



## NV04ASC-HW Asynchronous photon-driven camera

### Features

- **64×48 SPAD array**
- **Event-based output**
- **Up to 10 ns timing resolution**
- **Continuous stream at full speed**
- **Single USB-C for power and data**

### Applications

- **Quantum imaging**
- **Machine vision**
- **Low light imaging**
- **High speed imaging**
- **Obstacle detection**
- **Visual odometry**

### Description

The NV04ASC-HW Asynchronous photon-driven camera was developed for applications requiring high sensitivity and/or frame rate but with reduced output bandwidth. It is built around the NovoViz NV04ASC asynchronous single-photon avalanche diode (SPAD) sensor.

The system combines the benefits of a SPAD camera, namely the single-photon resolution and fast operating speeds, with the benefits of an event camera – low output data rates. The innovative sensor architecture streams photon events with nanosecond timestamp resolution and latency over a conventional, low cost USB interface.

The camera only sends out data for pixels that have detected a photon and remains inactive otherwise. This photon-driven output reduces the system data rate and power consumption by a factor of 10×. Due to the advanced architecture, the camera can operate at an equivalent frame rate of up to 100 million single-photon frames per second.

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## 1 Absolute maximum ratings

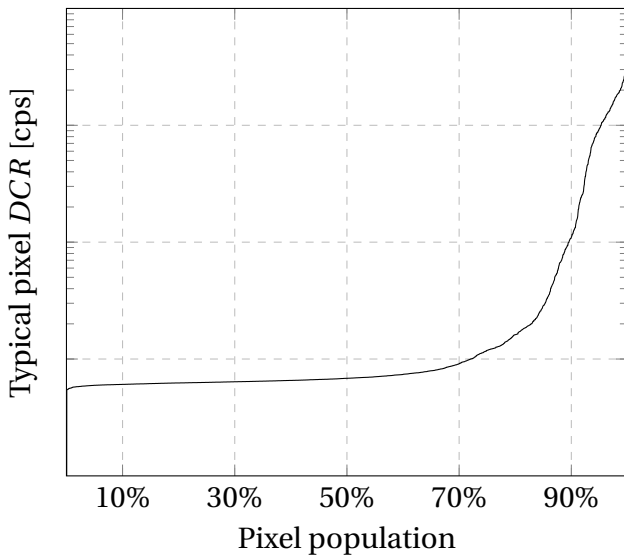
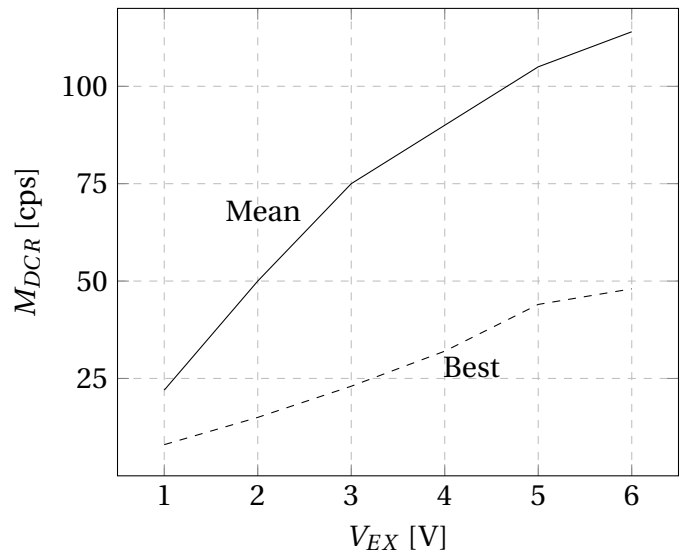
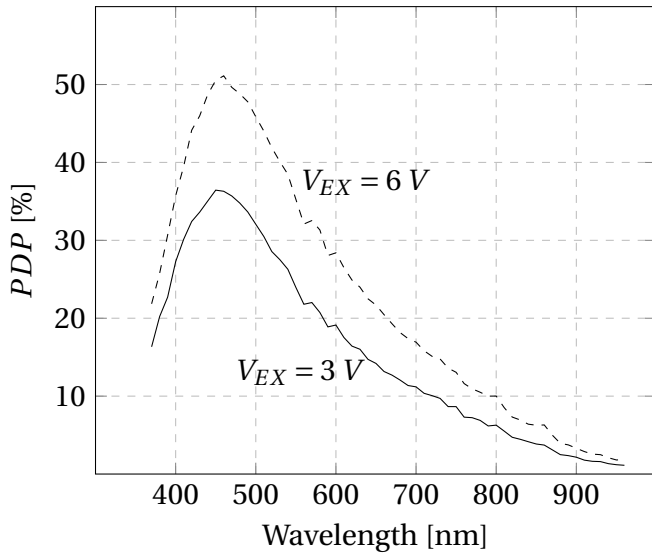
		MIN	MAX	UNIT
$V_{DD}$	Supply voltage	4.5	5.5	V
$V_{EX}$	Excess bias voltage		6	V
$P_{peak}$	Peak power consumption		2000	mW
$T_A$	Operating temperature	10	85	°C
$f_{CLK}$	System clock frequency		100	MHz
$E_G$	Global photon event rate		100 <sup>†</sup>	Mcps
$E_{pxl}$	Single pixel photon event rate		33	Mcps

