EMBERION

User manual

Emberion VS20 CL

Broad Spectrum
VIS-SWIR VGA Camera

Important safety information

Before using the camera, familiarise yourself with these safety warnings and cautions. These warning and cautions are intended to prevent device damage and personal injury to the operator and others.

Operating the VS20 CL camera

When operating the camera, please read these safety instructions first:

WARNING:

- A falling camera can cause injury and/ or damage to the camera.
- Always mount the camera on a stable tripod or stable mechanical mount using the 1/4" mounting threads.
- Secure the cables to the camera using the screws on the connector. Do not route the cables in such a way that they can be stepped on, tripped over or pinched.

CAUTION:

- The camera can be hot to the touch.
- Ensure free airflow around the camera to prevent overheating.

Operating the included power supply

When using the power supply that is supplied with the VS20 CL evaluation kit, please also read these safety instructions before operating the camera:

Important:
The VS20 CL power supply is delivered without a mains cable. It has an IEC 60320 C14 inlet for mains connection.

- Ensure you use a cable with an IEC 60320 C13 connector on one end and country specific mains connector on the other.
- Ensure you use a suitable power cord for your country or region.
- Ensure you use a cable with an electrical earth (ground) connection.
- Ensure a sufficient current rating of the power cable.
- Do not connect the power supply to a mains voltage or frequency which differs from the value stated on the power marking label.
- Do not connect the machine to a mains voltage or frequency which differs from the value stated on the power marking label.

WARNING:

- Do not scratch, abrade, heat, twist, or place a heavy object on the power cord or cause any other damage to it. The use of a damaged power cord could result in electrical shock, fire or malfunction of the camera.
- Do not open the power supply. Opening the supply can cause electric shock.
- Protect the power cord from being walked on or pinched.
- Protect he power supply from humidity and moisture.
- The maximum ambient temperature is 40°C.
- The maximum operating altitude is up to 5000 m.

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EMBERION

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Copyright

Copyright/ Intellectual Property Rights

Please also refer to Emberion Oy's General Sales Terms valid for this product.

Warranty: The warranty becomes void in case of unauthorized tampering, or any manipulations not approved by the manufacturer.

Environmental conditions: Operate the camera in dry and dust-free environment.

Disclaimer

European Export Laws and US Export Administration Regulations may apply to the sale, destination and end use of these items and any related technical data. Any diversion contrary to export control regulations is strictly prohibited.

Emberion Oy has no other obligation or liability for defects than those set forth therein.

Emberion Oy shall not be liable for any direct, indirect, special, incidental, or consequential loss of damage, whether based on contract, tort, product liability or any other legal theory.

Emberion Oy reserves the right to revise this publication and to make changes from time to time in the content hereof without obligation to notify any person of such revision or changes.

Compliance notifications

National regulations on disposal must be followed.

- This product is designated for separate collection at an appropriate collection point. Do not dispose of as household waste.
- The correct disposal of these products helps prevent potentially negative consequences on the environment and human health.
- For more information, contact Emberion or the local authorities in charge of waste management.

For customers in the EU, EEA, and Switzerland

This appliance is certified for compliance and distribution an use in the EU, EEA, Switzerland and other countries following CE regulations.

The VS20 CL is tested to be compliant with:

- EU Directive 2014/30/EU on electromagnetic compatibility (EMC)
- EU Directive 2011/65/EU and amendment Directive 2015/863/EU on restriction of hazardous substances in electrical and electronic equipment (RoHS)

For customers in the United Kingdom

This appliance is certified for compliance and distribution and use in the United Kingdom.

The VS20 CL is tested to be compliant with:

- Electromagnetic compatibility Regulations 2016
- The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012 and its amendments

For customers in the United States of America

Class A digital device

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Supplier Declaration of Conformity

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.

For customers in Canada

CAN ICES-003A/ NMB-003A

This Class A digital apparatus complies with Canadian ICES-003.
Cet appareil numérique de la classe A est conforme à la norme NMB-003 du Canada.

Intended use

The VS20 CL camera is designed to be used by professionals. It is intended to be used in a commercial, industrial or business environment. It can be used as a stand alone camera, or integrated in to a vision system.

Safety testing

This product is tested for safety, and shown to be compliant, for use in the above regions. Testing was done according to the following relevant harmonised standards, including national differences, to which conformity is declared. IEC 62368-1: 2018, and IEC 62368-1:2020+A11:2020.

EMC/ EMI

This product is tested for electromagnetic compatibility and immunity requirements, and shown to be compliant, for use in the above regions. Testing was done according to the following relevant harmonised standards, including national differences, to which conformity is declared.
EN 55032:2015/ AC:2016, EN 55035:2017, EN 61326-1:2013, and ANSI/ IEEE C63.4:2014+A1:2017.

This product has demonstrated EMC compliance under conditions that included the use of compliant peripheral devices and shielded cables between system components. It is important that you use compliant peripheral devices and shielded cables between system components to reduce the possibility of causing interference to radios, television sets, and other electronic devices.

Conventions used in this documentation

The following symbols are used in this manual to notify the reader or operator of important safety advice, useful tips and tricks, examples or version specific information.

WARNING:
This indicates a potential to cause bodily harm.

CAUTION:
This indicates the possibility of damage to data or equipment.

Important:
This is an important note.

Note:
This type of note to inform the reader of incompatibility.

Example:
This is an example.

Tip:
This is a tip.

Chapter 1: Introduction

The Emberion VS20 CL camera technology offers unique broad-spectrum and wide dynamic range imaging performance. The VGA-resolution image sensor is based on proprietary image sensor technology and comprises of a light-absorbing Colloidal Quantum Dots layer built monolithically on a tailor-made CMOS readout integrated circuit.

The CQDs provide an extremely wide spectral response range spanning from visible, to near infrared and up to short-wave infrared wavelengths. The use of colloidal quantum dots for the photo absorption stack allows for a broader wavelength range and better tunable photo response than conventional methods. By operating the sensor in open voltage circuit mode, the image sensor offers a low input noise, non-saturating photodetector with a very large dynamic range.

Emberion VS20 CL offers a full camera functionality with implementations for sensor readout and control, analog-to-digital signal conversion, calibration, image pre-processing, thermal control, power management and standard digital camera interface. The camera comes in a robust aluminium housing for efficient thermal management and protection against dust. A stable performance over a wide environmental temperature range is ensured with a thermoelectric cooling element built in the image sensor package.

Emberion provides a graphical user interface for Windows 10 (64 bit) and Windows 11 to operate the camera through a Camera Link frame grabber. The software can display the video stream and configure the camera through the Camera Link's serial communication channel. It also allows for updating the camera's firmware through a separate USB connection.

Figure 1-1: *Emberion VS20 CL*

The VS20 CL camera offers:

- Unique image sensor with large dynamic range enabling high dynamic range imaging.
- Camera Link Base configuration for 16-bit monochrome images.
- Non-uniformity and defect pixel corrections and optional linearisation.
- Anti-reflective coating on sensor glass that covers the full wavelength range.
- C-mount lens fitting for 1" sensors.
- Robust aluminium industrial housing.
- TEC stabilised image sensor and calibrated at 5, 10, and 20°C.

Table 1-1: *Emberion VS20 CL's sensor main features*

Test standard	Conditions
Sensor type	Emberion's colloidal quantum dot photo diode in OVCM
Pixel pitch	20 x 20 µm, 90% fill factor
Resolution	640 x 512 pixels, VGA
Sensor size	12.8 x 10.24 mm, 16.39 mm diagonal
Spectral range	400 to 2000 nm
Dynamic range	80 dB
Shutter	Electronic global shutter
Cooling	Built-in thermoelectric cooler
Frame rate	1 – 86 fps
A/D conversion	14-bit

Chapter 2: Before you start

You should familiarise yourself with the topics in this section before using the VS20 CL.

Introduction topic that gives an overview of the camera, and walks the user through the camera HW-features.

> **Important:**
> Ensure you have familiarised yourself with the safety notifications in "Important safety information" on page 1.

> **Important:**
> Ensure you have all required system components as described in "System components" below.

After you have familiarised yourself with this chapter, install the included Evaluation software. For more details see VS20 CL Evaluation Software Manual.

After you have installed the software, mount the camera on a stable base, connect the Camera Link cable and optional trigger connection. You can then power up the camera by plugging in the power connector.

> **Important:**
> Only (dis-)connect the Camera Link when the computer or frame grabber and camera are powered down. Doing otherwise may damage the equipment.

> **Important:**
> Cover the camera or lens with a lens-cap when the camera is not in use.

