



## NV01PNR-DEV Photon number resolver

### Features

- **4x4 SPAD cluster**
- **One, two, three and four photon threshold**
- **Single SPAD low jitter output channel**
- **Up to 300 Mevents/s per SPAD**
- **All digital outputs**
- **USB-C for power**

### Applications

- **Quantum imaging**
- **Quantum state analysis**
- **Fast QKD**
- **Metrology**

### Description

The NV01PNR-DEV photon number resolver was developed for applications requiring single photon point detectors with low timing jitter. The device does not require any external threshold circuitry and provides a fully digital output, compatible with standard CMOS electronics. It is built around the NovoViz NV01PNR photon number resolver single-photon avalanche diode (SPAD) sensor.

The sensor combines the benefits of a SPAD pixel, namely the single-photon resolution and fast operating speeds, with the benefits of on chip recharge and threshold circuitry – high event rates and reduced noise.

Our innovative sensor architecture has dedicated outputs for single, two, three and four photon thresholds as well as a separate output that connects to a single SPAD in order to optimize the timing jitter. The sensor is well suited for quantum imaging, metrology, depth sensing and QKD, among others.

## Contents

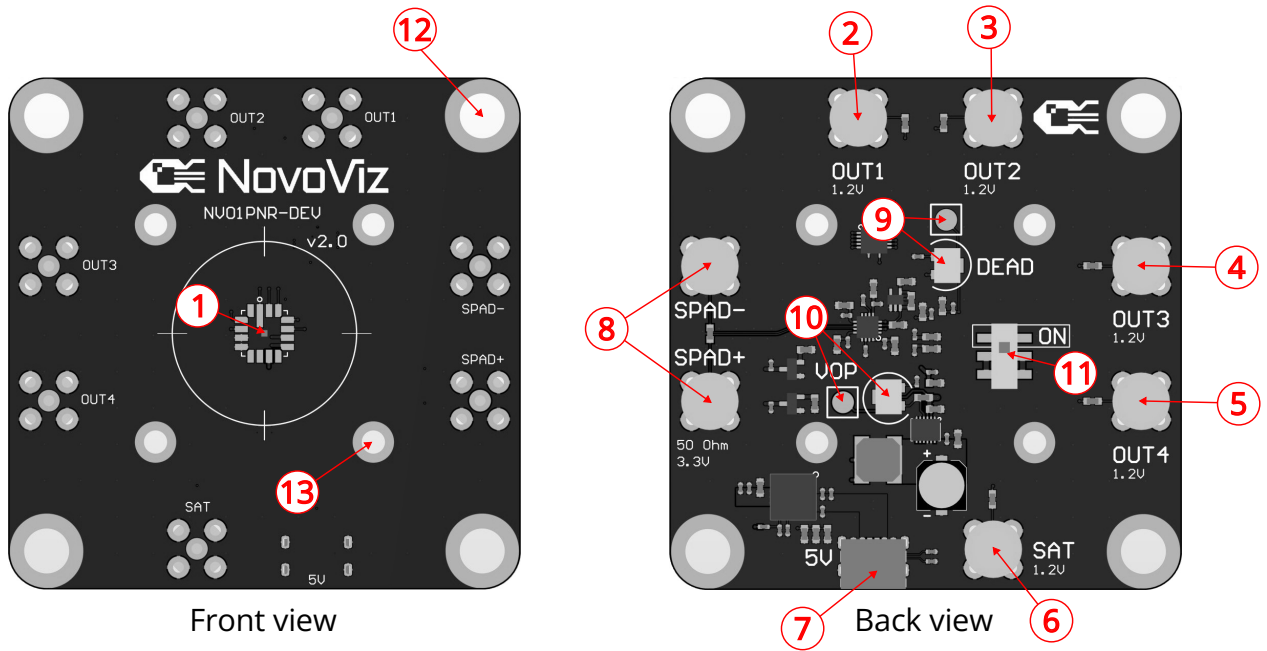
<b>1</b>	<b>Absolute maximum ratings</b>	<b>3</b>
<b>2</b>	<b>Specifications</b>	<b>3</b>
<b>3</b>	<b>Typical characteristics</b>	<b>5</b>
<b>4</b>	<b>Detailed description</b>	<b>6</b>
<b>5</b>	<b>Operation</b>	<b>7</b>
<b>6</b>	<b>Mechanical details</b>	<b>8</b>
<b>7</b>	<b>Resources</b>	<b>9</b>
	7.1 Documentation updates . . . . .	9
	7.2 Support . . . . .	9
<b>8</b>	<b>Ordering</b>	<b>10</b>
<b>9</b>	<b>Notice and disclaimer</b>	<b>11</b>

