #1, #9, #17, # 25 when testpattern_en = '1'. Note: Least significant bits are configured in register 146.	
		[5:4]	testpattern2_msb	0x0	0	Testpattern (MSBs) used on datapath #2, #10, #18, #26 when testpattern_en = '1'. Note: Least significant bits are configured in register 147.	
		[7:6]	testpattern3_msb	0x0	0	Testpattern (MSBs) used on datapath #3, #11, #19, #27 when testpattern_en = '1'. Note: Least significant bits are configured in register 147.	
		[9:8]	testpattern4_msb	0x0	0	Testpattern (MSBs) used on datapath #4, #12, #20, #28 when testpattern_en = '1'. Note: Least significant bits are configured in register 148.	
		[11:10]	testpattern5_msb	0x0	0	Testpattern (MSBs) used on datapath #5, #13, #21, #29 when testpattern_en = '1'. Note: Least significant bits are configured in register 148.	
		[13:12]	testpattern6_msb	0x0	0	Testpattern (MSBs) used on datapath #6, #14, #22, #30 when testpattern_en = '1'. Note: Least significant bits are configured in register 149.	
		[15:14]	testpattern7_msb	0x0	0	Testpattern (MSBs) used on datapath #7, #15, #23, #31 when testpattern_en = '1'. Note: Least significant bits are configured in register 149.	
26	154		reserved	0x0000	0		RW
		[15:0]	reserved	0x0000	0	Reserved	
27	155		reserved	0x0000	0		RW
		[15:0]	reserved	0x0000	0	Reserved	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
0	160		reserved				RW
		[15:0]	reserved			Reserved	
…	…	…	…			…	
31	191		reserved				RW
		[15:0]	reserved			Reserved	
Sequencer [Block Offset: 192]							
0	192		general_configuration	0x0000	0		RW
		[0]	enable	0x0	0	Enable sequencer ‘0’ = Idle, ‘1’ = enabled	
		[1]	rolling_shutter_enable	0x0	0	Operation Selection ‘0’ = Global Shutter, ‘1’ = Rolling Shutter	
		[2]	reserved	0x0	0	Reserved	
		[3]	reserved	0x0	0	Reserved	
		[4]	triggered_mode	0x0	0	Triggered Mode Selection (Global Shutter only) ‘0’ = Normal Mode, ‘1’ = Triggered Mode	
		[5]	slave_mode	0x0	0	Master/Slave Selection (Global Shutter only) ‘0’ = master, ‘1’ = slave	
		[6]	reserved	0x0	0	Reserved	
		[7]	subsampling	0x0	0	Subsampling mode selection ‘0’ = no subsampling, ‘1’ = subsampling	
		[8]	binning	0x0	0	Binning mode selection ‘0’ = no binning, ‘1’ = binning	
		[9]	reserved	0x0	0	Reserved	
		[10]	reserved	0x0	0	Reserved	
		[13:11]	monitor_select	0x0	0	Control of the monitor pins	
		[14]	reserved	0x0	0	Reserved	
1	193		delay_configuration	0x0000	0		RW
		[7:0]	rs_x_length	0x00	0	X-Readout duration in rolling shutter mode (extends lines with dummy pixels).	
		[15:8]	reserved	0x00	0	Reserved	
2	194		integration_control	0x0004	4		RW
		[1:0]	reserved	0x0	0	Reserved	
		[2]	fr_mode	0x1	1	Representation of fr_length. ‘0’: reset length ‘1’: frame length	
		[3]	reserved	0x0	0	Reserved	
		[5:4]	reserved	0x0	0	Reserved	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
		[8]	subsampling_mode	0x0	0	Subsampling Mode '0' = Subsampling / Binning in x and y '1' = Subsampling / Binning in y, not in x	
		[9]	binning_mode	0x0	0	Binning Mode '0' = Binning in x, subsample in y '1' = Binning in x and y	
		[10]	reserved	0x0	0	Reserved	
3	195		roi_active0	0x0001	1		RW
		[0]	roi_active0	0x1	1	Selection of ROI 0 '0' = inactive, '1' = active	
		[1]	roi_active1	0x0	0	Selection of ROI 1 '0' = inactive, '1' = active	
		[2]	roi_active2	0x0	0	Selection of ROI 2 '0' = inactive, '1' = active	
		[3]	roi_active3	0x0	0	Selection of ROI 3 '0' = inactive, '1' = active	
		[4]	roi_active4	0x0	0	Selection of ROI 4 '0' = inactive, '1' = active	
		[5]	roi_active5	0x0	0	Selection of ROI 5 '0' = inactive, '1' = active	
		[6]	roi_active6	0x0	0	Selection of ROI 6 '0' = inactive, '1' = active	
		[7]	roi_active7	0x0	0	Selection of ROI 7 '0' = inactive, '1' = active	
		[8]	roi_active8	0x0	0	Selection of ROI 8 '0' = inactive, '1' = active	
		[9]	roi_active9	0x0	0	Selection of ROI 9 '0' = inactive, '1' = active	
		[10]	roi_active10	0x0	0	Selection of ROI 10 '0' = inactive, '1' = active	
		[11]	roi_active11	0x0	0	Selection of ROI 11 '0' = inactive, '1' = active	
		[12]	roi_active12	0x0	0	Selection of ROI 12 '0' = inactive, '1' = active	
		[13]	roi_active13	0x0	0	Selection of ROI 13 '0' = inactive, '1' = active	
		[14]	roi_active14	0x0	0	Selection of ROI 14 '0' = inactive, '1' = active	
		[15]	roi_active15	0x0	0	Selection of ROI 15 '0' = inactive, '1' = active	
4	196		roi_active1	0x0000	0		RW
		[0]	roi_active16	0x0	0	Selection of ROI 16 '0' = inactive, '1' = active	
		[1]	roi_active17	0x0	0	Selection of ROI 17 '0' = inactive, '1' = active	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
		[2]	roi_active18	0x0	0	Selection of ROI 18 '0' = inactive, '1' = active	
		[3]	roi_active19	0x0	0	Selection of ROI 19 '0' = inactive, '1' = active	
		[4]	roi_active20	0x0	0	Selection of ROI 20 '0' = inactive, '1' = active	
		[5]	roi_active21	0x0	0	Selection of ROI 21 '0' = inactive, '1' = active	
		[6]	roi_active22	0x0	0	Selection of ROI 22 '0' = inactive, '1' = active	
		[7]	roi_active23	0x0	0	Selection of ROI 23 '0' = inactive, '1' = active	
		[8]	roi_active24	0x0	0	Selection of ROI 24 '0' = inactive, '1' = active	
		[9]	roi_active25	0x0	0	Selection of ROI 25 '0' = inactive, '1' = active	
		[10]	roi_active26	0x0	0	Selection of ROI 26 '0' = inactive, '1' = active	
		[11]	roi_active27	0x0	0	Selection of ROI 27 '0' = inactive, '1' = active	
		[12]	roi_active28	0x0	0	Selection of ROI 28 '0' = inactive, '1' = active	
		[13]	roi_active29	0x0	0	Selection of ROI 29 '0' = inactive, '1' = active	
		[14]	roi_active30	0x0	0	Selection of ROI 30 '0' = inactive, '1' = active	
		[15]	roi_active31	0x0	0	Selection of ROI 31 '0' = inactive, '1' = active	
5	197		black_lines	0x0102	258		RW
		[7:0]	black_lines	0x02	2	Number of black lines. Range 1-255	
		[8]	gate_first_line	0x1	1	Blank out first line '0': No blank-out '1': Blank-out	
6	198		dummy_lines	0x0000	0		RW
		[11:0]	dummy_lines	0x000	0	Number of Dummy lines (Rolling Shutter only) Range 0-4095	
7	199		mult_timer	0x0001	1		RW
		[15:0]	mult_timer	0x0001	1	Mult Timer (Global Shutter only) Defines granularity (unit = 1/68MHz) of exposure and reset_length	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
8	200		fr_length	0x0000	0		RW
		[15:0]	fr_length	0x0000	0	Frame/Reset length (Global Shutter only) Reset length when fr_mode = '0', Frame Length when fr_mode = '1' Granularity defined by mult_timer	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
9	201		exposure	0x0000	0		RW
		[15:0]	exposure	0x0000	0	Exposure Time Rolling Shutter: granularity lines Global Shutter: granularity defined by mult_timer	
10	202		reserved	0x0000	0		RW
		[15:0]	reserved	0x0000	0	Reserved	
11	203		reserved	0x0000	0		RW
		[15:0]	reserved	0x0000	0	Reserved	
12	204		gain_configuration	0x01E2	482		RW
		[4:0]	mux_gainsw	0x02	2	Column Gain Setting	
		[12:5]	afe_gain	0x0F	15	AFE Programmable Gain Setting	
		[13]	gain_lat_comp	0x0	0	Postpone gain update by 1 frame when ‘1’ to compensate for exposure time update latency. Gain is applied at start of next frame if ‘0’	
13	205		digital_gain_configuration	0x0080	128		RW
		[11:0]	db_gain	0x080	128	Digital Gain 5.7 unsigned format	
14	206		sync_configuration	0x033F	831		RW
		[0]	sync_rs_x_length	0x1	1	Update of rs_x_length will not be sync’ed at start of frame when ‘0’	
		[1]	sync_black_lines	0x1	1	Update of black_lines will not be sync’ed at start of frame when ‘0’	
		[2]	sync_dummy_lines	0x1	1	Update of dummy_lines will not be sync’ed at start of frame when ‘0’	
		[3]	sync_exposure	0x1	1	Update of exposure parameters will not be sync’ed at start of frame when ‘0’	
		[4]	sync_gain	0x1	1	Update of gain parameters (gain_sw, afe_gain) will not be sync’ed at start of frame when ‘0’	
		[5]	sync_roi	0x1	1	Update of roi updates (active_roi) will not be sync’ed at start of frame when ‘0’	
		[8]	blank_roi_switch	0x1	1	Blank first frame after ROI switching	
		[9]	blank_subsampling_ss	0x1	1	Blank first frame after subsampling/binning mode switching in Global shutter mode (always blanked out in rolling shutter mode)	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
		[10]	exposure_sync_mode	0x0	0	When '0', exposure parameters are sync'ed at the start of FOT. When '1', exposure parameters sync is disabled (continuously syncing). This mode is only relevant for Triggered Global - master mode, where the exposure parameters are sync'ed at the start of exposure rather than the start of FOT. For all other modes it should be set to '0'. Note: Sync is still postponed if sync_exposure='0'.	
16	208		mult_timer_status	0x0000	0		RO
		[15:0]	mult_timer	0x0000	0	Mult Timer Status (Master Global Shutter only)	
17	209		reset_length_status	0x0000	0		RO
		[15:0]	reset_length	0x0000	0	Current Reset Length (not in Slave mode)	
18	210		exposure_status	0x0000	0		RO