> **Tip:**
> If the camera is in an unresponsive state, remove the camera power for a couple of seconds to reboot the camera.

2.1 System components

Some components are supplied as part of the camera system. Others are required and must be supplied by the customer for proper system operation.

2.1.1 Supplied components

The evaluation camera kit contains:

- Camera with a C-mount body cap.
- Power supply with the camera-side cable and (IEC 60320) C14 inlet.
- USB memory stick with documentation and evaluation software.
- Watertight, airline safe storage and transportation case.
- Optional: Calibration report

2.1.2 Required additional accessories

The following components are not supplied as part of the system, but are required for correct operation.

- Camera Link frame grabber with support for Camera Link Base, Mono 16-bit profile and Serial Communication channel.
- C-mount lens for 1.0" or 1.1" sensors.
- Camera tripod or stable mechanical mount.

> **Tip:**
> To ease evaluation with the included Evaluation Software, it is highly recommended to use a frame grabber that is compatible with the VS20 CL Evaluation Software. See "Camera Link Interface" on page 24

2.1.3 Required additional cables

- Country-specific mains cable with (IEC 60320) C13 connector.
- Camera Link certified cable with SDR-26 connector.
- USB C cable for camera firmware updates.

2.2 Camera overview

The VS20 CL camera has a C-mount lens fitting. All connectors and indicators are on the back side. Mounting features are on the for the lens on the front and all connectors are on the back side. There are two rows of camera mount, one on the bottom and one on the side.

1. C-mount lens fitting
2. Camera mounting features, 6x ¼"-20 UNC
3. DC Power connector
4. Camera Link connector, SDR-26
5. Trigger connector, SMA

6. Status LEDs
7. USB connector, Type-C

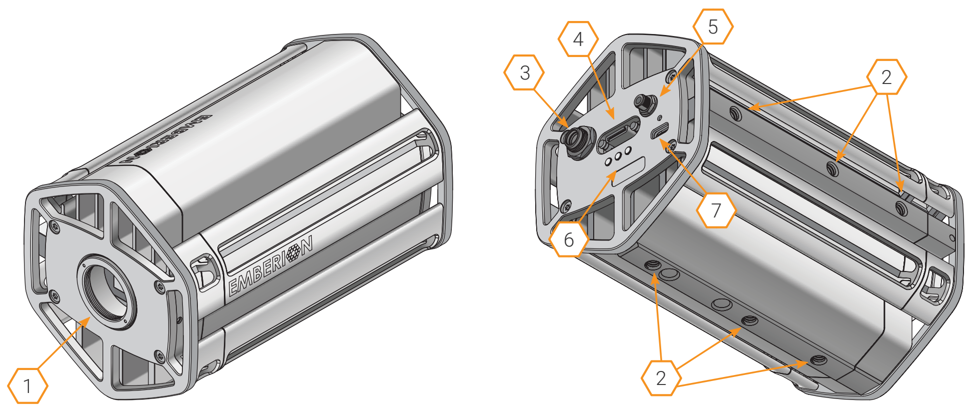

Figure 2-1: Side view of the VS20 showing the locations of the mounting features. Early VS20 model (left) and later models (right).

2.2.1 Lens mount

The VS20 CLcamera has an industry standard C-mount. The image sensor has a photosensitive area of 12.8 x 10.24 mm, 16.4 mm diagonal. Therefore, C-mount lenses that target 1 or 1.1 inch sensors can be used. Please refer to "Lens" on page 27 and "Image sensor" on page 31 for more details.

2.2.2 Mounting features

There are two rows of threaded camera mounts on the camera body. All six mounting features have a ¼"-20 UNC thread, for use with standard camera tripods. See "Mechanical mounting " on page 21.

2.2.3 Power connector

The camera has a 12 VDC power jack input to power the sensor. A universal 12 VDC power supply for use with 100-240 VAC/ 50-60 Hz is included in the VS20 CL camera evaluation delivery.

See "Power supply" on page 26 for details on powering the camera.

2.2.4 Camera Link connector

Video output and camera control is done through camera link. The connector is a single Mini Camera Link connector, also known as SDR or HDR connector. The camera supports Base mode, 16-bit monochrome profile. All camera control is done through the Camera Link’s serial channel. More details in"Camera Link Interface" on page 24.

2.2.5 Trigger connector

Trigger I/O is provided through an SMA connector. The trigger can be set as output or input. As output, it supports 5 V TTL logic levels. As input it supports 3.3 V and 5 V levels. By default, trigger I/O is disabled. See "Trigger" on page 24.

2.2.6 LEDs

Three RGB LEDs show the status of the camera. Please refer to "Rear panel LED indicators" on page 19 for a more detailed description on the LED behaviour.

2.2.7 USB connector

This connector is used only for firmware updates and loading calibration data. During normal operation, the USB connection is not needed. The connector is a USB Type C with optional single screw lock. Please note that the connector is slightly recessed, so some USB Type C connectors might not fit.

When plugged into a computer, the VS20 enumerates as a USB 2.0 High Speed mass storage device. For more details, see VS20 CL Evaluation Software Manual.

2.3 VS20 CL Evaluation Software

The VS20 CL Evaluation Software is an easy to use tool to operate the camera. For evaluation of the camera, we recommend to use a frame grabber that is fully supported by the software. See "Recommended frame grabbers for use with the Evaluation Software" on the next page.

Split between 'native supported' and only 'clallserial'.

As a fall-back option, the VS20 CL Evaluation Software can be used to only control the camera through ClAllSerial.dll. Viewing of the image stream will then have to be done with the viewer from the frame grabber manufacturer or a 3rd party viewer.

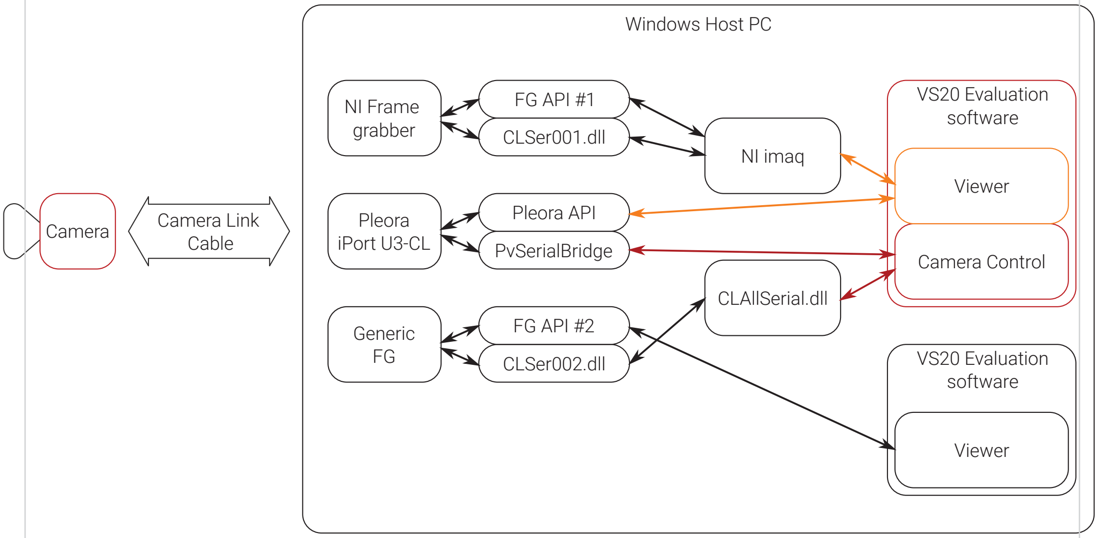

Figure 2-2: VS20 Evaluation Software configuration block diagram

2.3.1 Recommended frame grabbers for use with the Evaluation Software

Fully supported frame grabbers:

- NI PCIe-1433, PCIe
- NI PCIe 1427, PCIe
- Teledyne DALSA Xcelera-CL LX1 Base, PCIe
- Pleora iPORT U3-CL, USB3.0 SuperSpeed

The NI and Teledyne dalsa frame grabber are PCIe-based and require a desktop PC. The Pleora iPORT U3-CL is a bridge that bridges from Camera Link to USB, and is a good option for use with laptops.

2.4 Cleaning the camera

Write something nice on how to clean the sensor and camera.

For cleaning the lens, please pay attention to the instructions provided by each lens manufacturer.

Do not touch the imager itself or drop anything into the camera. There is no protection between the lens mount and the image sensor glass. The imager protective glass can easily be damaged by scratching or chemical solvents.

Please point the camera downwards whenever removing or attaching a lens. Also, do not expose the sensor for any excessive radiation.