## 1 Absolute maximum ratings

		MIN	MAX	UNIT
$V_{DD}$	Supply voltage	4.5	5.5	V
$V_{EX}$	Excess bias voltage		3	V
$P_{peak}$	Peak power consumption		550	mW
$T_A$	Operating temperature	10	85	°C
$E_{SPAD}$	Single SPAD photon event rate		300	Mcps

## 2 Specifications

		COMMENT	MIN	TYP	MAX	UNIT
	Cluster format			4×4		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	%
$V_{BRK}$	SPAD breakdown voltage			20.1		V
$PDP$	Photon detection probability	$\lambda=450$ nm, $V_{EX}=3$ V			35	%
$\lambda_W$	Wavelength window	$PDP>10\%$ , $V_{EX}=3$ V	350		720	nm
$DCR$	SPAD dark count rate	$T_A=27$ °C, $V_{EX}=3$ V	20	75		cps
$DCR^1$	OUT1 dark count rate	$T_A=27$ °C, $V_{EX}=3$ V	3500	25000		cps
$DCR^2$	OUT2 dark count rate	$T_A=27$ °C, $V_{EX}=3$ V		140		cps
$T_{DEAD}$	SPAD deadtime		2.5		9.6	ns
$T_W$	Output pulse width			$T_{DEAD}$		ns
$V_{OUT}^X$	OUTx output voltage	$R_{LOAD}=50$ Ω		0.4		V
$V_{OH}^X$	OUTx output voltage high	$R_{LOAD}=50$ Ω	0.3			V
$V_{OL}^X$	OUTx output voltage low	$R_{LOAD}=50$ Ω			0.05	V
$t_{rise}^X$	OUTx rise time	$R_{LOAD}=50$ Ω		1.3		ns
$J_{out}^X$	OUTx jitter	$R_{LOAD}=50$ Ω	415			ps
$V_{OUT}$	SPAD+/- output voltage differential	$R_{LOAD}=50$ Ω to 3.3 V		350		mV
$t_{rise}$	SPAD+/- rise time	$R_{LOAD}=50$ Ω to 3.3 V		1.5		ns
$J_{out}$	SPAD+/- jitter	$R_{LOAD}=50$ Ω to 3.3 V, $V_{EX}=1$ V		100		ps
$APP$	Afterpulsing probability	$T_A=27$ °C, $V_{EX}=3$ V		1.9		%