<sup>†</sup>See section 4.2.

## 2 Specifications

		COMMENT	MIN	TYP	MAX	UNIT
	Array format			64×48		pixels
$P_P$	Pixel pitch			28		μm
$P_\Phi$	Pixel sensitive area diameter			10		μm
$P_{FF}$	Pixel fill factor	Native		10		%
$P_{XTP}$	Pixel crosstalk probability				2	%
$PDP$	Photon detection probability	$\lambda=450$ nm, $V_{EX}=6$ V $\lambda=450$ nm, $V_{EX}=3$ V			50 35	% %
$\lambda_w$	Wavelength window	$PDP>10\%$ , $V_{EX}=6$ V	350		800	nm
$M_{DCR}$	Dark count rate (median)	$T_A=27$ °C, $V_{EX}=3$ V $T_A=27$ °C, $V_{EX}=6$ V	20 40	75 114		cps/pxl cps/pxl
$HPP$	Hot pixel percentage	$DCR > 100M_{DCR}$		10		%
$T_{LSB}$	Timestamp resolution	$T_{CLK}=100$ MHz $T_{CLK}=50$ MHz		10 20		ns ns
$T_{del}$	Latency	$T_{CLK}=100$ MHz $T_{CLK}=50$ MHz	40 80			ns ns
$D_{rate}$	Output data rate	$T_{CLK}=100$ MHz $T_{CLK}=50$ MHz			288 144	MB/s MB/s
	Output data format			24		bit

### 3 Typical characteristics



## 4 Detailed description

The NV04ASC-HW system is an asynchronous photon-driven camera based on the NovoViz NV04ASC sensor. Similarly to an event camera, the output does not consist of frames, so it occupies significantly less output bandwidth, but is dependent on photon flux. Each photon detection will result in an output event being sent via the USB3.0 interface to the host. Even at full speed, when the system clock frequency  $f_{CLK}$  is 100 MHz, the interface has enough bandwidth to support continuous streaming and does not require burst mode operation.

The sensor does not contain a time to digital converter (TDC) but instead has an internal time reference that, at maximum  $f_{CLK}$  updates every 10 ns. When a photon is detected by one of the pixels, the current timestamp is recorded and an internal request is generated. This will result in an output event and a pixel reset.

The output event stream can be processed by the user in order to generate binary frames with a maximum frame rate of 100 million frames per second. Additionally, the binary frames can be accumulated into grayscale frames of various bit depths or logically OR-ed into binary frames of specific exposure lengths.

### 4.1 Output data

The camera output data consists of events, each corresponding to a photon detection on the pixel array. The number of output events, and thus the output bandwidth, is dependent on the photon flux and reaches zero when no photons are detected. Each output event consists of the pixel column index  $X$ , row index  $Y$  and photon arrival timestamp  $T$ . An additional flag bit  $F$  is used to mark a time interval equal to the exposure duration set by the user, which allows easy binary frame accumulation. Figure 1 shows the bit allocation of the 24 bits of the output event.

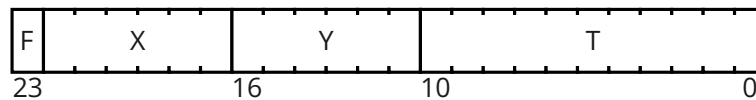


Figure 1: Composition of the 24 bit output event.