2.5 Preventing ESD and EMI problems

Electrostatic discharge can cause permanent damage to electronic equipment. The VS20 CL camera ships in a conductive ESD bag to prevent damage during shipping. The camera contains sensitive electronic components which can be destroyed by means of electrostatic charge. The camera has ESD protection on all the I/O, and has been tested to withstand direct and indirect discharge, full protection cannot be guaranteed.

Don't open the camera housing. Opening the camera housing voids the warranty. Internal camera components are sensitive to ESD damage, and opening the housing can inadvertently cause damage to these components. This included the image sensor which is accessible without opening the camera.

If you however for some reason need to handle the image sensor, observe extra ESD precautions:

- Always operate in an ESD safe environment.
- Use a static-dissipative mat to work on, keep the camera on the ESD mat.
- Ground yourself with an ESD wrist-strap.
- Wear ESD safe clothing and keep your clothing away from the camera.

During installation it is important to prevent electromagnetic interference. This can cause the camera to malfunction, cause the camera to seize operation or cause erroneous imagining. To avoid electromagnetic interference, observe the following:

- Use shielded cables only.
- Keep cables as short as possible. Avoid coiling and unnecessary bending of cables.
- Apply proper grounding and earthing techniques. Avoid ground loops.
- Install the camera as far away as possible from strong electromagnetic fields.

Chapter 3: VS20 CL in detail

3.1 Main features

The Emberion VS20 CL camera technology offers unique broad-spectrum and wide dynamic range imaging performance. The VGA-resolution image sensor is based on proprietary image sensor technology and comprises of a light-absorbing Colloidal Quantum Dots layer built monolithically on a tailor-made CMOS readout integrated circuit.

The CQDs provide an extremely wide spectral response range spanning from visible, to near infrared and up to short-wave infrared wavelengths. The use of colloidal quantum dots for the photo absorption stack allows for a broader wavelength range and better tunable photo response than conventional methods. By operating the sensor in open voltage circuit mode, the image sensor offers a low input noise, non-saturating photodetector with a very large dynamic range.

The VS20 CL camera offers:

- Unique image sensor with large dynamic range enabling high dynamic range imaging.
- Camera Link Base configuration for 16-bit monochrome images.
- Non-uniformity and defect pixel corrections and optional linearisation.
- Anti-reflective coating on sensor glass that covers the full wavelength range.
- C-mount lens fitting for 1" sensors.
- Single +12 V supply voltage.
- Image sensor calibrated at 5, 10, and 20°C.

Table 3-1: Emberion VS20 CL's sensor main features

Test standard	Conditions
Sensor type	Emberion's colloidal quantum dot photo diode in OVCM
Pixel pitch	20 x 20 µm, 90% fill factor
Resolution	640 x 512 pixels, VGA
Sensor size	12.8 x 10.24 mm, 16.39 mm diagonal
Spectral range	400 to 2000 nm
Dynamic range	80 dB
Shutter	Electronic global shutter
Cooling	Built-in thermoelectric cooler
Frame rate	1 – 86 fps
A/D conversion	14-bit

3.2 Rear panel LED indicators

The LEDs on the rear panel show the camera status:

POWER, TEC and CAM(ERA). For remote operation, the status of the LEDs can also be queried through the Camera Link serial interface.

- POWER: Indication if camera is powered-up/ booted-up.
- TEC: Indication if image sensor is at setpoint temperature.
- CAM: Indication if camera is acquiring, or is ready to acquire, images.

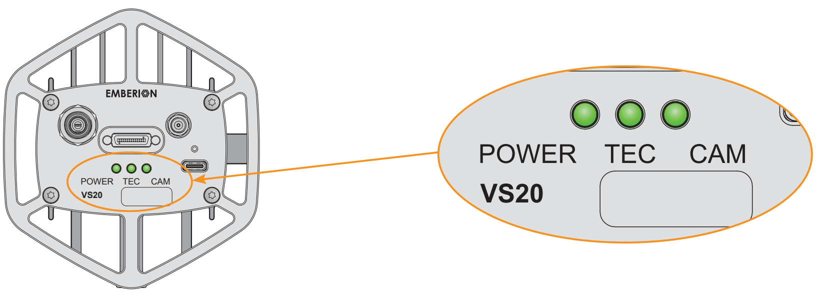

Figure 3-1: Rear panel status LED indicators

3.2.1 Power-up to normal operation

Approximately 15 seconds after applying power to the camera, the camera controller is active and the 'POWER'-LED switches on to yellow. At about 25 seconds after applying power, the camera if fully powered up and the 'POWER'-LED switches to green. At the same time, the 'TEC'- and 'CAM'-LED should switch on. From this point onwards, camera control and communication with the camera is enabled and the camera can be controlled through the Camera Link interface.

3.2.2 TEC/ sensor temperature

The 'TEC'-LED indicates the internal temperature of the sensor itself. Steady green means that the temperature is at the target temperature. Yellow indicates that the temperature has not reached its setpoint temperature. For optimal image quality it is important that the image sensor is at the setpoint temperature, i.e. the LED is green.

Tip:
If the LED remains yellow after start-up for more than a few seconds, try setting the TEC temperature (temporarily) to a different setpoint.

It is also possible to read out the temperature through the Camera Link serial interface. This option is also available in theVS20 CLEvaluation Software.

If the sensor temperature exceeds a pre-set limit, the thermal self protection activates. This is indicated by the 'TEC'-LED flashing red. In this state, the camera will stop imaging to reduce power consumption, and thus self-heating, of the image sensor. If the camera cools down, the 'TEC'-LED will switch to yellow and then green, and return to the pre-imaging stage. However, if the temperature continues to rise, all three LEDs will blink red before shutting down the camera.

3.2.3 Image and video capture

Images can be acquired as soon as the 'CAM'-LED has turned green. A yellow 'CAM'-LED indicates that the firmware is not yet ready for image capture. During image acquisition, the LED turns white. As soon as image capture is stopped, the 'CAM'-LED will return to green.

3.2.4 Power-up with firmware update

When a firmware update is initiated, all three LEDs show white and then switch to blue, to indicate a successful firmware update. In case of a failure the LEDs become all red, after which the camera is shut down. At such an incident, please report the problem to Emberion. The camera should still be able to power-up to its previous state.

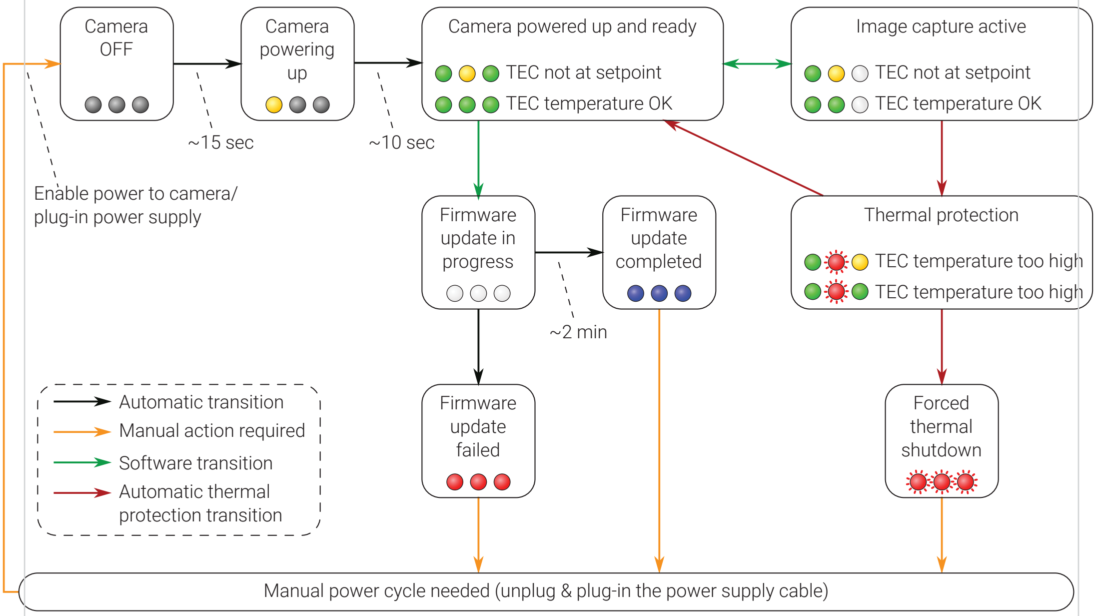

Figure 3-2: *VS20 CL state machine, indicated by the LED colours*

Tip:
The LED primary colours (red, green, and blue) show up clearly. However, the hue of mixed colours are dependant on the viewing angle. Yellow (red + green) can show up as orange-green, while white (red + green + blue) as light blue or pink.