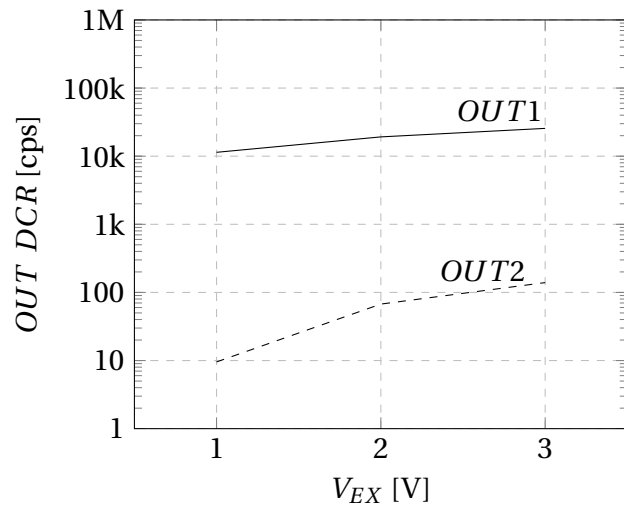
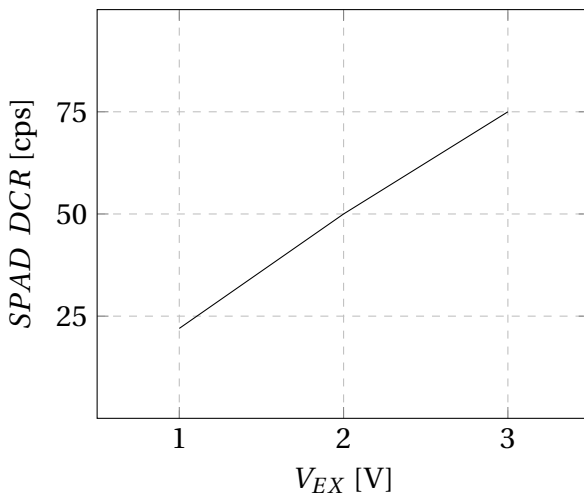
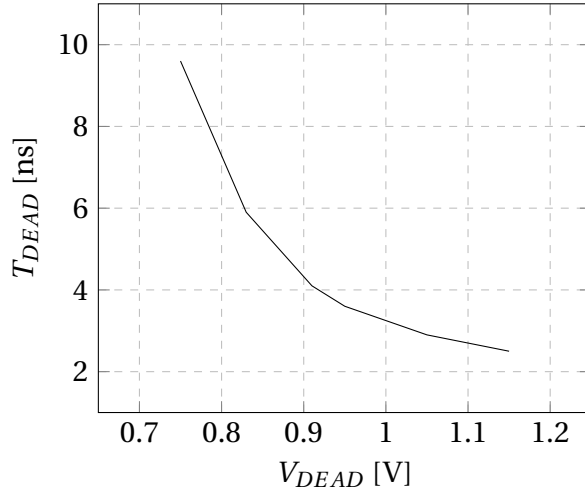
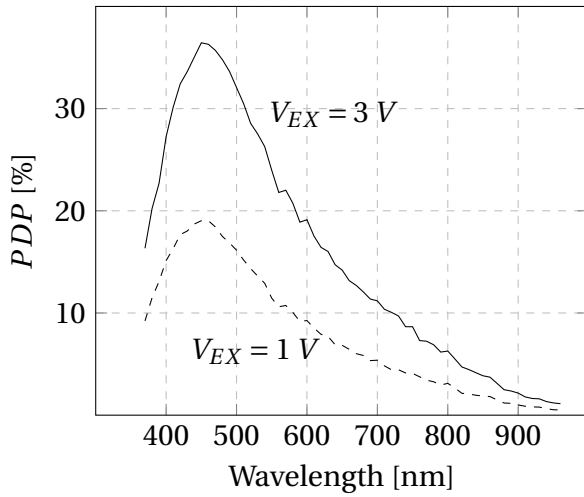


Front view

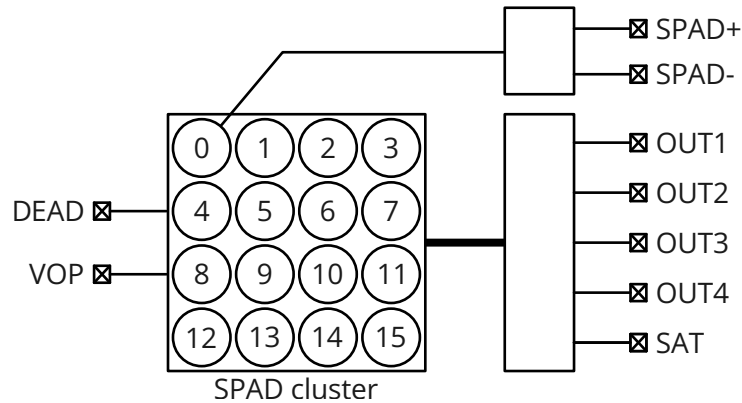
Back view

ITEM	NAME	DESCRIPTION
1		NV01PNR
2	<i>OUT1</i>	Output port for at least 1 photon detection
3	<i>OUT2</i>	Output port for at least 2 simultaneous photon detections
4	<i>OUT3</i>	Output port for at least 3 simultaneous photon detections
5	<i>OUT4</i>	Output port for at least 4 simultaneous photon detections
6	<i>SAT</i>	Output port for 16 simultaneous photon detections
7	USB-C	5 V input power port
8	<i>SPAD + / -</i>	Single SPAD low jitter CML differential output port
9	<i>DEAD</i>	Dead time adjustment trimmer potentiometer and test point
10	<i>VOP</i>	SPAD bias adjustment trimmer potentiometer and test point
11		SPAD power switch
12		6 mm mounting holes for 60 mm cage systems
13		M3 mounting holes for 30 mm cage systems

### 3 Typical characteristics



## 4 Detailed description



The NV01PNR-DEV system is a photon number resolver based on the NovoViz NV01PNR SPAD sensor. It produces a digital pulse at the output channel corresponding to a simultaneous detection of at least one, two, three or four photons across the 4x4 SPAD cluster. Additionally, a saturation output is pulsed in case of a simultaneous detection in all the SPADs of the cluster.