### 4.2 Event rate

As long as the global photon event rate  $E_G$  and the single pixel photon event rate  $E_{pxl}$  are below the maximum values specified in Section 1, all of the detected photons are guaranteed to be converted into output events. Both limits are dependent on the system clock frequency  $f_{CLK}$ . If  $E_G$  exceeds the specified limit, the sensor will automatically narrow the region of interest (ROI) by ignoring the pixels with the lowest priority. Due to the internal architecture of the sensor being split into two independent halves, the

ROI can shrink asymmetrically if the photon flux is not concentrated in the middle of the pixel array. The  $E_G$  limit is constant even when the user disables pixels through masking. It is recommended that before running the target application, the user masks the hot pixels in order to decrease the risk of automatic ROI shrinkage.

In case  $E_{pxl}$  exceeds the specified maximum limit, pileup is guaranteed to occur in the respective pixel. During normal operation, the pixel remains busy after detecting the first photon and all subsequent photons will be ignored until the corresponding output event is generated. This dead time interval  $T_{dead}$  is dependent on the photon flux as the pixels are serviced in order of priority, with the highest priority pixels located in the left column of each half and the lowest priority ones in the right ones. As long as there is a higher priority pixel that needs to be serviced following a photon detection, the lower priority one will remain busy. The two halves of the pixel array operate independently. The pixel priority map is shown in Figure 2.

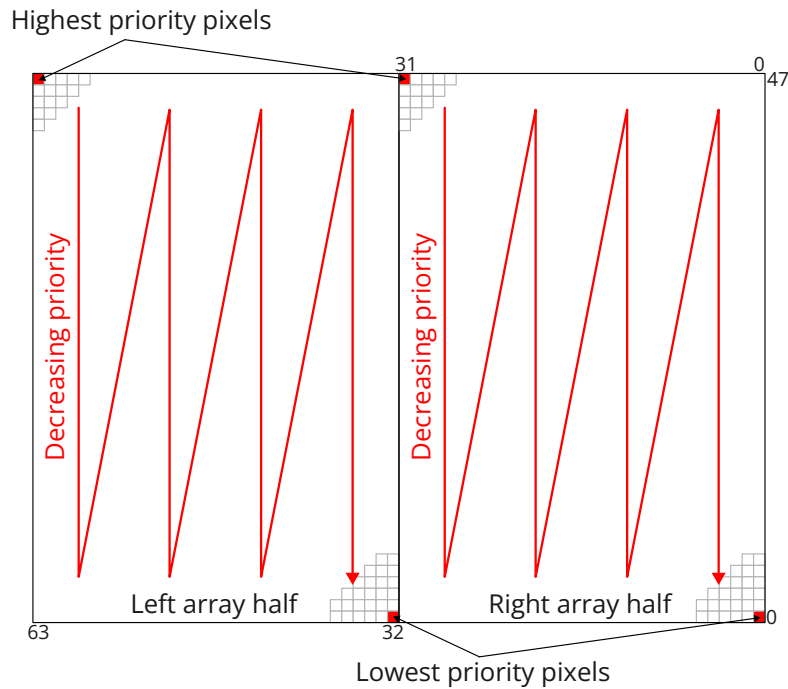


Figure 2: Pixel priority map used by the arbiter circuit when servicing the pixel events.

### 4.3 Pixel masking

The NovoViz NV04ASC sensor supports full custom pixel masking. Any pixel can be masked based on its  $X - Y$  address but the settings are volatile and will be erased after restart. Additionally, all the masks can be cleared simultaneously across the entire array. There is, however, no equivalent method of masking all the pixels at once, and instead the user needs to sequentially mask them. It is recommended that before running the target application, the user masks the hot pixels in order to decrease the risk of