3.3 Mechanical mounting

The VS20 CL has two rows of threaded camera mounts on the camera body. All six mounting features have a ¼"-20 UNC thread, with 11 mm thread, for use with standard camera tripods.

The mounts aligns with the camera's horizontal (landscape) and vertical (portrait) axes. The centre mounting threads on both sides are nearest to the centre of gravity. The mounting surfaces on both the landscape and portrait mount are 12 mm wide.

Chapter 3: VS20 CL in detail

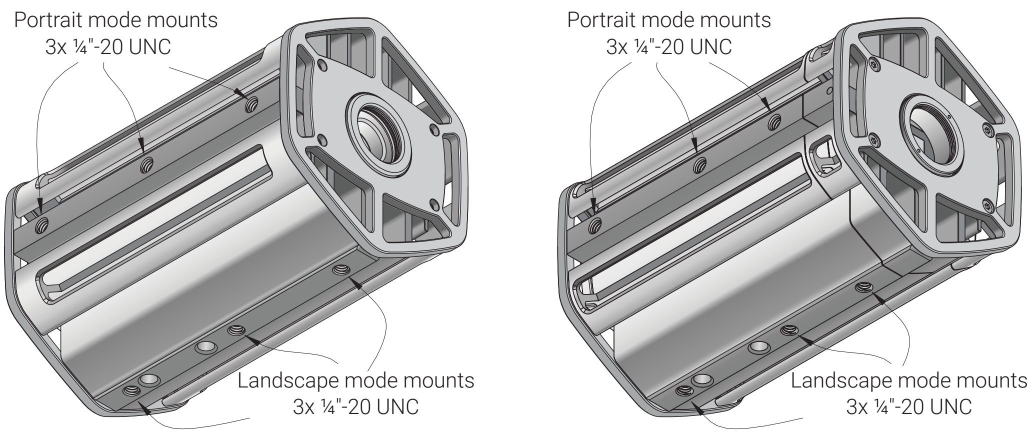

Figure 3-3: *Side view of the VS20 CL showing the locations of the mounting features. Early VS20 CL model (left) and later models (right).*

> **Note:**
> Early VS20 CL models' front mounting threads were further to the front than later models. See Figure 3-3 and TODO mechanical drawings.

> **Important:**
> The mounting surface is slightly recessed with respect to the front and back covers. See Figure 3-4, detail B.

Before operation, ensure that the camera is mounted securely to prevent damage or injury. The amount of mounting screws needed to secure the camera depends on your application.

Tighten the bolts to the correct torque. Do not over tighten the bolts, as this will damage the thread.

For a dynamic set-up, ensure the bolts don't come loose. For example with a toothed washers.

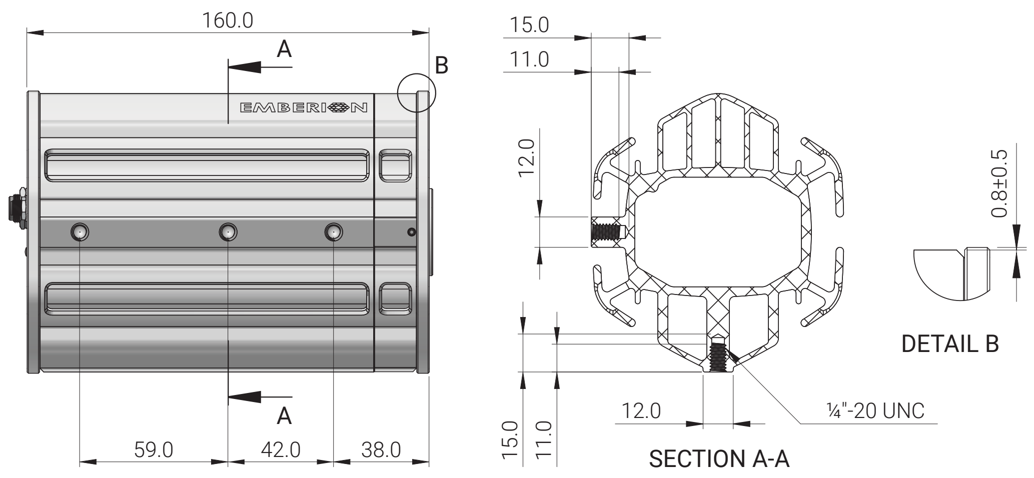

Figure 3-4: Side view of the VS20 CL showing the locations of the mounting features.

3.3.1 Shock and vibration results

To ensure stability during normal operations, selected models of the VS20 CL have been subjected to shock and vibration testing. The camera under test continued to operate as intended during and after the tests.

The camera under test was secured with all 3 screws in the landscape mounting orientation, using the entire length of the thread.

Table 3-2: Environmental test shock and vibration conditions

Test standard	Description	Conditions
IEC 60068-2-6, Test Fc	Sinusoidal vibration	5 — 500 Hz/ ±3.5mm, 5 — 9 Hz; 9 — 200 Hz/ 1 g_n/ 1 oct/min, 5x each axis
IEC 600682-64, Test Fh	Vibration, broadband random	5 — 200 Hz/ 0.44 g_{rms}, 30 min each axis
IEC 60068-2-27, Test Ea	Shock	10 g_n/ 16 ms/ axis, 3x positve, 3x negative
IEC 60068-2-27, Test Ea	Shock	5 g_n/ 11 ms/ axis, 100x postive, 100x negative

3.4 Camera Link Interface

The VS20 CL camera uses a proprietary communication to interface with the frame grabber. Emberion provides evaluation software that allows the operator to control the camera. The serial communication protocol is described in a separate document, VS20 CL Serial Commands. Additionally, there is a C++ SDK available that wraps these commands.

3.4.1 Camera Link configuration

The Camera Link interface operates in Base configuration. Image data is sent as mono 16-bit. All commands for the camera are sent over the Camera Link asynchronous serial communication channel. Camera Control signals are not used and Power over Camera Link is not supported.

Table 3-3: *Camera Link Configuration*

Parameter	Value
Configuration	Base, 16-bit mono, 1 tap
Image size	640 x 512, no offset
Clock rate	40 MHz
Connector	SDR-26
Camera Control 1-4	Not used
Serial interface (SerTFG, SerTC)	9600 baud
PoCL	Not supported

Table 3-4: *Camera Link Serial Interface settings*

Parameter	Value
Baud rate	9600
Data bits	8 bit
Parity bits	None
Number of start bits	None
Number of stop bits	1
Handshake mode	None (no handshake mode)

3.5 Trigger

The trigger connector is a female SMA connector (external thread, centre receptacle). It supports 5V TTL voltage levels. By default, it is configured as an input. But it can be set as an output through the Camera Link serial interface.

Figure 3-5 gives a simplified schematic of the trigger input and output circuit. If the trigger is set as input, the output buffer is disabled, i.e. the output buffer is set in high impedance mode. When the trigger is set as an output, the output buffer is enabled and any pulses on the trigger in line are ignored by the camera controller. There is a permanent 50 Ω resistor in series with the trigger-line for line termination.

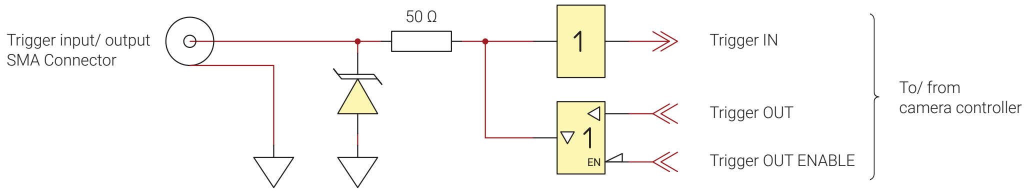

Figure 3-5: *Simplified camera trigger input/ output circuit*

Table 3-5: *Trigger input/ output voltage levels*

	Parameter	Min	Max	Unit
V_{IH}	High-level input voltage	2.0	5.5	V
V_{IL}	Low-level input voltage	0	0.8	V
V_{OH}	High-level output voltage, -32 mA load	3.8	5	V
V_{OL}	Low-level output voltage, 32 mA load	0	0.55	V

Note: A TVS diode protects the internal camera circuit against ESD damage. Overloading the input pin can permanently damage the circuit. Please only operate the camera within the maximum operating conditions as defined in 3.5. Table 3-6 gives the absolute maximum ratings. However, these are stress ratings only. Exposure to these conditions for extended periods of time may affect device reliability.

