

Deptrum[®] Nebula 241

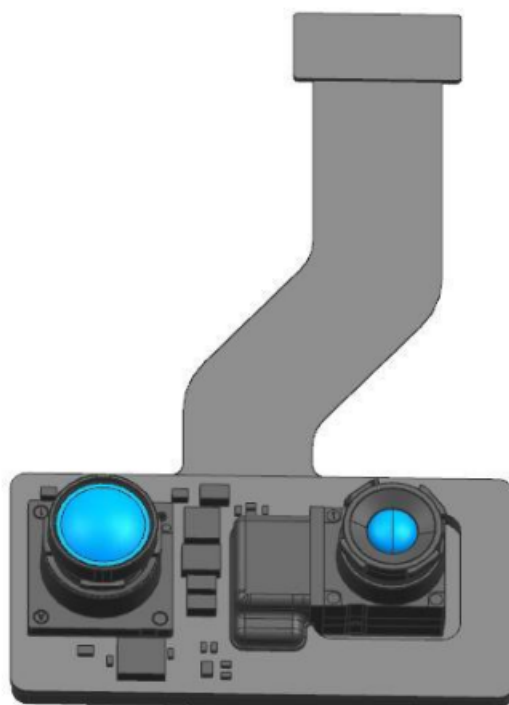
Product Specification

V1.3 - 2026/09/30

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1 Revision History

Version	Description	Date	Revised by
V1.3	Official release	2026/09/30	Hu Tao



Product appearance drawing (incl. FPC cable)

2 Product Overview

Product Introduction The Deptrum® Nebula 241 series depth camera combines 3D structured light technology with modulated ToF technology to capture the 3D structure of objects and spaces, providing both ultra-high-precision depth perception at short range and high-precision depth perception at long range. Based on Deptrum's self-developed WFP photonic chip that modulates the projected light field, the Nebula 241 camera adopts the proprietary structured-light/ToF fusion sToF algorithm and mToF algorithm, effectively eliminating the multipath interference of conventional ToF and greatly improving depth accuracy.¹² System Requirements Supports Windows / Linux / Android; point cloud computing power < 0.8 × A55 @ 1.6 GHz @ 6 Hz.	Product Features • High-precision ground obstacle detection • A single module meets both short-range obstacle avoidance and long-range SLAM depth requirements • Multipath interference resistance • Low motion blur • Large FOV • Compatible with ground obstacle segmentation algorithms and 3D SLAM algorithms Applications • Commercial service robots • Robot vacuum cleaners • Stair-climbing robots
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¹sToF: StructureLight + iToF, a 3D algorithm fusing the soft-core structured-light reconstruction algorithm with the iToF algorithm, mainly used for short-range obstacle avoidance;

²mToF: modulated ToF, a speckle iToF technology implemented based on the modulated projection light field of the WFP photonic chip, mainly used for long-range SLAM

3 Core Specifications

Nebula 241 Product Specifications		
Module Parameters	Optical module dimensions	31.25 × 15.35 × 8.78 mm
	Baseline	17.95 mm
	Operating temperature	-10°C ~ +40°C
	Operating humidity	0% ~ 95% RH, non-condensing
	Maximum average power consumption	< 0.8 W (in sToF/10 fps + mToF/10 fps HDR mode)
	Safety	Class 1 laser safety
	Mounting height	Recommended horizontal mounting height 5 ~ 8 cm; mounting pitch angle < ±10°, yaw angle < ±5°, roll angle < ±2°
sToF obstacle-avoidance depth image performance	sToF obstacle-avoidance working distance	3 ~ 120 cm
	sToF resolution / frame rate	≥ 248 × 180 @ 10 fps
	sToF precision (90% reflectivity white wall test)	≤ 3.5 mm @ [3 cm, 30 cm] ³ ≤ 1% @ (30 cm, 120 cm]
	sToF precision (20% reflectivity gray wall test)	≤ 3.5 mm @ [3 cm, 30 cm]; ≤ 1% @ (30 cm, 120 cm]
	sToF accuracy (90% reflectivity white wall test)	≤ 10 mm @ [3 cm, 35 cm]; ≤ 1.5% @ (35 cm, 60 cm]; ≤ 1% @ (60 cm, 120 cm]