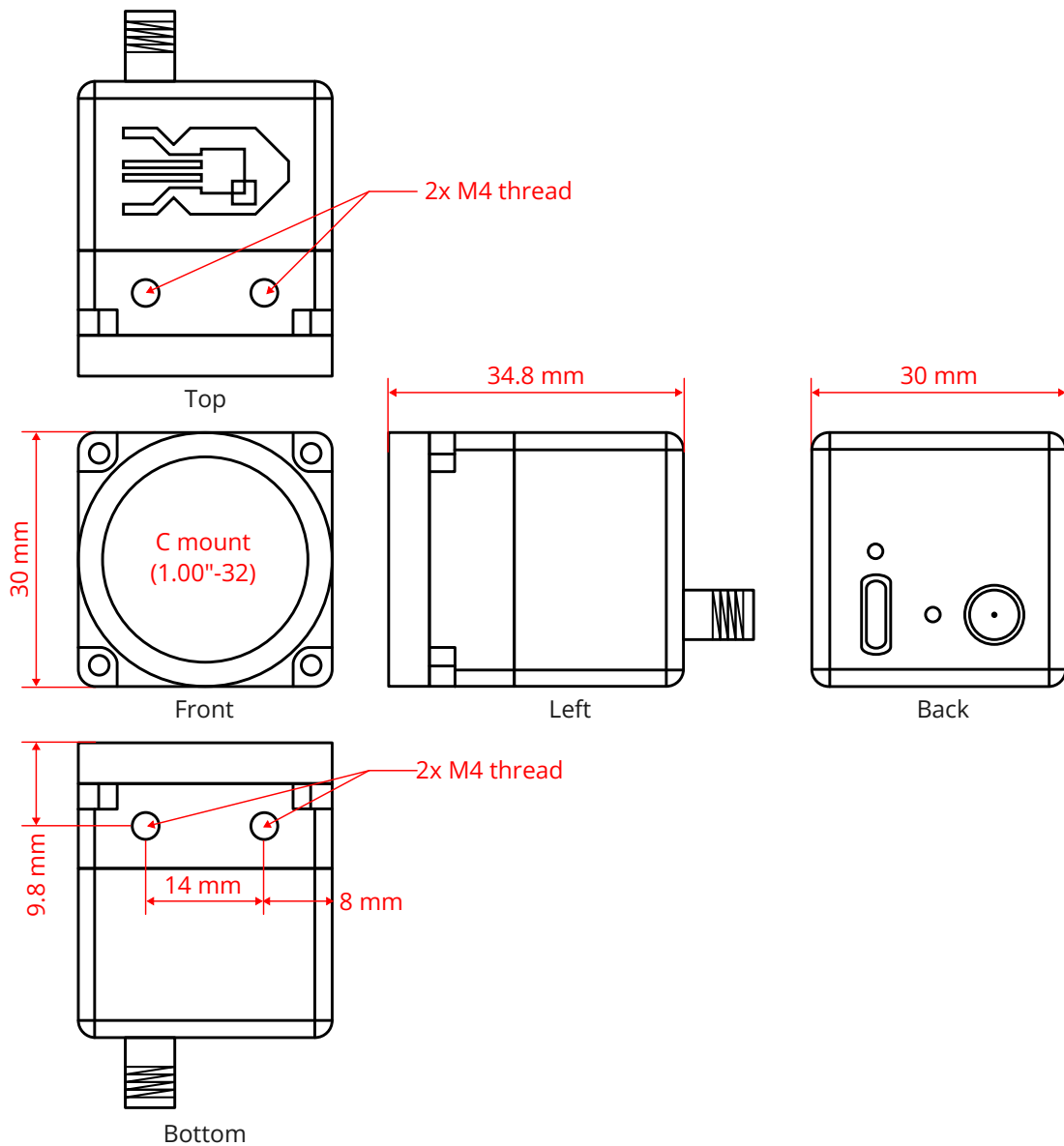
automatic *ROI* shrinkage due to the global event rate  $E_G$  exceeding the limit specified in Section 1.