To use the trigger, first set the camera into external trigger mode. This can be done with the Evaluation Software provided with the camera. The following modes are available to the user:

- Trigger as input; active high
- Trigger as input; active low
- Trigger as output; active high
- Trigger as output: active low

3.5.1 Trigger as input

When the trigger is set as an input, active high, the VS20 camera takes an image after the first rising edge it detects. When set as input, active low, it takes an image after the first falling edge. There are some delays involved. See Figure 3-6.

If bla bla.

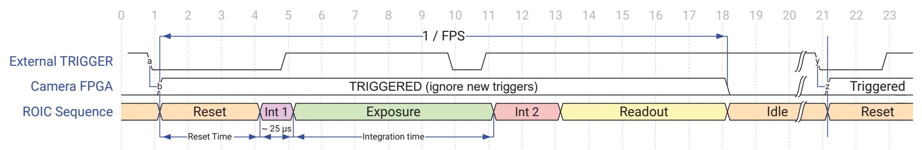

Figure 3-6: *External trigger as input, timing diagram*

Table 3-6: *Trigger input/ output voltage levels*

	Parameter	Min	Max	Unit
$V_{IH, max}$	Absolute maximum high-level input voltage		6.5	V
$V_{IL,max}$	Absolute maximum low-level input voltage	-0.5		V

3.6 Power supply

The VS20 CL is powered via a power jack connector. Power over Camera Link (PoCL) is not supported.

The power jack is a Switchcraft L712ASH with 2.5 mm centre pin. Compatible cable side connectors are the Switchcraft 761KS(H)12, 761KS(H)15, 761KS(H)17, Switchcraft CA(RA)761KS cable assembly or equivalent connectors. Nominal supply voltage for the camera is +12 VDC, with +12 V on the pin and 0V on the sleeve.

A universal 12 VDC power supply for use with 100-240 VAC/ 50-60 Hz is included in the VS20 camera delivery. The supply comes equipped with a Switchcraft 761KSw plug.

If VGA sensor is stabilized to +20C then power consumption is about 10.2W.

If VGA sensor is cooled to +5C then power consumption is about 13.2W.

Also add stuff about being PS2 source (5-100W), ES1 (<60V DC). SELV

https://docs.baslerweb.com/a2a1920-51gcbas

Stuff about included power supply

Push until you feel a 'click'

use screw to prevent accidental disconnect. 'finger tight' is good enough.

- INSERT DRAWING OF CONNECTOR, ETC.

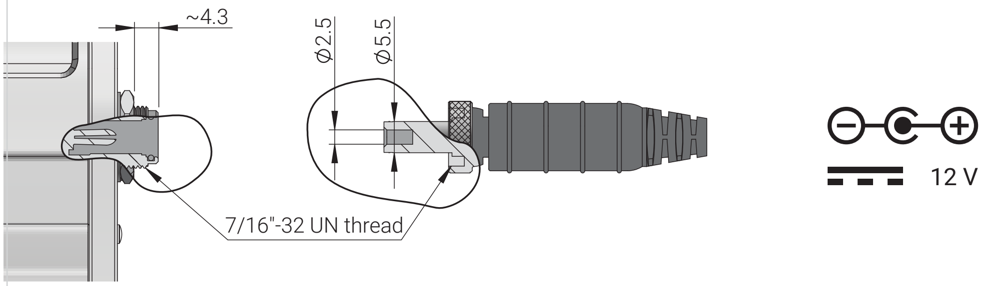

Figure 3-7: VS20 CL power connector and polarity

3.7 Lens

The VS20 CL camera model comes with an industry standard C-mount lens fitting.

A C-mount lens has a 1-32 UN thread. The distance between mounting flange and focal plane array is fixed at 17.526 mm (0.69 inch). The and later VS20 CL camera models differ slightly. Both have a C-mount lens fitting, which has by a 1-32 UN thread and a fixed focal length at 17.526 mm (0.69 inch). For the early VS20 CL camera models, the lens opening behind the C-mount thread narrows to 18 mm diameter, while the newer version has a 27 mm diameter opening. Both versions have a glass lid that covers the sensor package at approximately 16 mm from the front of the camera. The distance from mounting flange to the image sensor glass lid is approximately 16 mm.

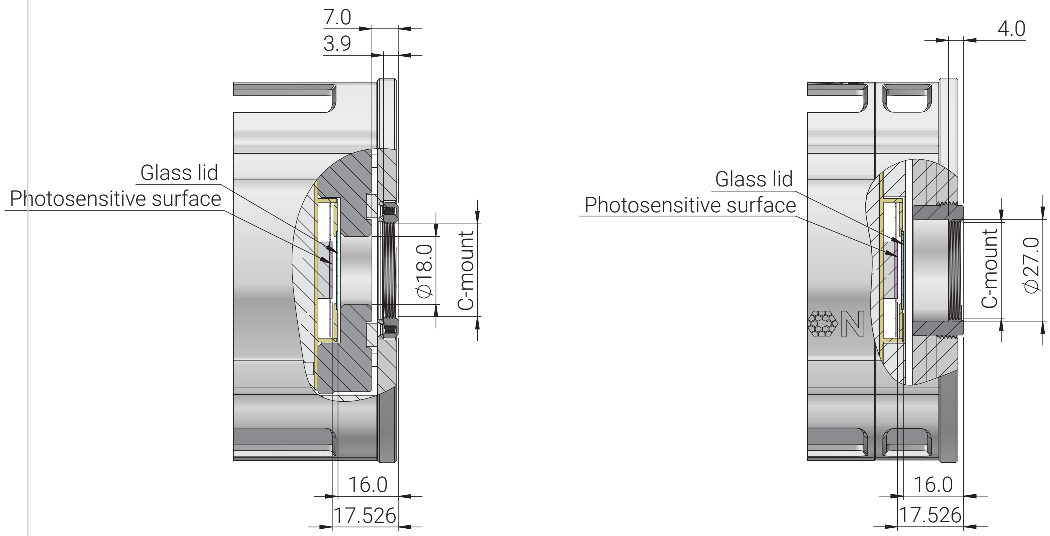

Figure 3-8: *C-mount and optical path for the early (left) and later (right) camera models*

Note:
The lens mount between early VS20 CL cameras and later models differ slightly. Early models have a lens opening that narrows after 7 mm to an 18 mm diameter opening. This could limit the use of some lenses. Newer models widen to a 27 mm diameter after the C-mount thread and do not have this issue.

The back focal distance is set during manufacturing to be close to the nominal 17.526 mm. Under normal circumstances, adjusting this distance is not needed. However, on the later models it is possible to adjust the back focus distance slightly by unscrewing the two set screws [1] on the side of the camera and then adjusting the C-mount lens fitting by rotating [2] as shown inFigure 3-9.

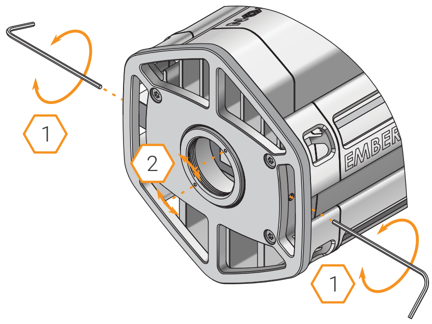

Figure 3-9: *Adjusting the C-mount back focal distance*

CAUTION:
Be aware that over-tightening of the set screws could lead to permanent damage of the camera. This procedure is only to be done as an exceptional adjustment.

3.7.1 Lens selection

When selecting a lens for your camera, you should take the following into account: lens mount, sensor size, pixel pitch, wavelength range, and focal length. If you are new to industrial SWIR lenses, the options can overwhelming. This section explains the basics and will hopefully get you started. For a more thorough primer on lenses, for example, Stemmer Imaging and Edmund Optics offer great online resources.

If a lens is used that is designed for smaller sensors, this leads to a darkened sections, or shadowing, around the edge of your image. The VS20 has a 12.8 x 10.24 mm sensor, or 16.39 mm diagonal. Sensor size, or optical format, is defined as 16 mm diagonal equals a ‘1 inch sensor’. By this definition, the Emberion VS20 has a 1.02 inch sensor. The aspect ratio of a ‘standard’ 1 inch sensor is 4:3; for VGA this results in 640 x 480 pixels. Often, as is the case with the Emberion VS20, this is increased to 5:4 or 640 x 512 pixels. As a result, many lenses designed for 1 inch sensors are also designed to work well with these 5:4 aspect ratio sensors without visible lens shading. When selecting lenses for the VS20 CL, both 1 or 1.1 inch sensors match nicely with the VS20 CL camera.