³In sToF precision, the 3 cm limit range refers to the nearest limit range at which the robot can stably reconstruct while dynamically moving from far to near; the nearest distance with streaming enabled in static conditions is about 5 cm

	sToF accuracy (20% reflectivity gray wall test)	$\leq 10 \text{ mm @ [3 cm, 35 cm]}$; $\leq 1.5\% \text{ @ (35 cm, 60 cm)}$; $\leq 1\% \text{ @ (60 cm, 120 cm)}$
	sToF obstacle depth relative precision ⁴	$8 \text{ mm @ } 7 \sim 15 \text{ cm}$; $1 \text{ cm @ } 15 \sim 25 \text{ cm}$
	Motion blur	$\leq 1 \text{ rad/s without blur}$
	FOV	$\geq \text{H}98^\circ \times \text{V}72^\circ (\pm 3^\circ)$
	Self-calibration ⁵	Supports self-calibration along edges and facing a white wall
mToF SLAM depth image performance	mToF SLAM working distance ⁶	$\geq 3.3 \text{ m @ } 10\% \text{ reflectivity gray wall}$; $\geq 4.5 \text{ m @ } 20\% \text{ reflectivity gray wall}$; $\geq 8 \text{ m @ } 90\% \text{ reflectivity white wall}$
	mToF resolution / frame rate	$\leq 248 \times 180 \text{ @ } 10 \text{ fps}$
	mToF precision (90% reflectivity white wall test)	$\leq 3.5 \text{ mm @ [3 cm, 30 cm]}$; $< 1.5\% \text{ @ (30 cm, 60 cm)}$; $\leq 1\% \text{ @ (60 cm, 6 m)}$
	mToF precision (20% reflectivity gray wall test)	$\leq 3.5 \text{ mm @ [3 cm, 30 cm]}$; $\leq 1.5\% \text{ @ (30 cm, 60 cm)}$; $\leq 1\% \text{ @ (60 cm, 4.5 m)}$
	mToF accuracy (90% reflectivity white wall test)	$\leq 10 \text{ mm @ [3 cm, 35 cm]}$; $\leq 1.5\% \text{ @ (35 cm, 60 cm)}$

⁴sToF obstacle depth relative precision refers to the size of obstacles above the ground that can be extracted in short-range scenes, e.g., a 5 mm-high object on the ground can be recognized within 15 cm

⁵Self-calibration: when module deformation degrades structured-light accuracy, the structured-light accuracy is calibrated back to the production-line factory specification in edge-following and front-facing wall scenes.

⁶The mToF SLAM working distance is calculated based on the 2.5° spatial angular resolution criterion.

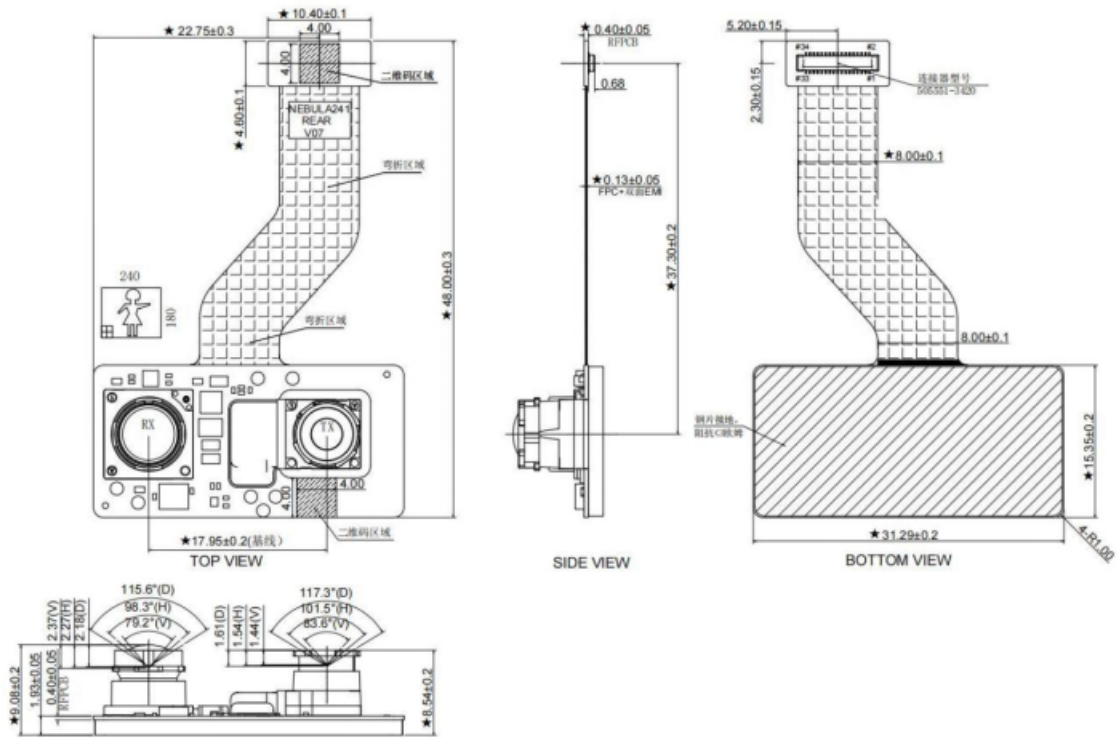
		$\leq 1\%$ @ (60 cm, 6 m]
	mToF accuracy (20% reflectivity gray wall test)	≤ 10 mm @ [3 cm, 35 cm]; $\leq 1.5\%$ @ (35 cm, 60 cm]; $\leq 1\%$ @ (60 cm, 4.5 m]
	FOV	H98° × V72° ($\pm 3^\circ$)
	Spatial angular resolution ⁷	$\leq 2.5^\circ$ @ 6 m (90% reflectivity white wall)
Synchronization	Synchronization	Supports master-slave mode
System compatibility	System compatibility	Supports Arm Linux