		[15:0]	exposure	0x0000	0	Current Exposure Time (not in Slave mode)	
19	211		reserved	0x0000	0		RO
		[15:0]	reserved	0x0000	0	Reserved	
20	212		reserved	0x0000	0		RO
		[15:0]	reserved	0x0000	0	Reserved	
21	213		gain_status	0x0000	0		RO
		[4:0]	mux_gainsw	0x00	0	Current Column Gain Setting	
		[12:5]	afe_gain	0x00	0	Current AFE Programmable Gain	
22	214		digital_gain_status	0x0000	0		RO
		[11:0]	db_gain	0x000	0	Current Digital Gain	
		[13:12]	reserved	0x0	0	Reserved	
24	216		reserved	0x7F00	32512		RW
		[6:0]	reserved	0x00	0	Reserved	
		[14:8]	reserved	0x7F	127	Reserved	
25	217		reserved	0x261E	9758		RW
		[6:0]	reserved	0x1E	30	Reserved	
		[14:8]	reserved	0x26	38	Reserved	
26	218		reserved	0x160E	5646		RW
		[6:0]	reserved	0xE	14	Reserved	
		[14:8]	reserved	0x16	22	Reserved	
27	219		reserved	0x3E2E	15918		RW
		[6:0]	reserved	0x2E	46	Reserved	
		[14:8]	reserved	0x3E	62	Reserved	
28	220		reserved	0x6750	26448		RW
		[6:0]	reserved	0x50	80	Reserved	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
		[14:8]	reserved	0x67	103	Reserved	
29	221		reserved	0.0008	8		RW
		[6:0]	reserved	0x08	8	Reserved	
…	…		…			…	
63	255		reserved				RW
		[13:0]	reserved			Reserved	
Sequencer ROI [Block Offset: 256]							
0	256		roi0_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 0 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 0 X End Configuration	
1	257		roi0_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 0 Y Start Configuration	
2	258		roi0_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 0 Y End Configuration	
3	259		roi1_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 1 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 1 X End Configuration	
4	260		roi1_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 1 Y Start Configuration	
5	261		roi1_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 1 Y End Configuration	
6	262		roi2_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 2 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 2 X End Configuration	
7	263		roi2_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 2 Y Start Configuration	
8	264		roi2_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 2 Y End Configuration	
9	265		roi3_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 3 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 3 X End Configuration	
10	266		roi3_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 3 Y Start Configuration	
11	267		roi3_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 3 Y End Configuration	
12	268		roi4_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 4 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 4 X End Configuration	
13	269		roi4_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 4 Y Start Configuration	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
14	270		roi4_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 4 Y End Configuration	
15	271		roi5_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 5 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 5 X End Configuration	
16	272		roi5_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 5 Y Start Configuration	
17	273		roi5_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 5 Y End Configuration	
18	274		roi6_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 6 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 6 X End Configuration	
19	275		roi6_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 6 Y Start Configuration	
20	276		roi6_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 6 Y End Configuration	
21	277		roi7_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 7 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 7 X End Configuration	
22	278		roi7_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 7 Y Start Configuration	
23	279		roi7_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 7 Y End Configuration	
24	280		roi8_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 8 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 8 X End Configuration	
25	281		roi8_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 8 Y Start Configuration	
26	282		roi8_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 8 Y End Configuration	
27	283		roi9_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 9 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 9 X End Configuration	
28	284		roi9_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 9 Y Start Configuration	
29	285		roi9_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 9 Y End Configuration	
30	286		roi10_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 10 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 10 X End Configuration	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
31	287		roi10_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 10 Y Start Configuration	
32	288		roi10_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 10 Y End Configuration	
33	289		roi11_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 11 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 11 X End Configuration	
34	290		roi11_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 11 Y Start Configuration	
35	291		roi11_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 11 Y End Configuration	
36	292		roi12_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 12 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 12 X End Configuration	
37	293		roi12_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 12 Y Start Configuration	
38	294		roi12_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 12 Y End Configuration	
39	295		roi13_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 13 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 13 X End Configuration	
40	296		roi13_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 13 Y Start Configuration	
41	297		roi13_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 13 Y End Configuration	
42	298		roi14_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 14 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 14 X End Configuration	
43	299		roi14_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 14 Y Start Configuration	
44	300		roi14_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 14 Y End Configuration	
45	301		roi15_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 15 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 15 X End Configuration	
46	302		roi15_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 15 Y Start Configuration	
47	303		roi15_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 15 Y End Configuration	
48	304		roi16_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 16 X Start Configuration	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
		[15:8]	x_end	0x4F	79	ROI 16 X End Configuration	
49	305		roi16_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 16 Y Start Configuration	
50	306		roi16_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 16 Y End Configuration	
51	307		roi17_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 17 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 17 X End Configuration	
52	308		roi17_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 17 Y Start Configuration	
53	309		roi17_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 17 Y End Configuration	
54	310		roi18_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 18 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 18 X End Configuration	
55	311		roi18_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 18 Y Start Configuration	
56	312		roi18_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 18 Y End Configuration	
57	313		roi19_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 19 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 19 X End Configuration	
58	314		roi19_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 19 Y Start Configuration	
59	315		roi19_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 19 Y End Configuration	
60	316		roi20_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 20 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 20 X End Configuration	
61	317		roi20_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 20 Y Start Configuration	
62	318		roi20_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 20 Y End Configuration	
63	319		roi21_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 21 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 21 X End Configuration	
64	320		roi21_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 21 Y Start Configuration	
65	321		roi21_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 21 Y End Configuration	