A unique feature of the VS20 CL is the very broad wavelength range, from 400 nm up to 2000 nm. This poses unique challenges for lens design. All lenses depend on light refraction, which is wavelength dependent. Thus, all lenses suffer from chromatic aberration or wavelength-dependent focal-points. This effect is easy to spot in colour images as colour gradients around sharp edges. For monochromatic cameras, like the VS20 CL, this can be seen as blurry edges and is therefore a little harder to spot. In practice, this effect becomes clearly visible when you switch between filters, you will have to re-focus to get a sharp image of the object. The pixel pitch or megapixel value that is often given in lens datasheets is closely related to this. If the chromatic aberration is too large, decreasing the pixel pitch of an image sensor does not lead to a sharper image. Neither does grinding to a higher precision lead to better images. The VS20 CL has relatively large pixels/ low resolution (20 µm/ 0.3 Mpixel) but very broad wavelength range, so the resolution for which a lens is designed is likely not a driving requirement when selecting a lens for your application.

Emberion has evaluated several sensors, but there are many more lenses available on the market. Table 3-7 gives an overview of the lenses that are tested and work well with the VS20 CL.

Table 3-7: *Lenses evaluated for use with the Emberion VS20 CL.*

Manufacturer	Lens	Spectral Range	Max aperture	Focal length	F.O.V.
Kowa	S10-591	450 - 2000 nm	f/1.8	35 mm	10.2° x 7.7°
Stingray	SR2814-A01	450 - 1700 nm	f/1.4	50 mm	
VS Technology	VS-5018H1-SWIR	800 - 2000 nm	f/1.8	50 mm	12.8° x 12.8°
VS Technology	VS-1214H1-SWIR	800 - 2000 nm	f/1.4	12 mm	50.8° x 50.8°
Edmund optics	68-689	800 - 2000 nm	f/1.4	35 mm	14.4° [H]
Edmund optics	83-817	800 - 2000 nm	f/1.4	16 mm	44.3° [H]

Figure 3-10 shows the following:

- Left: VS20 VGA sensor (1) compared to a ‘standard’ 1 inch sensor (2).
- Right: chromatic aberration becomes more prominent as wavelength range increases.

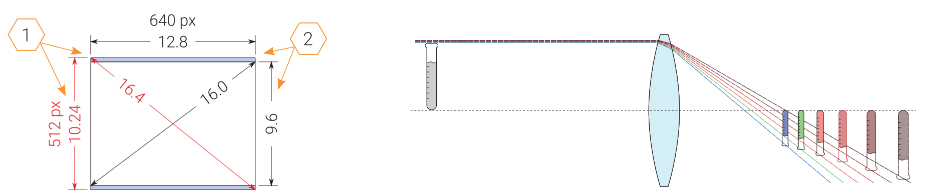

Figure 3-10: *Sensor size and chromatic aberration*

3.8 Image sensor

Add stuff from Sami (superfisial working of the sensor), Surama (package design, AR-coating, ALD, SU8, etc.)

3.8.1 Image sensor, sensor package and protection

The image sensor in the Emberion VS20 camera consists of a CMOS ROIC with a proprietary CQD layer on top.[1] The active sensor area is 12.8 x 10.24 mm, with square 20 x 20 µm pixels. This gives a resolution of 640 x 512 pixels, a 16.39 mm diagonal and an optical format of 1.02 inch.[2]

To protect the image sensor and ensure long term stability of the photosensitive material, there are protective layers on top of the CQD layers. The image sensor is housed in a hermetically sealed metal package. Inside the package, the sensor sits on top of a two-stage TEC cooler. The TEC cooler keeps the ROIC at one of the calibration temperatures.

The package has a sapphire window with Anti-Reflective (AR) coating on both sides. The AR coating is for 400 up to 2500 nm, with an average transmission of over 90% for the entire range.[3]

Please contact Emberion if your application has special requirements, or you would like more details on these protection measures. In Figure 3-11, the focal plane array (FPA) or photosensitive area is highlighted in red. The ROIC sits on top of the TEC (dashed lines).

[1]CMOS Read-Out Integrated Circuit with Colloidal Quantum Dots

[2]Optical format is defined as 16 mm equals a ‘1 inch sensor’; 16.39 mm is an optical format of 1.02 inch

[3]Angle of Incidence, A.O.I. = 0°

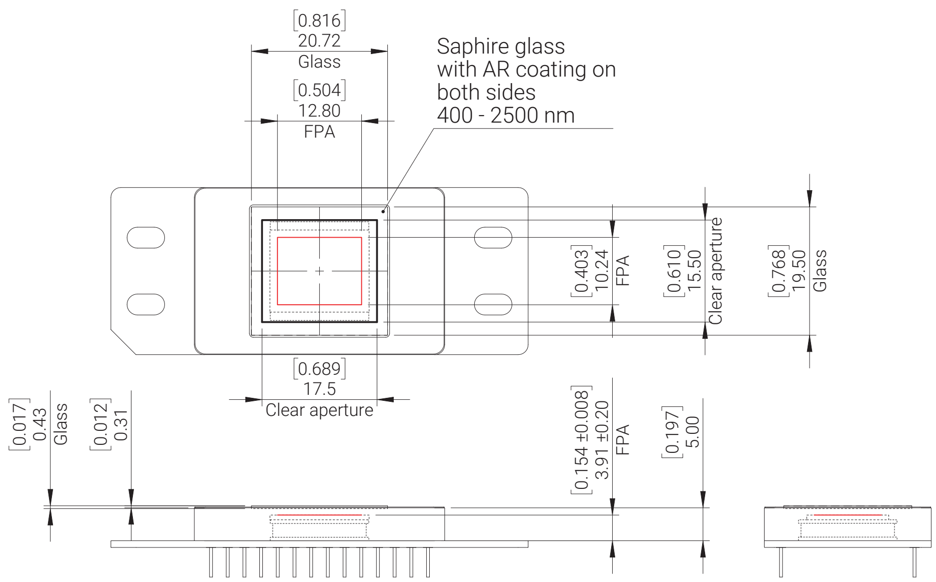

Figure 3-11: *VS20 image sensor package details*

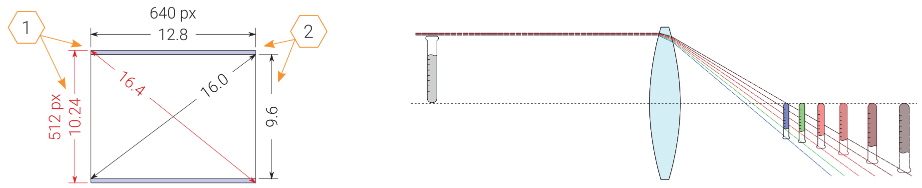

Figure 3-12: *Sensor size and chromatic aberration*

Insert some crap about TEC, copied from footer:

Thermoelectric cooler, a solid-state heat pump used to stabilize the temperature of the image sensor. TEC and (image) sensor temperature are used interchangeably in this document.

3.9 Pixel response

TBD.

Chapter 4: Image processing pipeline

The image processing pipeline is embedded in the camera hardware. It sits between the ADC and the Camera Link interface (that communicates data between the camera and the PC).