#### **4.4 Auxiliary port**

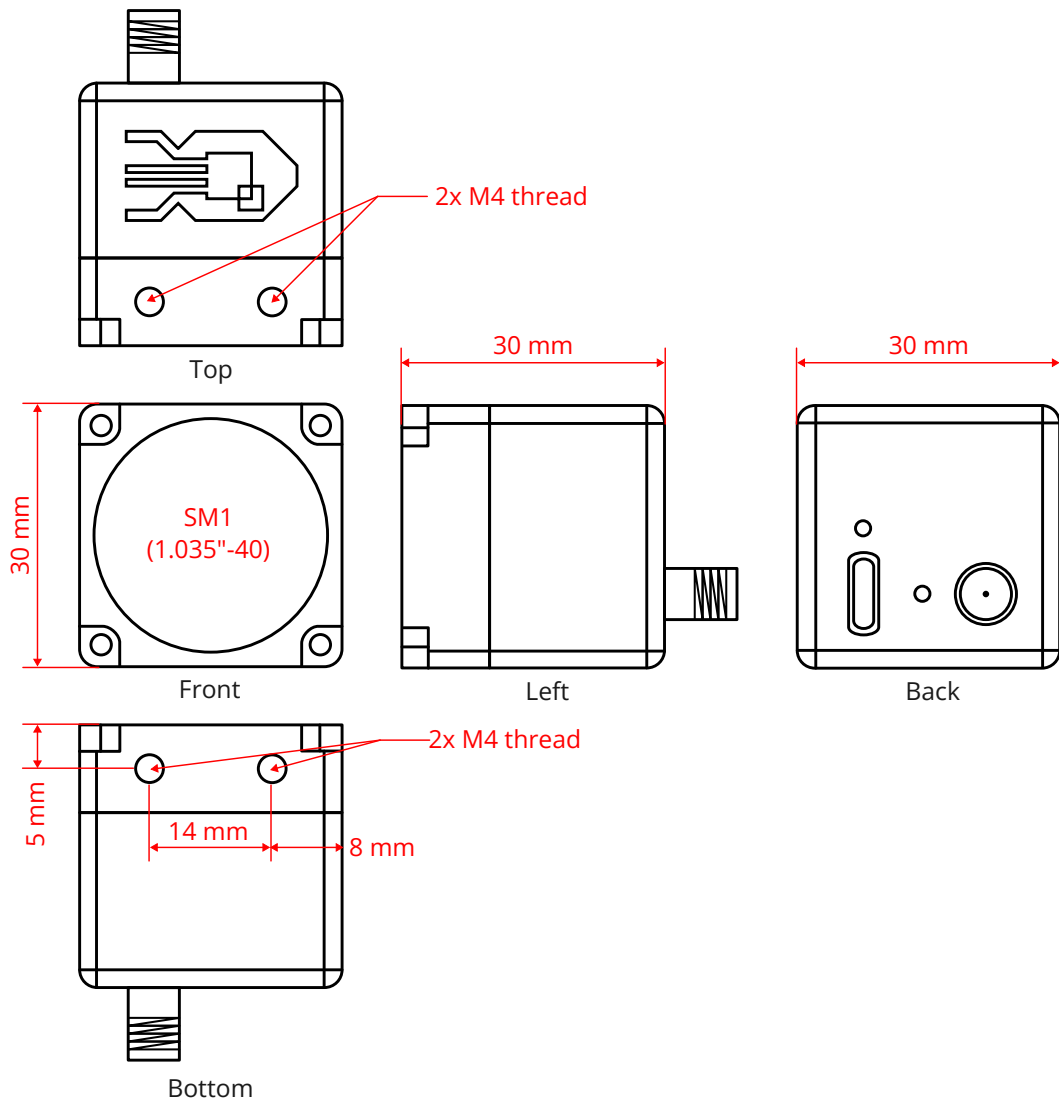
Apart from the USB-C connector, the camera possesses an SMA auxiliary port that functions as a user-defined input/output. This signal can be used for external synchronisation purposes, among others. The default state is HiZ input.