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
66	322		roi22_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 22 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 22 X End Configuration	
67	323		roi22_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 22 Y Start Configuration	
68	324		roi22_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 22 Y End Configuration	
69	325		roi23_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 23 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 23 X End Configuration	
70	326		roi23_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 23 Y Start Configuration	
71	327		roi23_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 23 Y End Configuration	
72	328		roi24_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 24 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 24 X End Configuration	
73	329		roi24_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 24 Y Start Configuration	
74	330		roi24_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 24 Y End Configuration	
75	331		roi25_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 25 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 25 X End Configuration	
76	332		roi25_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 25 Y Start Configuration	
77	333		roi25_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 25 Y End Configuration	
78	334		roi26_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 26 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 26 X End Configuration	
79	335		roi26_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 26 Y Start Configuration	
80	336		roi26_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 26Y End Configuration	
81	337		roi27_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 27 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 27 X End Configuration	
82	338		roi27_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 27 Y Start Configuration	
83	339		roi27_configuration2	0x13FF	5119		RW

Table 38. REGISTER MAP

Address Offset	Address	Bit Field	Register Name	Default Hex	Default	Description	Access
		[12:0]	y_end	0x13FF	5119	ROI 27 Y End Configuration	
84	340		roi28_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 28 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 28 X End Configuration	
85	341		roi28_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 28 Y Start Configuration	
86	342		roi28_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 28 Y End Configuration	
87	343		roi29_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 29 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 29 X End Configuration	
88	344		roi29_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 29 Y Start Configuration	
89	345		roi29_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 29 Y End Configuration	
90	346		roi30_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 30 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 30 X End Configuration	
91	347		roi30_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 30 Y Start Configuration	
92	348		roi30_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 30 Y End Configuration	
93	349		roi31_configuration0	0x4F00	20224		RW
		[7:0]	x_start	0x00	0	ROI 31 X Start Configuration	
		[15:8]	x_end	0x4F	79	ROI 31 X End Configuration	
94	350		roi31_configuration1	0x0000	0		RW
		[12:0]	y_start	0x0000	0	ROI 31 Y Start Configuration	
95	351		roi31_configuration2	0x13FF	5119		RW
		[12:0]	y_end	0x13FF	5119	ROI 31 Y End Configuration	
Sequencer Program [Block Offset: 384]							
0	384		reserved				RW
		[15:0]	reserved			Reserved	
…	…		…			…	
127	511		reserved				RW
		[15:0]	reserved			Reserved	

NOTE: applicable to Production silicon only and is not backward compatible with “ES1” silicon

PACKAGE INFORMATION

Pin Description

Refer to Electrical Specifications on page 4 for power supplies and references. The CMOS I/O follow the JEDEC Standard (JEDEC−JESD8C−01).

Table 39. PIN DESCRIPTION

Pin No.	Name	Type	Direction	Description
A01	vddd_18	Supply		Digital supply - 1.8 V domain
A02	mbs2_out	Analog	Out	For test purposes only. Do not connect
A03	adc_dout1	CMOS	Out	For test purposes only. Do not connect
A04	gnd_colbias	Ground		Column biasing ground - Connect to ground
A05	gnd_colbias	Ground		Column biasing ground - Connect to ground
A06	vdda_33	Supply		Analog supply - 3.3 V domain
A07	vdda_33	Supply		Analog supply - 3.3 V domain
A08	vdda_33	Supply		Analog supply - 3.3 V domain
A09	vdda_33	Supply		Analog supply - 3.3 V domain
A10	vdda_33	Supply		Analog supply - 3.3 V domain
A11	vdda_33	Supply		Analog supply - 3.3 V domain
A12	vdda_33	Supply		Analog supply - 3.3 V domain
A13	vdda_33	Supply		Analog supply - 3.3 V domain
A14	vdda_33	Supply		Analog supply - 3.3 V domain
A15	vdda_33	Supply		Analog supply - 3.3 V domain
A16	vdda_33	Supply		Analog supply - 3.3 V domain
A17	vdda_33	Supply		Analog supply - 3.3 V domain
A18	vdda_33	Supply		Analog supply - 3.3 V domain
A19	vdda_33	Supply		Analog supply - 3.3 V domain
A20	vdda_33	Supply		Analog supply - 3.3 V domain
A21	vdda_33	Supply		Analog supply - 3.3 V domain
A22	vdda_33	Supply		Analog supply - 3.3 V domain
A23	vdda_33	Supply		Analog supply - 3.3 V domain
A24	vddd_18	Supply		Digital supply - 1.8 V domain
A25	vddd_18	Supply		Digital supply - 1.8 V domain
B01	vddd_33	Supply		Digital supply - 3.3 V domain
B02	ibias_master	Analog	In/Out	Bias reference - Connect with 47 kΩ to ibias_out
B03	adc_dout2	CMOS	Out	For test purposes only. Do not connect
B04	gnd_colbias	Ground		Column biasing ground - Connect to ground
B05	doutn30	LVDS	Out	LVDS data out negative - Channel 30
B06	doutp28	LVDS	Out	LVDS data out positive - Channel 28
B07	doutn27	LVDS	Out	LVDS data out negative - Channel 27
B08	doutn25	LVDS	Out	LVDS data out negative - Channel 25
B09	doutn23	LVDS	Out	LVDS data out negative - Channel 23
B10	doutn21	LVDS	Out	LVDS data out negative - Channel 21
B11	doutn19	LVDS	Out	LVDS data out negative - Channel 19
B12	doutp17	LVDS	Out	LVDS data out positive - Channel 17
B13	doutn16	LVDS	Out	LVDS data out negative - Channel 16

Table 39. PIN DESCRIPTION

Pin No.	Name	Type	Direction	Description
B14	doutn14	LVDS	Out	LVDS data out negative - Channel 14
B15	doutp12	LVDS	Out	LVDS data out positive - Channel 12
B16	doutp10	LVDS	Out	LVDS data out positive - Channel 10
B17	doutp8	LVDS	Out	LVDS data out positive - Channel 8
B18	doutp6	LVDS	Out	LVDS data out positive - Channel 6
B19	doutp4	LVDS	Out	LVDS data out positive - Channel 4
B20	doutn3	LVDS	Out	LVDS data out negative - Channel 3
B21	doutp1	LVDS	Out	LVDS data out positive - Channel 1
B22	gnd_colbias	Ground		Column biasing ground - Connect to ground
B23	clock_inp	LVDS	In	LVDS clock in positive
B24	clock_inn	LVDS	In	LVDS clock in negative
B25	vddd_33	Supply		Digital supply - 3.3 V domain
C01	vddd_33	Supply		Digital supply - 3.3 V domain
C02	ibias_out	Analog	In/Out	Bias ground reference – Connect with 47 kΩ to ibias_master
C03	adc_dout9	CMOS	Out	For test purposes only. Do not connect
C04	gnd_colbias	Ground		Column biasing ground - Connect to ground
C05	doutp30	LVDS	Out	LVDS data out positive - Channel 30
C06	doutn28	LVDS	Out	LVDS data out negative - Channel 28
C07	doutp27	LVDS	Out	LVDS data out positive - Channel 27
C08	doutp25	LVDS	Out	LVDS data out positive - Channel 25
C09	doutp23	LVDS	Out	LVDS data out positive - Channel 23
C10	doutp21	LVDS	Out	LVDS data out positive - Channel 21
C11	doutp19	LVDS	Out	LVDS data out positive - Channel 19
C12	doutn17	LVDS	Out	LVDS data out negative - Channel 17
C13	doutp16	LVDS	Out	LVDS data out positive - Channel 16
C14	doutp14	LVDS	Out	LVDS data out positive - Channel 14
C15	doutn12	LVDS	Out	LVDS data out negative - Channel 12
C16	doutn10	LVDS	Out	LVDS data out negative - Channel 10
C17	doutn8	LVDS	Out	LVDS data out negative - Channel 8
C18	doutn6	LVDS	Out	LVDS data out negative - Channel 6
C19	doutn4	LVDS	Out	LVDS data out negative - Channel 4
C20	doutp3	LVDS	Out	LVDS data out positive - Channel 3
C21	doutn1	LVDS	Out	LVDS data out negative - Channel 1
C22	gnd_colbias	Ground		Column biasing ground - Connect to ground
C23	gnd_colbias	Ground		Column biasing ground - Connect to ground
C24	gnd_colbias	Ground		Column biasing ground - Connect to ground
C25	vddd_33	Supply		Digital supply - 3.3 V domain
D01	mbs1_out	Analog	Out	For test purposes only. Do not connect
D02	adc_dout5	CMOS	Out	For test purposes only. Do not connect
D03	adc_dout10	CMOS	Out	For test purposes only. Do not connect
D04	gnd_colbias	Ground		Column biasing ground - Connect to ground