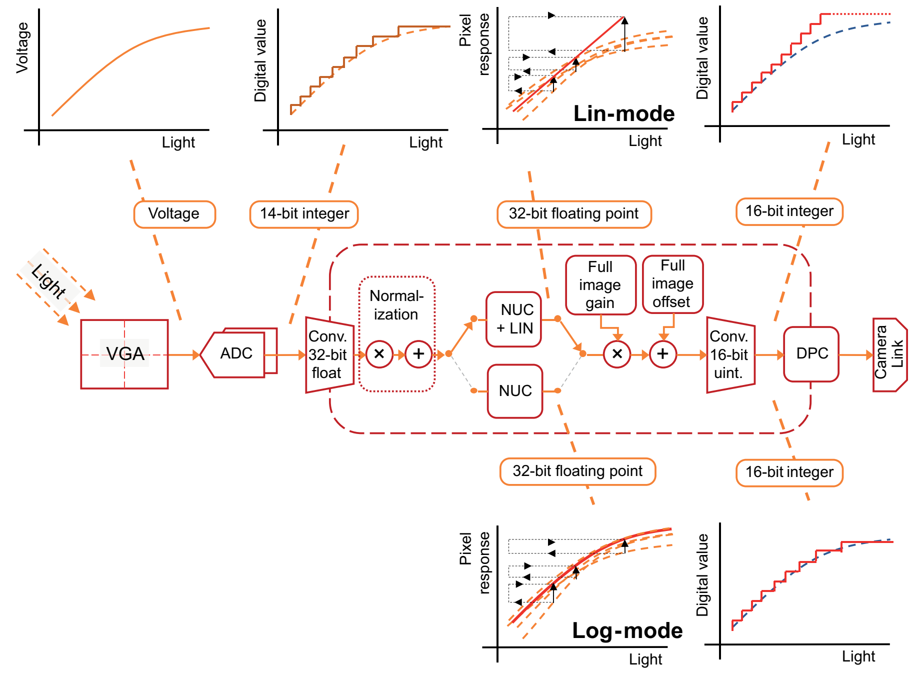

Figure 4-1: Image processing pipeline: block diagram

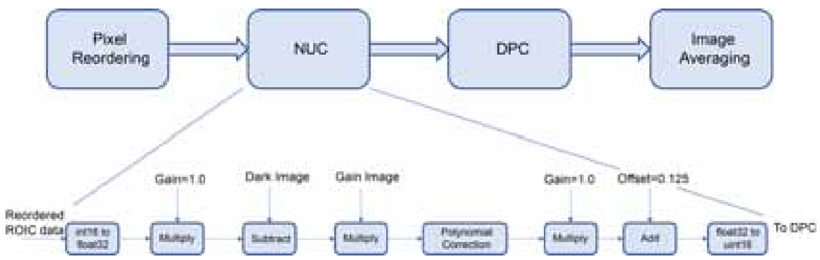

Figure 4-2: Image processing pipeline: NUC modules

4.1 Defective Pixel Correction (DPC)

Note: Throughout this guide we use the terms ‘defective’ and ‘inoperable’ interchangeably. ‘Defective’ is used most often when talking about the DPC algorithm. Inoperable is used most often when talking about the pixels themselves. A pixel might be completely inoperable, in that it does not respond to light at all. Pixels that respond to light, but not as expected, can also be declared as inoperable. For example, poor pixel response might result from poor adhesion to the sensor substrate. Currently, after testing, we set an ‘inoperable pixel map’ in firmware before the camera leaves the factory (data is supplied as part of the standard Measurement Report).

DPC only processes inoperable pixels; it has no effect on data from good pixels. It uses a simple neighbourhood averaging technique, applying data from good pixels surrounding the inoperable pixel. DPC is on by default. You can disable it in the software user interface if you wish.

We use the following criteria to decide whether a pixel is declared as inoperable:

Pixels with very high noise.

Pixels with a poor fit to one or more of the image models (Dark Image model, Gain Image model and Final Image model).

4.2 Image Averaging

Averaging image data across the sensor array can lead to blurring, so we use temporal averaging to reduce temporal noise. You can enable or disable this function in the camera’s software user interface. By default it is disabled.

This can be useful for very short exposure times (up to 1.0 ms) which are more likely to have poor SNR.

Note: Image Averaging does not reduce spatial non-uniformity noise. If you increase the Image Averaging factor by a large amount (e.g. 100 images), temporal noise will almost completely disappear, any residual spatial non-uniformity noise not removed by the NUC will be revealed.

4.3 Pixel reordering

The image array is divided into four quadrants, with data from each quadrant being taken from the read-out IC (ROIC) simultaneously, in parallel.

Pixel reordering allows the image data to be sent to the PC in the correct order, row by row (each pixel image is buffered in memory then shuffled into the correct order).

4.4 Non uniformity correction (NUC)

Needs an introduction.

4.4.1 Data format

14-bit data from the ADC is sign-extended to 16-bit, then converted to 32-bit floating point for all computations within the NUC.

4.4.2 Gain=1.0 multiplication

Every pixel value in the image is multiplied by an optional constant, set by default to 1.0. This would compensate for any tunable gain in the ROIC (the ROIC is calibrated to one specific gain value, but that value can be changed during operation). So, for example, if you used a tunable gain of 2.0 in the ROIC, you would set this optional gain value to 0.5 to compensate.

4.4.3 Dark Image

This is a pixel-specific correction to account for any non-zero voltage signal present when no light is incident on the sensor. During calibration, recorded dark image readings for different exposure time values are used to calculate dark image model parameters; the dark images are then discarded. The model parameters are saved into camera memory and used to generate the required dark images during operation.

4.4.4 Gain Image

Non-uniformity of pixel values when light is incident on the sensor (the Gain Image values) is dependent on exposure time – in a similar fashion to the Dark Image values – but it is also dependent on light intensity. To avoid unnecessary complication in the next stage of the image processing pipeline, a single Gain Image multiplication factor is arrived at for each pixel using a reference exposure value of 10ms. So for example if the exposure time is less than 10 ms, the Gain Image factor would amplify the received voltage to bring it in line with the reference exposure time of 10 ms.

Sensor output is a non-linear function of both light intensity and exposure time. We split this dependence into two separate functions:

- A polynomial function that models sensor output as a function of light intensity for a fixed 10 ms exposure time.
- A non-linear function that models sensor output as function of exposure time for a fixed light intensity. This non-linear function gives the appropriate gain value that should be used for each exposure time:
  - Gain = 1 for 10 ms exposure
  - Gain < 1 for exposure time > 10 ms
  - Gain > 1 for exposure time < 10 ms.

4.4.5 Polynomial Correction

This performs the actual Non Uniformity Correction on the normalised pixel values from the ROIC, taking into account the reference Gain Image multiplication factor from the previous stage. This allows us to approximate each pixel's NUC value at any given light intensity, by multiplying the actual Polynomial Correction value by the reference Polynomial Correction function.

4.4.6 Gain (user-definable)

These are global factors, applied to every pixel. Everything within the NUC is in 32-bit floating point format, which gives the potential to represent very large values, but at the end of the Image Processing Pipeline everything needs to be compressed to 16-bit integer format. So, for a very bright image (for example), without any gain applied, everything gets saturated during the compression/conversion. Typically, the optional Gain applied =1.0, but if you want to attenuate the image you can set it to a lower value. Similarly, if you want to amplify the image, you can use a higher value.

4.4.7 Offset (user-definable)

Set by default to 0.125, you can add or subtract a constant value from every pixel to adjust the overall image intensity. If you don't want to adjust the image, set the Offset to zero.

Post-NUC offset is provided as an option in case float32 values drift towards the negative side. Converting negative float32 values to unsigned-16 format will result in loss of information, so negative values can be brought back to the positive side by adding a small offset before conversion to unsigned-16 format.

4.4.8 Data format

After the NUC calculations have been performed, data is converted back to uint16 format before being fed into the Defective Pixel Correction (DPC) module.

4.5 FAQ

This topic answers some typical questions asked by users about the image processing pipeline.

What does the pixel-response do if we change the integration (exposure) time?

The signal response follows the exponential function shown in the figure below, where V_{out} is the signal output from the sensor, t the exposure (integration) time, and τ the pixel time constant.

$$V_{\text{out}} = V_{\text{out,max}}\,(1.0 - \exp(-t/\tau))$$

Figure 4-3: Pixel response: exponential function

Here, $V_{out,max}$ = Responsivity*Optical power.

Tau depends on temperature and is roughly 50 ms for the VS20 (CL/GigE) camera.

Tau depends on temperature and is roughly xx ms for the VS17 camera.

The pixel (signal) response is immediate and is proportional to the optical power. So, increasing the light intensity leads to a stronger signal response. The optical power to signal response has a logarithmic function (see section <> on dynamic range).

From the inverse exponential function shown in "Pixel response: exponential function" above we see that the pixel signal level has its upper limit at $V_{out,max}$. For very low light intensities this means that, even for infinitely long integration times, the signal does not not rise above the noise level of the sensor. Increasing the exposure time beyond 2τ results in limited increase in the signal quality. This can be counter-intuitive, as a ‘regular’ camera does see increased signal response at high integration times.

"Pixel response variation with exposure time" on the next page illustrates this behaviour with three arbitrary optical signals: a very low optical power (orange line), a medium power (blue line) and a high intensity input (green line). All three signals settle to their respective $V_{out,max}$, yet the low-power signal never climbs above a signal-to-noise ratio of 1.

In practice, this means that the best result can found by varying the integration time between 0.1 and 100 ms. At lower exposure times, the available optical power is often limiting, and at higher exposure times, there is limited increase in signal response. At even higher exposure times, other factors such as leakage current, become dominant.