4 Image performance notes with cover glass

- The sToF obstacle-avoidance image performance maintains the same accuracy as without cover glass.
- For the mToF SLAM image, accuracy and ranging range degrade with cover glass due to cover-glass transmittance, ground glare, and crosstalk.
- 10% reflectivity gray board, mToF maximum ranging range and accuracy with cover glass: ≤ 10 mm @ [3 cm, 35 cm], $\leq 1.5\%$ @ (35 cm, 60 cm], $\leq 1\%$ @ (60 cm, 2.2 m] @ 80% valid point rate. Test conditions: with cover glass (90% transmittance), optical center height 16.5 cm, tilted 25° forward and downward (spliced tile and wood floor).

⁷Spatial angular resolution: perform Delaunay triangulation on valid depth points and calculate the mean of the spatial angular resolutions corresponding to all edge lengths.

5 Module Dimensions & Structure



Module dimension drawing (TOP / SIDE / BOTTOM VIEW, optical module $31.25 \times 15.35 \times 8.78$ mm, baseline 17.95 ± 0.2 mm, total FPC length 48.00 ± 0.3 mm)

5.1 Module Description

The Nebula 241 module consists of a ToF camera and a dot projector, with an external FPC cable and connector model 505551-3420. The optical module dimensions are $31.25 \times 15.35 \times 8.78$ mm and the baseline is 17.95 ± 0.2 mm; refer to the module dimension drawing for details.

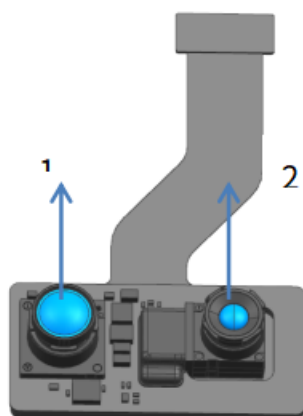


Figure: Module layout diagram (numbers correspond to the System Components table)

System Components	No.
ToF Camera	1
Dot projector	2

6 Key component specifications

Item	Key parameter	Specification
Sensor	Active Array Size	240 × 180
Sensor	Pixel Size	10 × 10 μm
Sensor	QE @ 940 nm	30%
Sensor	Operating Temperature Range	-20°C ~ +85°C
RX lens	F/NO	1.4
RX lens	FOV	98.3°(H) × 79.2°(V) × 115.6°(D)
RX lens	EFL	1.09 mm
RX lens	TTL	7 mm
TX	Optical Power	700 mW

TX	Center Wavelength	940 nm
TX	Eye Safety	Class I
TX lens	F/NO	2.4
TX lens	FOV	101.1°(H) × 83.6°(V) × 117.3°(D)
TX lens	EFL	0.695 mm
TX lens	TTL	4.8 mm