Table 39. PIN DESCRIPTION

Pin No.	Name	Type	Direction	Description
D05	clock_outp	LVDS	Out	LVDS clock out positive
D06	doutn31	LVDS	Out	LVDS data out negative - Channel 31
D07	doutn29	LVDS	Out	LVDS data out negative - Channel 29
D08	doutn26	LVDS	Out	LVDS data out negative - Channel 26
D09	doutn24	LVDS	Out	LVDS data out negative - Channel 24
D10	doutn22	LVDS	Out	LVDS data out negative - Channel 22
D11	doutn20	LVDS	Out	LVDS data out negative - Channel 20
D12	doutn18	LVDS	Out	LVDS data out negative - Channel 18
D13	doutp15	LVDS	Out	LVDS data out positive - Channel 15
D14	doutp13	LVDS	Out	LVDS data out positive - Channel 13
D15	doutp11	LVDS	Out	LVDS data out positive - Channel 11
D16	doutp9	LVDS	Out	LVDS data out positive - Channel 9
D17	doutp7	LVDS	Out	LVDS data out positive - Channel 7
D18	doutp5	LVDS	Out	LVDS data out positive - Channel 5
D19	doutp2	LVDS	Out	LVDS data out positive - Channel 2
D20	doutp0	LVDS	Out	LVDS data out positive - Channel 0
D21	syncp	LVDS	Out	LVDS sync positive
D22	gnd_colbias	Ground		Column biasing ground - Connect to ground
D23	miso	CMOS	Out	SPI master in -slave out
D24	mosi	CMOS	In	SPI master out - slave in
D25	ss_n	CMOS	In	SPI slave select (active low)
E01	adc_dout0	CMOS	Out	For test purposes only. Do not connect
E02	adc_dout4	CMOS	Out	For test purposes only. Do not connect
E03	srd2_n	Analog		Not connected
E04	gnd_colbias	Ground		Column biasing ground - Connect to ground
E05	clock_outn	LVDS	Out	LVDS clock out negative
E06	doutp31	LVDS	Out	LVDS data out positive - Channel 31
E07	doutp29	LVDS	Out	LVDS data out positive - Channel 29
E08	doutp26	LVDS	Out	LVDS data out positive - Channel 26
E09	doutp24	LVDS	Out	LVDS data out positive - Channel 24
E10	doutp22	LVDS	Out	LVDS data out positive - Channel 22
E11	doutp20	LVDS	Out	LVDS data out positive - Channel 20
E12	doutp18	LVDS	Out	LVDS data out positive - Channel 18
E13	doutn15	LVDS	Out	LVDS data out negative - Channel 15
E14	doutn13	LVDS	Out	LVDS data out negative - Channel 13
E15	doutn11	LVDS	Out	LVDS data out negative - Channel 11
E16	doutn9	LVDS	Out	LVDS data out negative - Channel 9
E17	doutn7	LVDS	Out	LVDS data out negative - Channel 7
E18	doutn5	LVDS	Out	LVDS data out negative - Channel 5
E19	doutn2	LVDS	Out	LVDS data out negative - Channel 2
E20	doutn0	LVDS	Out	LVDS data out negative - Channel 0
E21	syncn	LVDS	Out	LVDS sync negative

Table 39. PIN DESCRIPTION

Pin No.	Name	Type	Direction	Description
E22	gnd_colbias	Ground		Column biasing ground - Connect to ground
E23	trigger	CMOS	In	Trigger
E24	sck	CMOS	In	SPI clock
E25	reset_n	CMOS	In	Active low system reset
F01	adc_dout3	CMOS	Out	For test purposes only. Do not connect
F02	adc_dout6	CMOS	Out	For test purposes only. Do not connect
F03	srd2_nguard	Analog		Not connected
F04	gnd_colbias	Ground		Column biasing ground - Connect to ground
F05	gnd_colbias	Ground		Column biasing ground - Connect to ground
F06	gnd_colbias	Ground		Column biasing ground - Connect to ground
F07	gnd_colbias	Ground		Column biasing ground - Connect to ground
F08	gnd_colbias	Ground		Column biasing ground - Connect to ground
F09	gnd_colbias	Ground		Column biasing ground - Connect to ground
F10	gnd_colbias	Ground		Column biasing ground - Connect to ground
F11	gnd_colbias	Ground		Column biasing ground - Connect to ground
F12	gnd_colbias	Ground		Column biasing ground - Connect to ground
F13	gnd_colbias	Ground		Column biasing ground - Connect to ground
F14	gnd_colbias	Ground		Column biasing ground - Connect to ground
F15	gnd_colbias	Ground		Column biasing ground - Connect to ground
F16	gnd_colbias	Ground		Column biasing ground - Connect to ground
F17	gnd_colbias	Ground		Column biasing ground - Connect to ground
F18	gnd_colbias	Ground		Column biasing ground - Connect to ground
F19	gnd_colbias	Ground		Column biasing ground - Connect to ground
F20	gnd_colbias	Ground		Column biasing ground - Connect to ground
F21	gnd_colbias	Ground		Column biasing ground - Connect to ground
F22	gnd_colbias	Ground		Column biasing ground - Connect to ground
F23	scan_in2	CMOS	In	Scan chain input #2 - Connect to ground
F24	scan_in1	CMOS	In	Scan chain input #1 - Connect to ground
F25	mux_mode	CMOS	In	Multiplexing mode selection. Connect to gndd_33 (‘0’) for 32 data channels, connect to vddd_33 (‘1’) for 16 data channels.
G01	adc_dout8	CMOS	Out	For test purposes only. Do not connect
G02	adc_dout7	CMOS	Out	For test purposes only. Do not connect
G03	afe_clk	CMOS	Out	For test purposes only. Do not connect
G04	srd1_nguard	Analog		Not connected
G05	srd1_n	Analog		Not connected
G06	td_anode	Analog	In/Out	Temperature diode - Anode
G07	td_cathode	Analog	In/Out	Temperature diode - Cathode
G08	mbs3_in	Analog	In	Analog test input - Connect to ground
G09	mbs4_in	Analog	In	Analog test input - Connect to ground
G10	spare_ana	Analog	Out	For test purposes only. Do not connect
G11	spare_ana	Analog	Out	For test purposes only. Do not connect