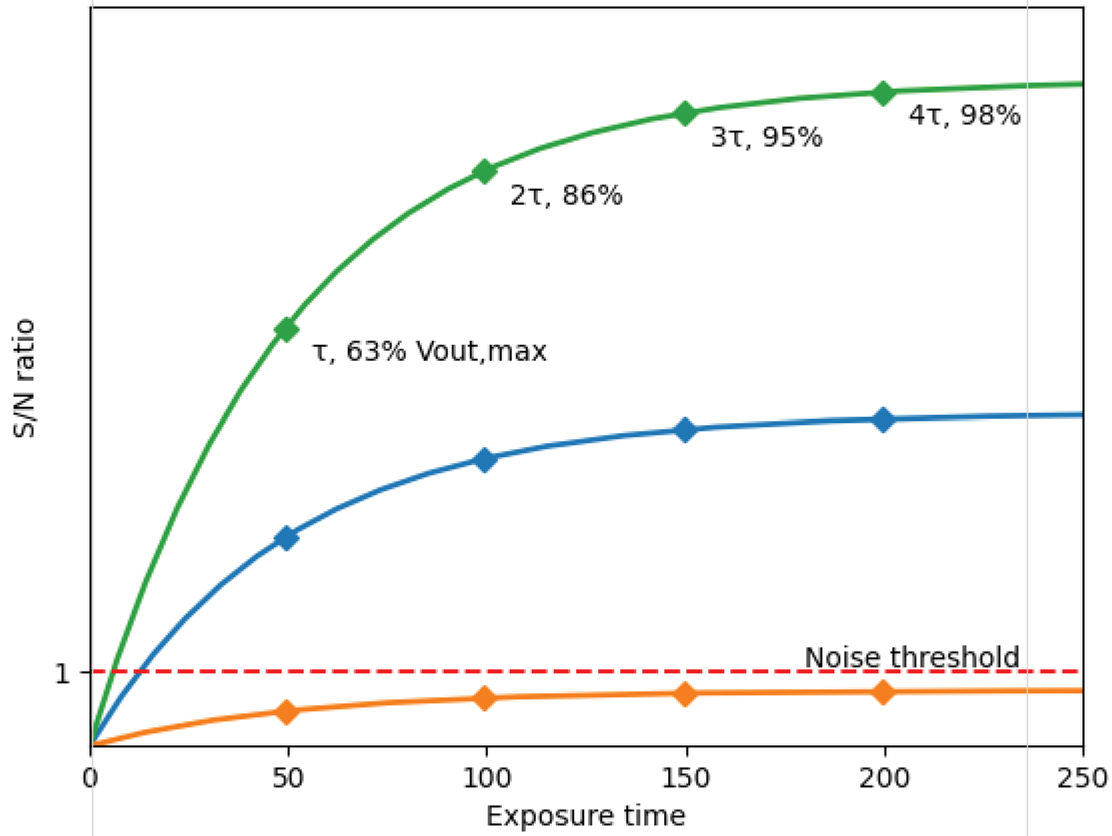

Figure 4-4: *Pixel response variation with exposure time*

What does the pixel response do if we increase the light input?

The pixel response w.r.t. light intensity (optical power) is logarithmic, so it will never saturate. The logarithmic nature of these pixels makes them well suited to capturing HDR scenes.

What is the difference between the 14-bit input, 32-bit floating inside the pixel pipeline, and the 16-bit output?

Data from the ADC is 14-bit, but we sign extend it to 16-bit data (it has to be a multiple of 8). We then convert that to 32-bit floating-point format for all the computations inside the NUC block. After NUC, data is converted back to 16-bit integer format before being passed to the DPC block.

We use floating point arithmetic due to its superior dynamic range. This is useful in calculating polynomial terms involving higher powers. DPC does not require large dynamic range so we use unsigned-16 format.

What do we understand as the 'raw' image?

We define this as the point between the Dark Image and the Gain Image, rather than the output from the ROIC. While other manufacturers apply some preprocessing in the ROIC, our 'preprocessed' image is the result of the ROIC data minus the Dark Image.

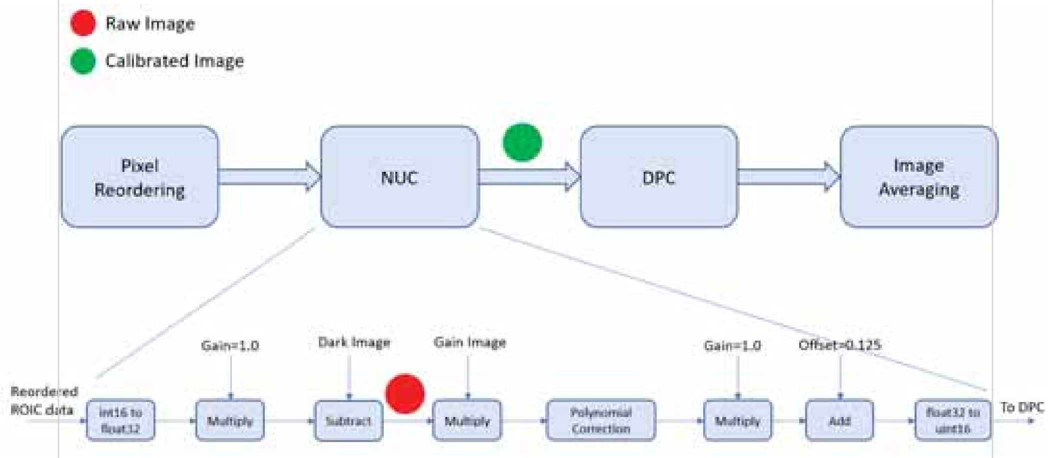

Figure 4-5: RAW and calibrated image position in image pipeline

What does the NUC (non-uniformity correction do)?

NUC removes pixel-to-pixel variations. Without NUC, different pixels will output different values even when same amount of light falls on them.

What is linearization (and why is it not useful for high dynamic range images, where you have bright and dark)?

This is where we assume that, after non-uniformity correction, the sensor's pixel response is linear. It is useful in situations such as spectral analysis, where you want to avoid distorting the spectral results: using logarithmic analysis would be overly complicated, and you would have to perform complicated calculations to compensate. Another example might be if you were using a robotic arm to items from a conveyor belt based on reflected light intensity; again, here it is better to assume the sensor has a linear pixel response. On the other hand, if you have a high dynamic range (HDR) image, a linear pixel response would have difficulty discerning different intensity levels in highlights and/or shadows. In this case, assuming a logarithmic response is much better.

Why do I need to tweak gain and offset?

Gain and offset are applied to floating point data just before we convert it to unsigned-16 format. By adjusting gain and offset you can ensure that floating point data fits nicely in the unsigned-16 range before it is converted.

Why is 10 ms a magic number in our pixel response?

When calibrating the camera, we measure pixel response across a range of light intensities, keeping the exposure at 10 ms. 10 ms is a convenient number between 1 ms and 80 ms. This is the range of exposure values where we expect these pixels to vary their output. We don't expect any increase above 80 ms exposure time.

How can I use the camera to measure the number of photons or amount of light?

Or, how does what I see on the output correlate back to a physical quantity that I want to measure?

To measure the number of photons you need to do two things:

- Operate the camera in linear mode: You can select this in the user interface.
- Find the missing scaling factor that would convert the unsigned-16 value to the actual number of photons: You need to capture an image for which you know the actual number of photons falling on each pixel. This will give you the scaling factor. You can then use this scaling factor to convert from unsigned-16 to the number of photons for arbitrary lighting conditions.

Chapter 5: CAD Drawings

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Chapter 6: Glossary

0

0b

Indication that number following '0b' is a binary number

0x

Indication that number following '0x' is a hexadecimal number

C

Camera Link

Interface used in industrial cameras based on serialised parallel LVDS data transmission

CQD

Colloidal quantum dots are nanoscale semiconductor crystals with surface ligands that enable their dispersion in solvents.

F

FPA

Focal plane array, the light sensitive area (pixels) of image the sensor

G

GigE Vision

Interface standard for industrial cameras based on Gigabit Ethernet

N

NIR

Near-infrared, commonly defined as wavelenght range 750 - 1400 nm. Although 0.7 - 1.4 μm, 0.78 - 3 μm and 0.7 - 2.5 μm are also used.

NTC

Negative Temperature Coefficient (thermistor), temperature sensor

R

ROIC

Read out integrated circuit, part of image sensor that amplifies and multiplexes signal from

S

SWIR

Short-wavelength infrared, commonly defined as wavelenght range 1400 - 3000 nm. Although 1.4 - 3 μm, 0.78 - 3 μm and 0.7 - 2.5 μm are also used.

T

TEC

Thermoelectric cooler, cooler/ heater inside the image sensor package

V

VIS

Visible light, commonly defined as wavelenght range 400 - 700 nm. Although 380 - 780 nm are also used.