7 Module Electrical Requirements

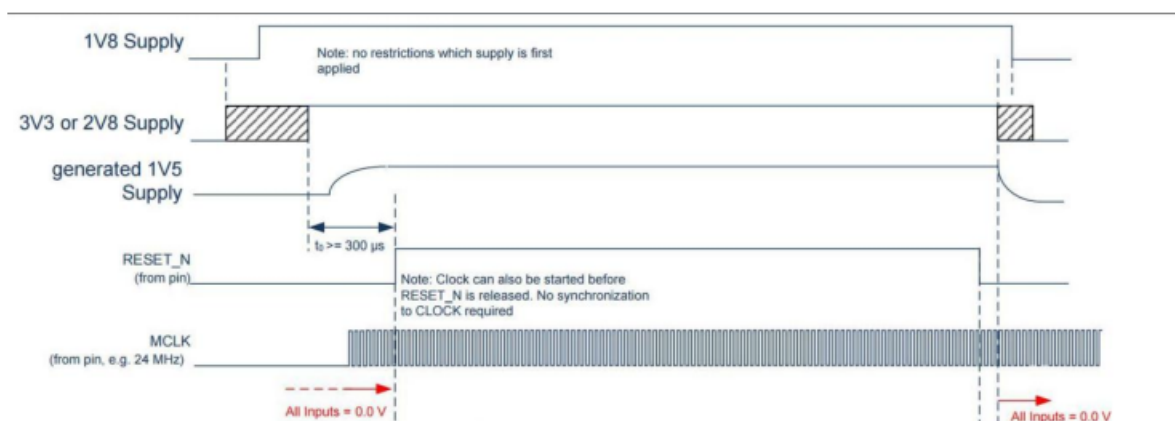
7.1 PIN Definition

PIN NO.	Name	Type	Description
1	AVDD	P	Power for analog circuit 3.3 V (low noise, high PSRR, I _{max} = 300 mA)
2	LDVCC	P	Power for LDVCC; 5 ± 0.5 V, I _{max} = 2 A
3	AVDD	P	Power for analog circuit 3.3 V (3.1 V ~ 3.5 V) (low noise, high PSRR, I _{max} = 300 mA)
4	LDVCC	P	Power for LDVCC; 5 ± 0.5 V, I _{max} = 2 A
5	GND	G	Ground (0 V)
6	LDVCC	P	Power for LDVCC; 5 ± 0.5 V, I _{max} = 2 A
7	GND	G	Ground (0 V)
8	LDVCC	P	Power for LDVCC; 5 ± 0.5 V, I _{max} = 2 A
9	DOVDD	P	I/O power 1.8 V (1.7 V ~ 1.9 V) (I _{max} = 200 mA)
10	GND	G	Ground (0 V)
11	EN_ILLU	-	Please keep NC, no connection

12	WP	I/O	SPI write protection, please keep NC
13	GND	G	Ground (0 V)
14	TRG OUT	I/O	Sync output (value max: DOVDD + 0.3 V). This pin can generally also be configured as a sync input.
15	Mclk	I	Main clock input (value max: DOVDD + 0.3 V)
16	NC	-	Please keep NC, no connection
17	GND	G	Ground (0 V)
18	GND	G	Ground (0 V)
19	MD0P	O	MIPI data lane 0 (positive)
20	SCL	I	I2C input clock (value max: DOVDD + 0.3 V)
21	MD0N	O	MIPI data lane 0 (negative)
22	SDA	I/O	I2C data (value max: DOVDD + 0.3 V)
23	GND	G	Ground (0 V)
24	GND	G	Ground (0 V)
25	MCP	O	MIPI clock lane (positive)
26	Reset	I	Master reset, active low
27	MCN	O	MIPI clock lane (negative)
28	NC	-	Please keep NC, no connection
29	GND	G	Ground (0 V)
30	NC	-	Please keep NC, no connection
31	MD1P	O	MIPI data lane 1 (positive)
32	NC	-	Please keep NC, no connection

33	MD1N	O	MIPI data lane 1 (negative)
34	NC	-	Please keep NC, no connection

7.2 Power-on Sequence



Power-on sequence diagram (1V8 corresponds to DOVDD, 3V3 to AVDD, and 1V5 is the sensor internal voltage; 5V is the laser supply voltage, which only needs to be powered on before laser emission; $t_0 \geq 300 \mu s$)