Table 39. PIN DESCRIPTION

Pin No.	Name	Type	Direction	Description
G12	spare_dig_in	CMOS	In	Digital test input - Connect to ground
G13	spare_dig_in	CMOS	In	Digital test input - Connect to ground
G14	spare_dig_in	CMOS	In	Digital test input - Connect to ground
G15	gnd_colbias	Ground		Column biasing ground - Connect to ground
G16	gnd_colbias	Ground		Column biasing ground - Connect to ground
G17	gnd_colbias	Ground		Column biasing ground - Connect to ground
G18	gnd_colbias	Ground		Column biasing ground - Connect to ground
G19	gnd_colbias	Ground		Column biasing ground - Connect to ground
G20	gnd_colbias	Ground		Column biasing ground - Connect to ground
G21	gnd_colbias	Ground		Column biasing ground - Connect to ground
G22	scan_clk	CMOS	In	Scan chain clock - Connect to ground
G23	monitor2	CMOS	Out	Monitor output #2
G24	monitor1	CMOS	Out	Monitor output #1
G25	monitor0	CMOS	Out	Monitor output #0
H21	test_enable	CMOS	In	Test enable - Connect to ground
H22	adc_mode	CMOS	In	ADC mode selection Connect to Gndd_33 (‘0’) for 10-bit mode operation, Connect to vddd_33 (‘1’) for 8-bit mode operation
H23	spare_dig_out	CMOS		Not connected
H24	spare_dig_out	CMOS		Not connected
H25	spare_dig_out	CMOS		Not connected
J01	spare_vref6t_hv	Analog		Not connected
J02	spare_vref6t_hv	Analog		Not connected
J03	spare_vref6t_hv	Analog		Not connected
J04	spare_vref6t_hv	Analog		Not connected
J05	gndd_33	Ground		Digital ground - 3.3 V domain
J06	gndd_33	Ground		Digital ground - 3.3 V domain
J07	gndd_33	Ground		Digital ground - 3.3 V domain
J08	gndd_33	Ground		Digital ground - 3.3 V domain
J09	gndd_33	Ground		Digital ground - 3.3 V domain
J10	gndd_33	Ground		Digital ground - 3.3 V domain
J11	gndd_33	Ground		Digital ground - 3.3 V domain
J12	gndd_33	Ground		Digital ground - 3.3 V domain
J13	gndd_18	Ground		Digital ground - 1.8 V domain
J14	gndd_18	Ground		Digital ground - 1.8 V domain
J15	gndd_18	Ground		Digital ground - 1.8 V domain
J16	gndd_18	Ground		Digital ground - 1.8 V domain
J17	gndd_18	Ground		Digital ground - 1.8 V domain
J18	gndd_18	Ground		Digital ground - 1.8 V domain
J19	gndd_18	Ground		Digital ground - 1.8 V domain
J20	gndd_18	Ground		Digital ground - 1.8 V domain
J21	gndd_18	Ground		Digital ground - 1.8 V domain

Table 39. PIN DESCRIPTION

Pin No.	Name	Type	Direction	Description
J22	gnd_trans	Ground		Pixel transfer ground - Connect to ground
J23	gnd_respd	Supply		Photo diode reset ground - sinking supply
J24	gnd_resfd	Ground		Floating diffusion reset ground - Connect to ground
J25	gnd_resfd	Ground		Floating diffusion reset ground - Connect to ground
K01	spare_vref6t	Analog		Not connected
K02	spare_vref6t	Analog		Not connected
K03	spare_vref6t	Analog		Not connected
K04	spare_vref6t	Analog		Not connected
K05	spare_vref6t	Analog		Not connected
K06	spare_vref6t	Analog		Not connected
K07	spare_vref6t	Analog		Not connected
K08	spare_vref6t	Analog		Not connected
K9	vdd_pix	Supply		Pixel array supply
K10	vdd_pix	Supply		Pixel array supply
K11	vdd_pix	Supply		Pixel array supply
K12	vdd_pix	Supply		Pixel array supply
K13	vdd_pix	Supply		Pixel array supply
K14	vdd_pix	Supply		Pixel array supply
K15	vdd_pix	Supply		Pixel array supply
K16	vdd_pix	Supply		Pixel array supply
K17	gnd_sel	Ground		Pixel select ground - Connect to ground
K18	gnd_sel	Ground		Pixel select ground - Connect to ground
K19	gnd_sel	Ground		Pixel select ground - Connect to ground
K20	gnd_sel	Ground		Pixel select ground - Connect to ground
K21	vdd_trans	Supply		Pixel transfer supply
K22	gnd_trans	Ground		Pixel transfer ground - Connect to ground
K23	gnd_respd	Supply		Photo diode reset ground - sinking supply
K24	gnd_resfd	Ground		Floating diffusion reset ground - Connect to ground
K25	gnd_resfd	Ground		Floating diffusion reset ground - Connect to ground
L01	vref_colmux	Supply		Column multiplexer reference supply
L02	vdd_pix	Supply		Pixel array supply
L03	vdd_pix	Supply		Pixel array supply
L04	vdd_pix	Supply		Pixel array supply
L05	vdd_pix	Supply		Pixel array supply
L06	vdd_pix	Supply		Pixel array supply
L07	vdd_pix	Supply		Pixel array supply
L08	vdd_pix	Supply		Pixel array supply
L09	vdd_pix	Supply		Pixel array supply
L10	vdd_pix	Supply		Pixel array supply
L11	vdd_pix	Supply		Pixel array supply
L12	vdd_pix	Supply		Pixel array supply
L13	vdd_pix	Supply		Pixel array supply

Table 39. PIN DESCRIPTION

Pin No.	Name	Type	Direction	Description
L14	vdd_pix	Supply		Pixel array supply
L15	vdd_pix	Supply		Pixel array supply
L16	vdd_pix	Supply		Pixel array supply
L17	vdd_casc	Supply		Cascode supply
L18	vdd_casc	Supply		Cascode supply
L19	vdd_sel	Supply		Pixel select supply
L20	vdd_sel	Supply		Pixel select supply
L21	vdd_trans	Supply		Pixel transfer supply
L22	gnd_trans	Ground		Pixel transfer ground - Connect to ground
L23	gnd_respd	Supply		Photo diode reset ground - sinking supply
L24	vdd_resfd	Supply		Floating diffusion reset supply
L25	vref_colmux	Supply		Column multiplexer reference supply
M01	vref_colmux	Supply		Column multiplexer reference supply
M02	vdd_pix	Supply		Pixel array supply
M03	vdd_pix	Supply		Pixel array supply
M04	vdd_pix	Supply		Pixel array supply
M05	vdd_pix	Supply		Pixel array supply
M06	vdd_pix	Supply		Pixel array supply
M07	vdd_pix	Supply		Pixel array supply
M08	vdd_pix	Supply		Pixel array supply
M09	vdd_pix	Supply		Pixel array supply
M10	vdd_pix	Supply		Pixel array supply
M11	vdd_pix	Supply		Pixel array supply
M12	vdd_pix	Supply		Pixel array supply
M13	vdd_pix	Supply		Pixel array supply
M14	vdd_pix	Supply		Pixel array supply
M15	vdd_pix	Supply		Pixel array supply
M16	vdd_pix	Supply		Pixel array supply
M17	vdd_casc	Supply		Cascode supply
M18	vdd_casc	Supply		Cascode supply
M19	vdd_sel	Supply		Pixel select supply
M20	vdd_sel	Supply		Pixel select supply
M21	vdd_trans	Supply		Pixel transfer supply
M22	gnd_trans	Ground		Pixel transfer ground - Connect to ground
M23	gnd_respd	Supply		Photo diode reset ground - sinking supply
M24	vdd_resfd	Supply		Floating diffusion reset supply
M25	vref_colmux	Supply		Column multiplexer reference supply
N01	vddd_33	Supply		Digital supply - 3.3-V domain
N02	vdd_pix	Supply		Pixel array supply
N03	gnd_colpc	Ground		Column precharge ground - Connect to ground
N04	gnd_colpc	Ground		Column precharge ground - Connect to ground
N05	gnd_colpc	Ground		Column precharge ground - Connect to ground