A single SPAD (SPAD0) is connected to a dedicated CML differential output, optimized for low jitter operation. Both signals forming this differential pair need to be terminated with a 50  $\Omega$  resistor to a 3.3 V supply at the receiver end.

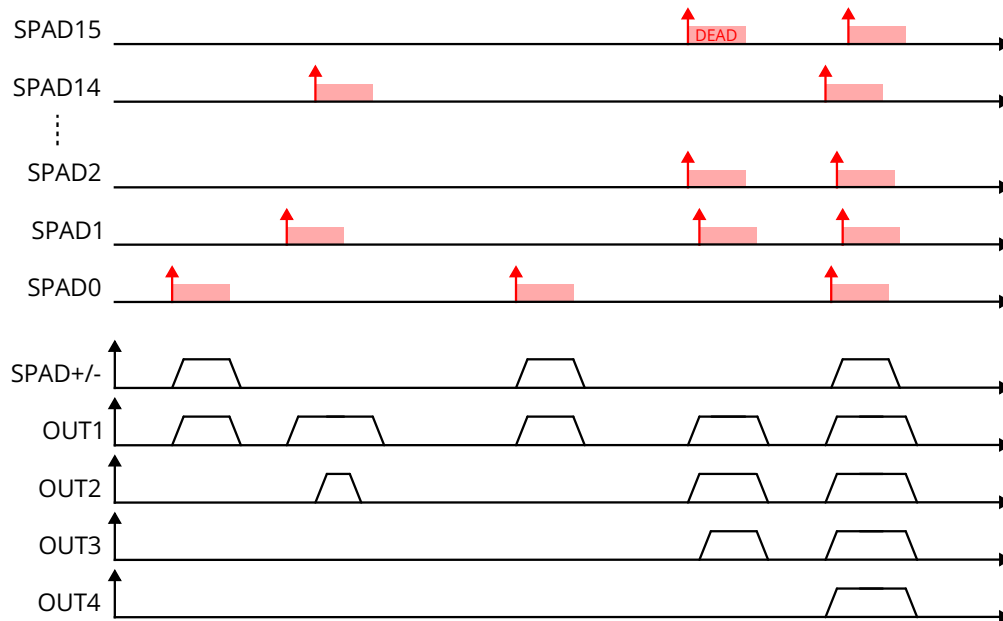
The output pulse width for all channels is equal to the SPAD dead time selected by the user. Each SPAD from the cluster has an independent active recharge circuit with an adjustable dead time, controlled through an external voltage. The user can change this value by adjusting the *DEAD* trimmer potentiometer on the board.

The board requires a single 5 V supply provided through a USB-C connector. The SPAD bias voltage can be adjusted via the *VOP* trimmer potentiometer.



The CML SPAD+/- output has to be terminated at the receiver end with 50  $\Omega$  to 3.3 V, not GND.