## 5 Mechanical details

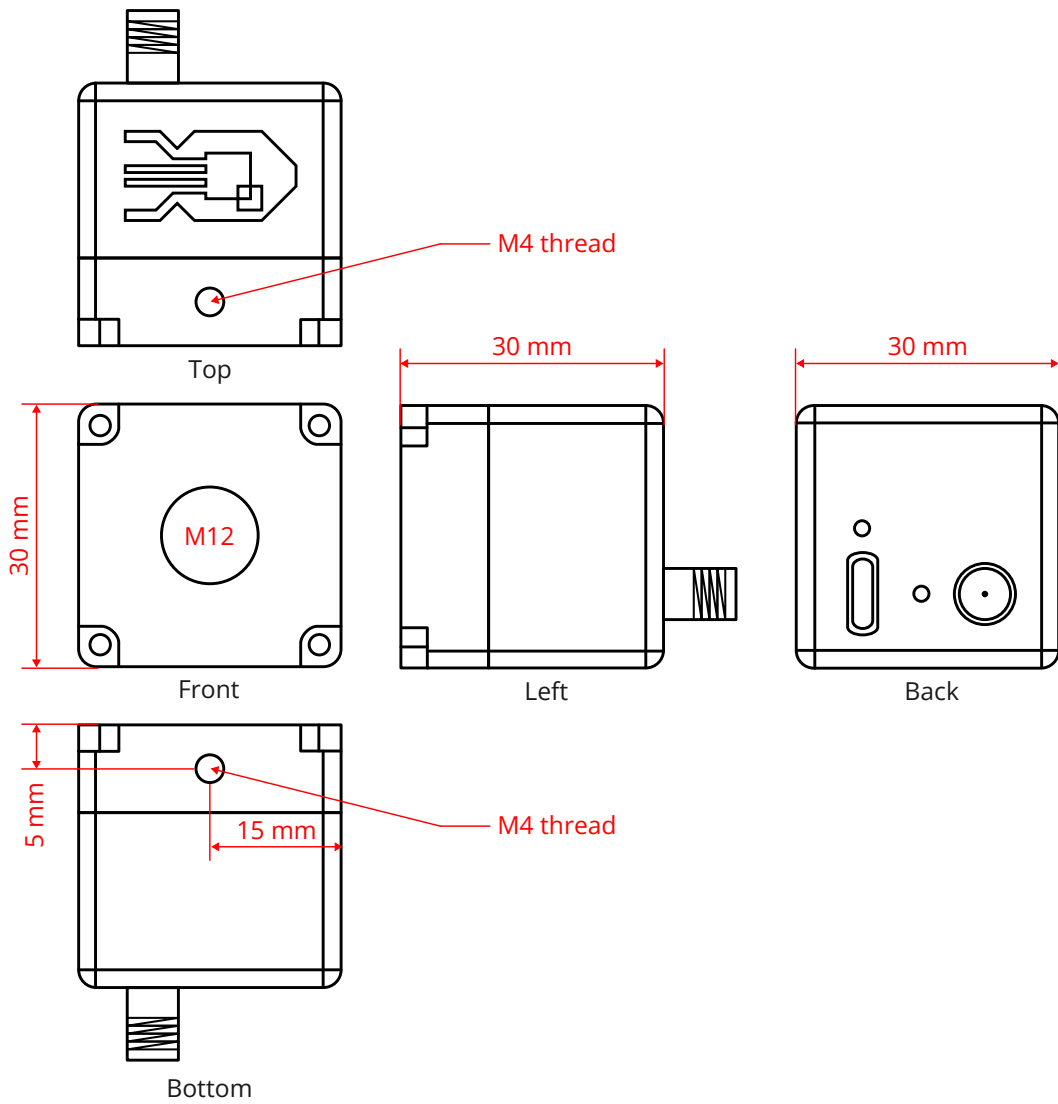
### 5.1 NV04ASC-HW-C - C-mount variant



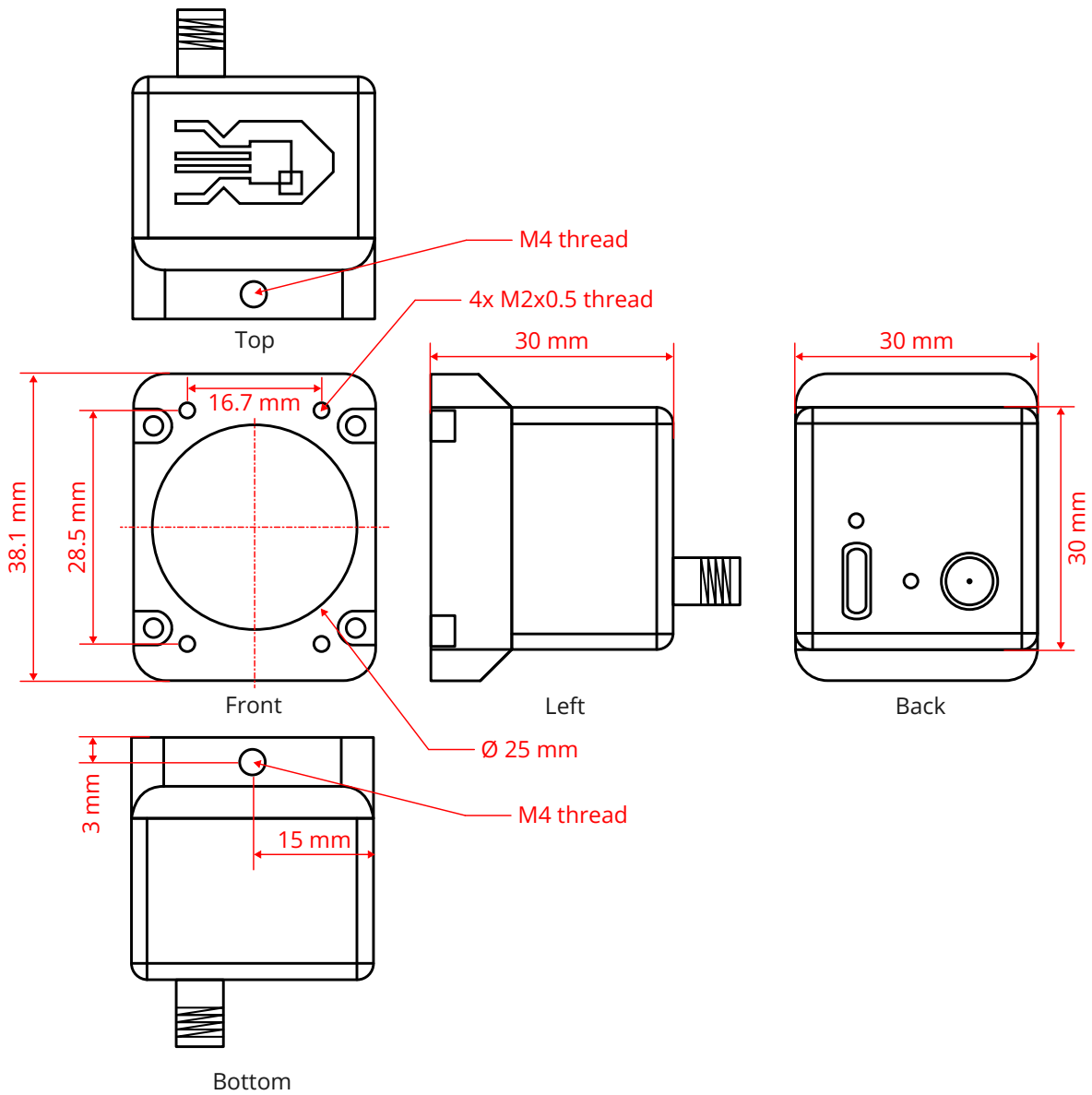
**5.2 NV04ASC-HW-S - SM1-mount variant**



### 5.3 NV04ASC-HW-M - M12/S-mount variant



**5.4 NV04ASC-HW-F - fiber collimator variant**



## **6 Resources**

### **6.1 Documentation updates**

The latest documentation can be found on the specific product page on [www.novoviz.com](http://www.novoviz.com). Please take note of the current document version and review the revision history included in the updated documentation.

### **6.2 Support**

For inquiries please use the contact form on [www.novoviz.com](http://www.novoviz.com).

## 7 Ordering

Part number	Description
NV04ASC-HW-C	Cmount optical port version
NV04ASC-HW-S	SM1 optical port version
NV04ASC-HW-M	M12 optical port version
NV04ASC-HW-F	Fiber coupler version

The NV04ASC-HW comes complete with the latest firmware and a short USB cable. Visit [www.novoviz.com](http://www.novoviz.com) to download the necessary software. The objective/fiber collimator is not included.

The SPAD  $V_{EX}$  is fixed, but the user has the choice to order a 3 V or 6 V camera version, depending on their application needs.

## 8 Notice and disclaimer

### Important notice

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### ESD caution



This device is vulnerable to damage from electrostatic discharge (ESD). NovoViz recommends that all devices be handled using proper ESD precautions. Failure to follow correct handling and installation procedures may result in damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits are often more susceptible, which may cause the device to fail to meet published specifications.