Table 39. PIN DESCRIPTION

Pin No.	Name	Type	Direction	Description
N06	gnd_colpc	Ground		Column precharge ground - Connect to ground
N07	gnd_colpc	Ground		Column precharge ground - Connect to ground
N08	gnd_colpc	Ground		Column precharge ground - Connect to ground
N09	gnd_colpc	Ground		Column precharge ground - Connect to ground
N10	gnd_colpc	Ground		Column precharge ground - Connect to ground
N11	gnd_colpc	Ground		Column precharge ground - Connect to ground
N12	gnd_colpc	Ground		Column precharge ground - Connect to ground
N13	gnd_colpc	Ground		Column precharge ground - Connect to ground
N14	gnd_colpc	Ground		Column precharge ground - Connect to ground
N15	gnd_colpc	Ground		Column precharge ground - Connect to ground
N16	gnd_colpc	Ground		Column precharge ground - Connect to ground
N17	gnd_colpc	Ground		Column precharge ground - Connect to ground
N18	gnd_colpc	Ground		Column precharge ground - Connect to ground
N19	gnd_colpc	Ground		Column precharge ground - Connect to ground
N20	gnd_colpc	Ground		Column precharge ground - Connect to ground
N21	vdd_trans	Supply		Pixel transfer supply
N22	vdd_respd	Supply		Photo diode reset supply
N23	vdd_respd	Supply		Photo diode reset supply
N24	vdd_resfd	Supply		Floating diffusion reset supply
N25	vddd_33	Supply		Digital supply - 3.3 V domain
P01	vddd_33	Supply		Digital supply - 3.3 V domain
P02	vdd_pix	Supply		Pixel array supply
P03	gnd_colpc	Ground		Column precharge ground - Connect to ground
P04	gnd_colpc	Ground		Column precharge ground - Connect to ground
P05	gnd_colpc	Ground		Column precharge ground - Connect to ground
P06	gnd_colpc	Ground		Column precharge ground - Connect to ground
P07	gnd_colpc	Ground		Column precharge ground - Connect to ground
P08	gnd_colpc	Ground		Column precharge ground - Connect to ground
P09	gnd_colpc	Ground		Column precharge ground - Connect to ground
P10	gnd_colpc	Ground		Column precharge ground - Connect to ground
P11	gnd_colpc	Ground		Column precharge ground - Connect to ground
P12	gnd_colpc	Ground		Column precharge ground - Connect to ground
P13	gnd_colpc	Ground		Column precharge ground - Connect to ground
P14	gnd_colpc	Ground		Column precharge ground - Connect to ground
P15	gnd_colpc	Ground		Column precharge ground - Connect to ground
P16	gnd_colpc	Ground		Column precharge ground - Connect to ground
P17	gnd_colpc	Ground		Column precharge ground - Connect to ground
P18	gnd_colpc	Ground		Column precharge ground - Connect to ground
P19	gnd_colpc	Ground		Column precharge ground - Connect to ground
P20	gnd_colpc	Ground		Column precharge ground - Connect to ground
P21	gnd_colpc	Ground		Column precharge ground - Connect to ground
P22	vdd_respd	Supply		Photo diode reset supply

Table 39. PIN DESCRIPTION

Pin No.	Name	Type	Direction	Description
P23	vdd_respd	Supply		Photo diode reset supply
P24	vdd_resfd	Supply		Floating diffusion reset supply
P25	vddd_33	Supply		Digital supply - 3.3 V domain
R01	vddd_18	Supply		Digital supply - 1.8 V domain
R02	vddd_18	Supply		Digital supply - 1.8 V domain
R03	vddd_18	Supply		Digital supply - 1.8 V domain
R04	gnd_colpc	Ground		Column precharge ground - Connect to ground
R05	gnda_33	Ground		Analog ground - 3.3 V domain
R06	gnda_33	Ground		Analog ground - 3.3 V domain
R07	gnda_33	Ground		Analog ground - 3.3 V domain
R08	gnda_33	Ground		Analog ground - 3.3 V domain
R09	gnda_33	Ground		Analog ground - 3.3 V domain
R10	gnda_33	Ground		Analog ground - 3.3 V domain
R11	gnda_33	Ground		Analog ground - 3.3 V domain
R12	gnda_33	Ground		Analog ground - 3.3 V domain
R13	gnda_33	Ground		Analog ground - 3.3 V domain
R14	gnda_33	Ground		Analog ground - 3.3 V domain
R15	gnda_33	Ground		Analog ground - 3.3 V domain
R16	gnda_33	Ground		Analog ground - 3.3 V domain
R17	gnda_33	Ground		Analog ground - 3.3 V domain
R18	gnda_33	Ground		Analog ground - 3.3 V domain
R19	gnda_33	Ground		Analog ground - 3.3 V domain
R20	gnda_33	Ground		Analog ground - 3.3 V domain
R21	gnda_33	Ground		Analog ground - 3.3 V domain
R22	gnda_33	Ground		Analog ground - 3.3 V domain
R23	vddd_18	Supply		Digital supply - 1.8 V domain
R24	vddd_18	Supply		Digital supply - 1.8 V domain
R25	vddd_18	Supply		Digital supply - 1.8 V domain