## 5 Operation



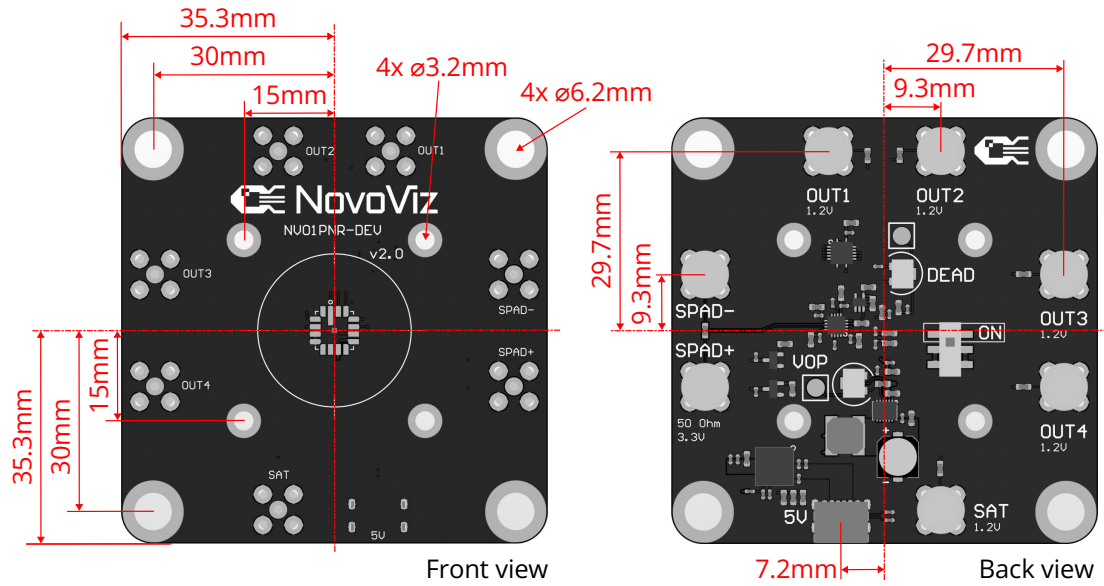
The figure above shows normal operation of the NV01PNR-DEV system, assuming that the SPADs which are not shown do not generate any events. The *SPAD + / -* output pulses with each detection at SPAD0. The other four outputs respond to activity at all 16 SPAD pixels. Namely, *OUT1* pulses every time there is at least one detection in the cluster, *OUT2* for at least two, *OUT3* for at least three and *OUT4* for at least four simultaneous detections. Two events are considered in coincidence if the time interval between them is less than  $T_{DEAD} - 3$  ns. The *SAT* output only triggers when all 16 SPADs have detected a photon.

The switch on the back of the board should be in the OFF position when the power supply is turned on or off. This prevents damage to the SPAD pixels. It must be noted that the SPADs do not turn off instantaneously when the switch is moved to the OFF position after normal operation. A few seconds is needed for the decoupling capacitors to fully discharge below the SPAD breakdown voltage.

Adjusting the SPAD bias voltage with the *VOP* trimmer potentiometer should be done with the switch in the OFF position. The current bias voltage can be measured at the *VOP* test point.

Adjusting the SPAD dead time is done via the *DEAD* trimmer potentiometer, with the control voltage available at the *DEAD* test point. However, the easiest method is to adjust the trimmer potentiometer with the switch in the ON position and to monitor the pulse width at output channel *OUT1*.

## 6 Mechanical details



## **7 Resources**

### **7.1 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.

### **7.2 Support**

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

## 8 Ordering

Part number	Description
NV01PNR-DEV	Standalone board

The NV01PNR-DEV comes as a standalone board. There is no software required to operate the device. There are no cables included.

## 9 Notice and disclaimer

### Important notice

NovoViz provides technical and reliability information (including data sheets), design and application guidance, software tools, safety notes, and other supporting resources for general use only. All such materials are provided “as is” and may contain errors or omissions. NovoViz makes no representations or warranties, express or implied, including any implied warranties of merchantability, fitness for a particular purpose, or non-infringement of third-party intellectual property rights.

These resources are intended for qualified users who are developing applications with NovoViz products. You bear sole responsibility for (1) choosing the appropriate NovoViz products for your specific application, (2) designing, validating, and testing your application, and (3) ensuring that your application complies with all applicable standards, as well as any relevant safety, security, regulatory, or other requirements.

These resources may be updated or modified without prior notice. NovoViz grants you permission to use these materials solely for the development of applications incorporating NovoViz products described therein. Any reproduction, distribution, or display beyond this limited use is strictly prohibited. No license or rights are granted with respect to any other NovoViz intellectual property or any third-party intellectual property. NovoViz disclaims all liability for claims, damages, costs, losses, and liabilities arising from your use of these resources, and you agree to fully indemnify NovoViz and its agents against any such claims.

NovoViz products are provided subject to the NovoViz Terms of Sale or other applicable terms available either on [www.novoviz.com](http://www.novoviz.com) or provided in conjunction with such NovoViz products. NovoViz’s provision of these resources does not expand or otherwise alter NovoViz’s applicable warranties or warranty disclaimers for NovoViz products.

NovoViz objects and rejects any additional or different terms you may have proposed.

### 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.