8 Environment & Reliability

Item	Parameter	Specification
Operating environment	Temperature	-10°C ~ +40°C
	Humidity	Relative humidity 0% ~ 95%, non-condensing
	Illuminance	0 ~ 40,000 lux (indoor/by window)
Storage environment	Temperature	-40°C ~ +65°C
	Humidity	Relative humidity 10% ~ 95%, non-condensing

9 Reliability test

Reliability test item	Conditions	Acceptance criteria
Low-temperature storage	Temperature: $-40^{\circ}\text{C} \pm 3^{\circ}\text{C}$; duration: 72 H	1. No abnormality in appearance or function; 2. Performance meets the shipping standard after self-calibration is triggered
High-temperature high-humidity storage	Temperature: $70^{\circ}\text{C} \pm 3^{\circ}\text{C}$; humidity: $93\% \pm 3\% \text{ RH}$; duration: 72 H	1. No abnormality in appearance or function; 2. Performance meets the shipping standard after self-calibration is triggered
High/low temperature shock	Temperature: $70^{\circ}\text{C} \pm 3^{\circ}\text{C} \sim -30^{\circ}\text{C} \pm 3^{\circ}\text{C}$; 60 min dwell at each position, 50 cycles in total	1. No abnormality in appearance or function; 2. Performance meets the shipping standard after self-calibration is triggered
High-temperature high-humidity operation	Temperature: $40^{\circ}\text{C} \pm 3^{\circ}\text{C}$; humidity: $93\% \pm 3\% \text{ RH}$; duration: 48 H	1. No abnormality in appearance or function; 2. Performance meets the shipping standard after self-calibration is triggered
Low-temperature operation + startup	Temperature: $-10^{\circ}\text{C} \pm 3^{\circ}\text{C}$; stored for 12 H first, then powered on and operated for 36 H, 48 H in total	1. No abnormality in appearance or function; 2. Performance meets the shipping standard after self-calibration is triggered
Package drop	Test cycles: 3; height: 100 cm; floor: concrete. Check the sample's	1. No abnormality in appearance or function; 2.

	appearance, structure, and function; drop once on each of one corner, three edges, and six faces for 3 test cycles; inspect after the test in the same manner as before the test	Performance meets the shipping standard after self-calibration is triggered
Random vibration test	Pack the module with protective film attached during the test and place it on the vibration table; vibration frequency 5 ~ 500 Hz, acceleration 2G, 2 hours per axis on the X/Y/Z axes	1. No abnormality in appearance or function; 2. Performance meets the shipping standard after self-calibration is triggered
Lifetime (MIPI)	Temperature: 45°C; operating duration: 2000 H	1. No abnormality in appearance or function; 2. Performance meets the shipping standard after self-calibration is triggered

10 Certification

Item	Specification
Environmental certification	RoHS 2.0, REACH
Laser eye safety	IEC60825-1: Class 1

11 EMC

Item	Specification
ESD level	Per IEC 55014-2, following the host device's typical operating conditions, meets performance criterion A or B: contact

	discharge (± 4 kV) applied to the MIPI module's PIN pins (VCC & GND), 10 times each
RE level	Per IEC 55014-1, following the host device's most stringent operating conditions, meets QP margin ≥ 6 dB; module operating conditions: AVDD 3.3 V, LDVCC 5 V, DOVDD 1.8 V, frame rate @ 6 Hz

12 Software Development

Customers can work with Deptrum on driver integration and 3D algorithm SDK integration as needed to obtain sToF and mToF point cloud data on the target platform.

13 Disclaimer

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14 Technical Support

You can obtain support through the following channels:

- Email support: please send your questions to support@deptrum.com
- FAE support: please contact our sales team for FAE support

15 Precautions

- Do not heat this product with any other heat source.
- Do not drop or subject this product to impact, as this may damage internal components and degrade accuracy; improper handling may damage internal components.
- Do not attempt to modify or disassemble this device in any way, as this may damage the module and degrade accuracy.
- The module heats up after a period of use, which is normal; heat dissipation measures can be applied to the back of the module.
- Do not store the module in a high-temperature, high-humidity environment, as this may degrade module accuracy or cause depth reconstruction failure.