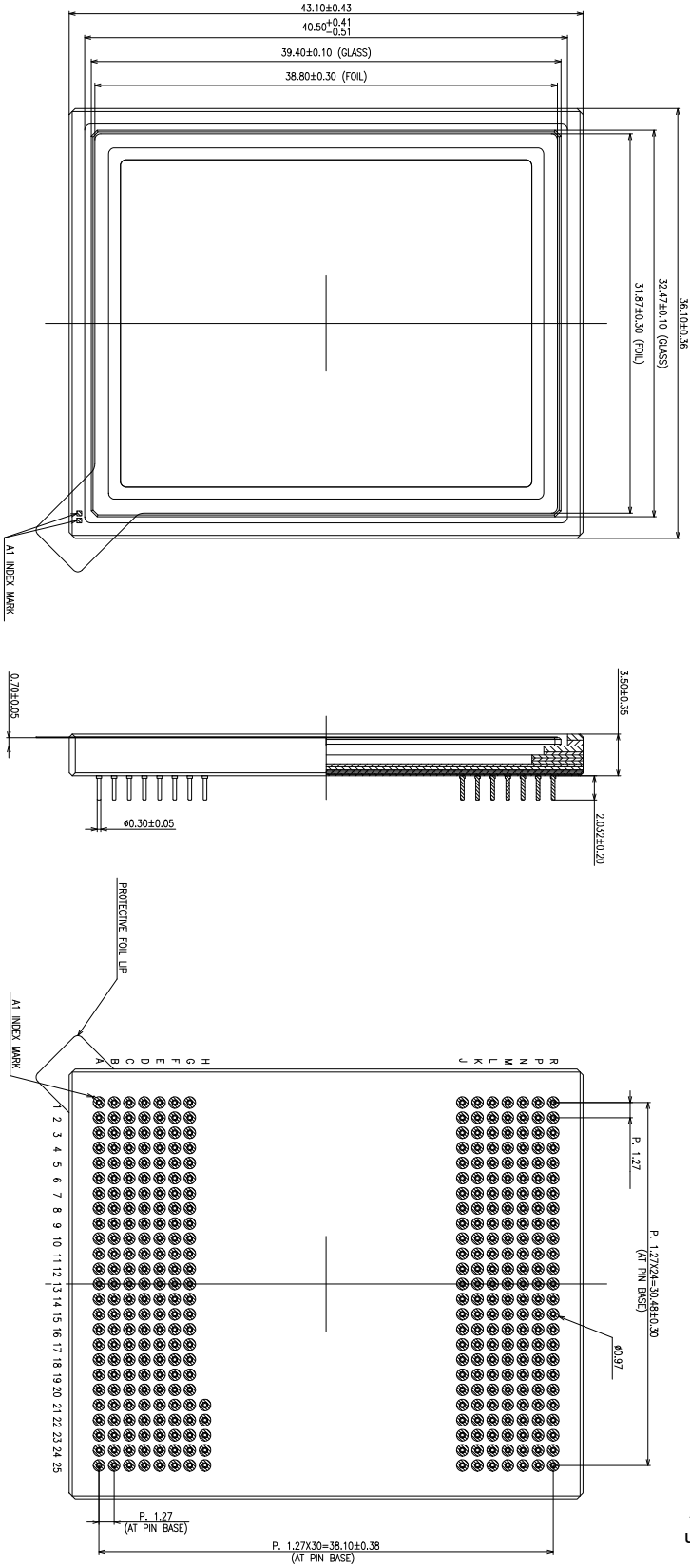
Mechanical Specifications

Table 40. MECHANICAL SPECIFICATIONS

Parameter	Description	Min	Typ	Max	Units
Die (Refer to Figure 42 with Pin A1 bottom right)	Die thickness		725		μm
	Die size		25.5 x 32.5		mm^2
	Die center, X offset to the center of package	-50	0	50	μm
	Die center, Y offset to the center of the package	-50	0	50	μm
	Die position, tilt to the die attach pad plane		0		deg
	Die rotation accuracy between die scribe and lead fingers of package on all four sides		0		deg
	Optical center referenced from the package center with Pin1 located bottom right (X-dir)		0		μm
	Optical center referenced from the package center with Pin1 located bottom right (Y-dir)		3602		μm
	Distance from bottom of the package to top of the die surface		1.75		mm
	Distance from top of the die surface to top of the glass lid		1.45		mm
Glass Lid Specification	XY size		32.47 x 39.4		mm^2
	Thickness		0.7		mm
	Spectral range for glass window	400		1000	nm
	Transmission of the Glass lid (refer to Figure 44)			92	%
Glass Lid Material	D263 Teco (no coatings on glass)				
Mechanical Shock	JESD22-B104C; Condition G			2000	g
Vibration	JESD22-B103B; Condition 1			2000	Hz
Mounting Profile	Pb−free wave soldering profile for pin grid array package				
Recommended Socket	Andon Electronics Corporation (www.andonelectronics.com)	10−31−13A−355−400T4−R27−L14			

NOTE: Optical center min/max tolerance is calculated on X/Y package tolerances with Pin 1 as a reference.

Package Drawing



All dimensions are in mm, unless specified otherwise.

Figure 41. Package Diagram

Optical Center Information

The center of the die (CD) is the center of the cavity

The center of the die (CD) is exactly at 50% between the outsides of the two outer seal rings

The center of the cavity is exactly at 50% between the insides of the finger pads.

- Die outer dimensions:
  - B4 is the reference for the Die (0,0) in μm
  - B1 is at (0,32500) μm
  - B2 is at (25500,32500) μm
  - B3 is at (25500,0) μm
- Active Area outer dimensions (VITA 16K)
  - A1 is at (2960, 29084) μm
  - A2 is at (22540, 29084) μm
  - A3 is at (22540, 10620) μm
  - A4 is at (2960, 10620) μm
- Active Area outer dimensions (VITA 12K)
  - A1* is at (2960, 26780) μm
  - A2* is at (22540, 26780) μm
  - A3* is at (22540, 12924) μm
  - A4* is at (2960, 12924) μm
- Center of the Active Area
  - AA is at (12750, 19852) μm
- Center of the Die
  - CD is at (12750, 16250) μm

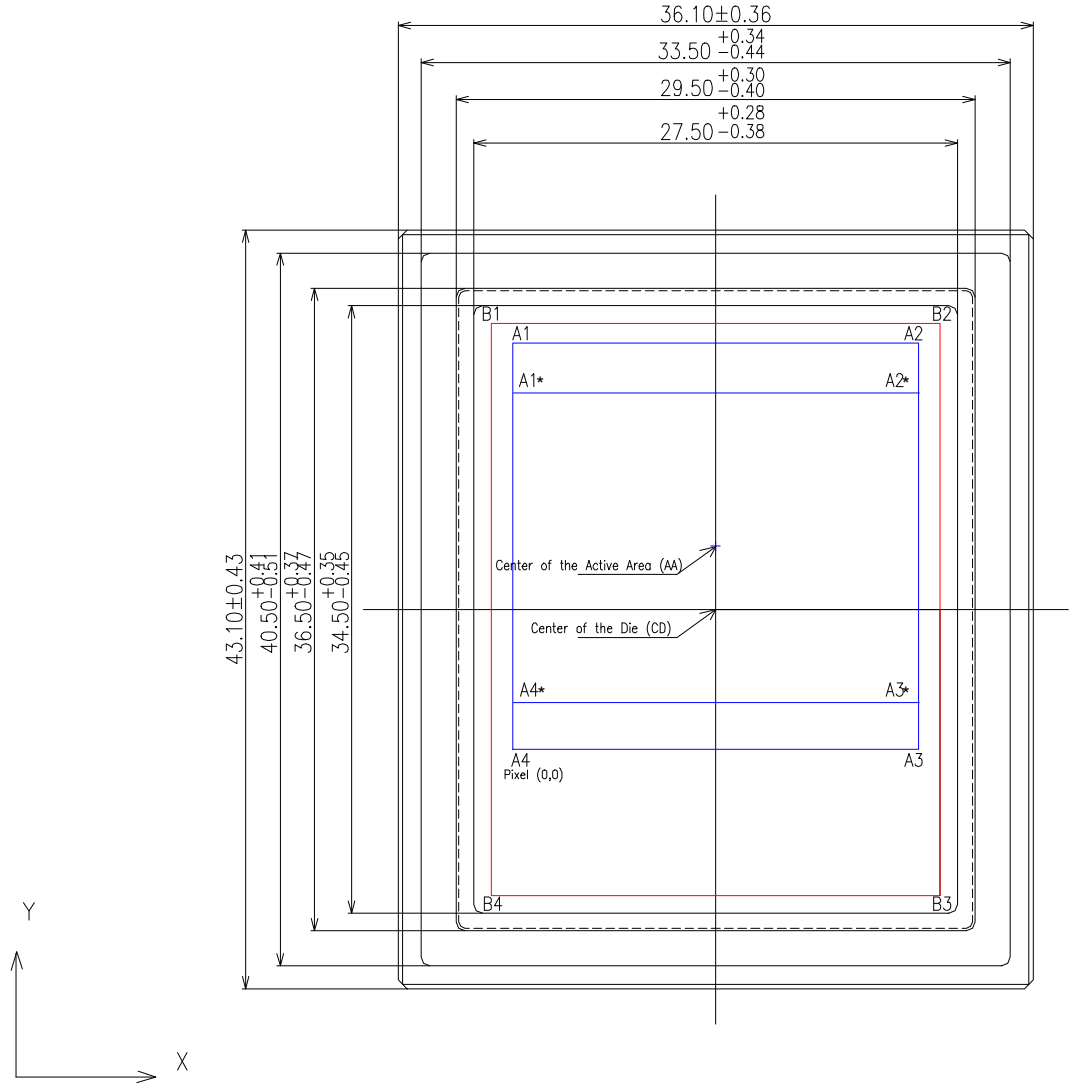


Figure 42. Graphical Representation of the Optical Center

Glass Lid

The VITA image sensor uses a glass lid without any coating. Figure 43 shows the transmission characteristics of the glass lid.

As seen in Figure 43, the sensor does not have an infrared attenuating filter glass. A filter must be provided in the optical path when color devices are used (source: http://www.pgo-online.com).

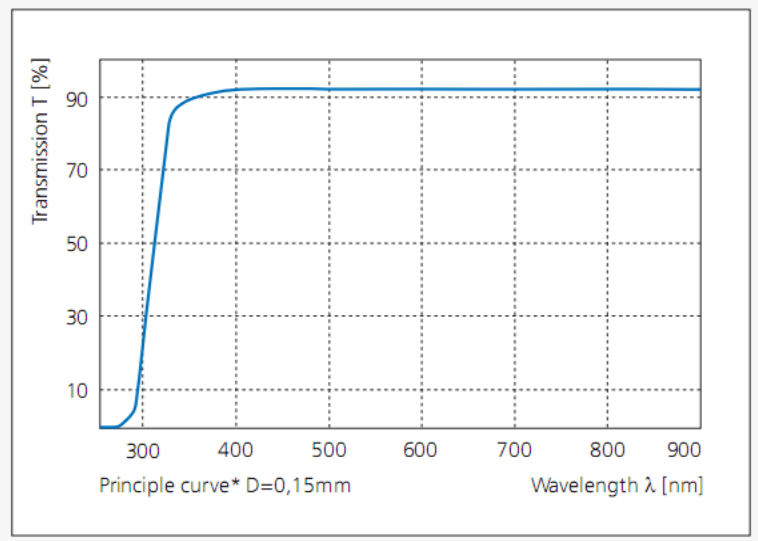


Figure 43. Transmission Characteristics of Glass Lid

SPECIFICATIONS AND USEFUL REFERENCES

Specifications, Application Notes and useful resources can be accessible via customer login account at MyON - CISP Extranet.
https://www.onsemi.com/PowerSolutions/myon/erCispFolder.do

Useful References

For information on ESD and cover glass care and cleanliness, please download the *Image Sensor Handling and Best Practices* Application Note (AN52561/D) from www.onsemi.com.

For quality and reliability information, please download the *Quality & Reliability* Handbook (HBD851/D) from www.onsemi.com.

For information on Standard terms and Conditions of Sale, please download Terms and Conditions from www.onsemi.com.

Application Note and References

- AND9049 VITA Family Global Reset
- AN66426 FPN and PRNU Correction for the VITA family
- AN65466 VITA 25K HSMC Cyclone Reference Board
- VITA 25K Delivery Specification
- VITA 25K Layout DSN drawing
- VITA 25K 3D package STP file for CAD
- AN5606 Zero ROT Application Note
- AND9123 VITA 25K Temperature Curves

Acceptance Criteria Specification

The Product Acceptance Criteria is available on request. This document contains the criteria to which the VITA xK is tested prior to being shipped.

Return Material Authorization (RMA)

Refer to the ON Semiconductor RMA policy procedure at http://www.onsemi.com/site/pdf/CAT_Returns_FailureAnalysis.pdf

ACRONYMS

Acronym	Description
ADC	Analog-to-Digital Converter
AFE	Analog Front End
BL	Black pixel data
CDM	Charged Device Model
CDS	Correlated Double Sampling
CMOS	Complementary Metal Oxide Semiconductor
CRC	Cyclic Redundancy Check
DAC	Digital-to-Analog Converter
DDR	Double Data Rate
DNL	Differential Non-Llinearity
DS	Double Sampling
EIA	Electronic Industries Alliance
ESD	Electrostatic Discharge
FE	Frame End
FOT	Frame Overhead Time
FPGA	Field Programmable Gate Array
FPN	Fixed Pattern Noise
FPS	Frames per Second
FS	Frame Start
HBM	Human Body Model
IMG	Image data (regular pixel data)
INL	Integral Non-Linearity
IP	Intellectual Property

Acronym	Description
LE	Line End
LS	Line Start
LSB	least significant bit
LVDS	Low-Voltage Differential Signaling
MSB	most significant bit
PGA	Programmable Gain Amplifier
PLS	Parasitic Light Sensitivity
PRBS	Pseudo-Random Binary Sequence
PRNU	Photo Response Non-Uniformity
QE	Quantum Efficiency
RGB	Red-Green-Blue
RMA	Return Material Authorization
RMS	Root Mean Square
ROI	Region of Interest
ROT	Row Overhead Time
S/H	Sample and Hold
SNR	Signal-to-Noise Ratio
SPI	Serial Peripheral Interface
TIA	Telecommunications Industry Association
T_J	Junction temperature
TR	Training pattern
% RH	Percent Relative Humidity

GLOSSARY

conversion gain	A constant that converts the number of electrons collected by a pixel into the voltage swing of the pixel. Conversion gain = q/C where q is the charge of an electron (1.602E 19 Coulomb) and C is the capacitance of the photodiode or sense node.
CDS	Correlated double sampling. This is a method for sampling a pixel where the pixel voltage after reset is sampled and subtracted from the voltage after exposure to light.
CFA	Color filter array. The materials deposited on top of pixels that selectively transmit color.
DNL	Differential non-linearity (for ADCs)
DSNU	Dark signal non-uniformity. This parameter characterizes the degree of non-uniformity in dark leakage currents, which can be a major source of fixed pattern noise.
fill-factor	A parameter that characterizes the optically active percentage of a pixel. In theory, it is the ratio of the actual QE of a pixel divided by the QE of a photodiode of equal area. In practice, it is never measured.
INL	Integral nonlinearity (for ADCs)
IR	Infrared. IR light has wavelengths in the approximate range 750 nm to 1 mm.
Lux	Photometric unit of luminance (at 550 nm, 1lux = 1 lumen/m^2 = 1/683 W/m^2)
pixel noise	Variation of pixel signals within a region of interest (ROI). The ROI typically is a rectangular portion of the pixel array and may be limited to a single color plane.
photometric units	Units for light measurement that take into account human physiology.
PLS	Parasitic light sensitivity. Parasitic discharge of sampled information in pixels that have storage nodes.
PRNU	Photo-response non-uniformity. This parameter characterizes the spread in response of pixels, which is a source of FPN under illumination.
QE	Quantum efficiency. This parameter characterizes the effectiveness of a pixel in capturing photons and converting them into electrons. It is photon wavelength and pixel color dependent.
read noise	Noise associated with all circuitry that measures and converts the voltage on a sense node or photodiode into an output signal.
reset	The process by which a pixel photodiode or sense node is cleared of electrons. ”Soft” reset occurs when the reset transistor is operated below the threshold. ”Hard” reset occurs when the reset transistor is operated above threshold.
reset noise	Noise due to variation in the reset level of a pixel. In 3T pixel designs, this noise has a component (in units of volts) proportionality constant depending on how the pixel is reset (such as hard and soft). In 4T pixel designs, reset noise can be removed with CDS.
responsivity	The standard measure of photodiode performance (regardless of whether it is in an imager or not). Units are typically A/W and are dependent on the incident light wavelength. Note that responsivity and sensitivity are used interchangeably in image sensor characterization literature so it is best to check the units.
ROI	Region of interest. The area within a pixel array chosen to characterize noise, signal, crosstalk, and so on. The ROI can be the entire array or a small subsection; it can be confined to a single color plane.
sense node	In 4T pixel designs, a capacitor used to convert charge into voltage. In 3T pixel designs it is the photodiode itself.
sensitivity	A measure of pixel performance that characterizes the rise of the photodiode or sense node signal in Volts upon illumination with light. Units are typically V/(W/m^2)/sec and are dependent on the incident light wavelength. Sensitivity measurements are often taken with 550 nm incident light. At this wavelength, 1 683 lux is equal to 1 W/m^2; the units of sensitivity are quoted in V/lux/sec. Note that responsivity and sensitivity are used interchangeably in image sensor characterization literature so it is best to check the units.
spectral response	The photon wavelength dependence of sensitivity or responsivity.
SNR	Signal-to-noise ratio. This number characterizes the ratio of the fundamental signal to the noise spectrum up to half the Nyquist frequency.
temporal noise	Noise that varies from frame to frame. In a video stream, temporal noise is visible as twinkling pixels.

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Вы можете разместить у нас заказ для любого Вашего проекта, будь то серийное производство или разработка единичного прибора.

В нашем ассортименте представлены ведущие мировые производители активных и пассивных электронных компонентов.

Нашей специализацией является поставка электронной компонентной базы двойного назначения, продукции таких производителей как XILINX, Intel (ex.ALTERA), Vicor, Microchip, Texas Instruments, Analog Devices, Mini-Circuits, Amphenol, Glenair.

Сотрудничество с глобальными дистрибьюторами электронных компонентов, предоставляет возможность заказывать и получать с международных складов практически любой перечень компонентов в оптимальные для Вас сроки.

На всех этапах разработки и производства наши партнеры могут получить квалифицированную поддержку опытных инженеров.

Система менеджмента качества компании отвечает требованиям в соответствии с ГОСТ Р ИСО 9001, ГОСТ РВ 0015-002 и ЭС РД 009

Офис по работе с юридическими лицами:

105318, г.Москва, ул.Щербаковская д.3, офис 1107, 1118, ДЦ «Щербаковский»

Телефон: +7 495 668-12-70 (многоканальный)

Факс: +7 495 668-12-70 (доб.304)

E-mail: info@moschip.ru

Skype отдела продаж:
moschip.ru
moschip.ru_4
moschip.ru_6
moschip.ru_9