NEPHOTONICS

NDS03 Datasheet

5-meter Direct-Time-of-Flight (D-ToF) ranging sensor

V1.3 ● 10-July-2024

Content Guide

1 Product Overview

The NDS03 is a miniature, high integrated D-ToF (Direct Time-of-Flight) ranging sensor. The NDS03 incorporates a high-performance ToF chip containing a SPAD pixel array with a control and computation unit, as well as a 940nm VCSEL laser, a VCSEL driver, and a micro-lens. The NDS03 sensor can allows absolute distance measurement whatever the target color and reflectance, and texture. It achieves high-precision object ranging within a 5-meter range and supports multi-object detection. The sensor features ambient light suppression capabilities, enabling it to perform ranging even under outdoor sunlight conditions.

Features:

- Ranging distance up to 5 meters
- High ambient-light suppression suitable for outdoor use
- High accuracy across varying object reflectivity, color, or texture
- Multi-object detection
- Cover window calibration
- Low power-consumption
- IIC interface (up to 1MHz)
- Ultra-compact size:4.4 mm x 2.4 mm x 1 mm

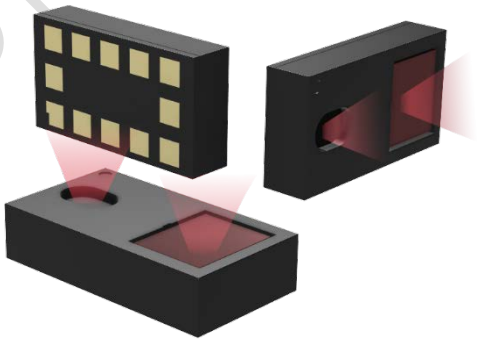


Figure 1-1. Model view of the NDS03 sensor

1.1 System Block Diagram

Figure 1-2 shows the functional blocks of the NDS03.

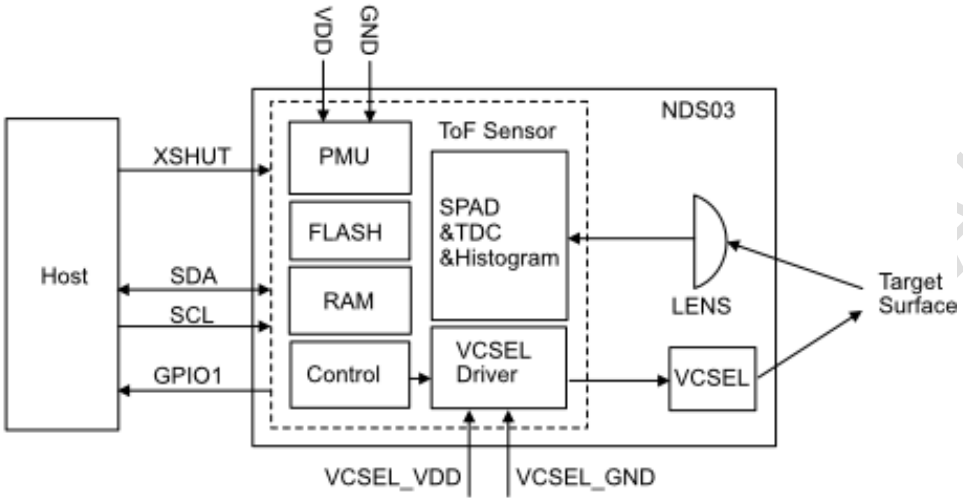


Figure 1-2. Block Diagram of NDS03

1.2 Technical Specification

Parameter	Description
FoV	25°
Ranging Distance	5 m
Accuracy	±1 cm or ≤ 4 %
VCSEL Wavelength (IR emitter)	940 nm
Operating Voltage	• VDD/VCSEL_VDD: 2.7 to 3.5 V • IOVDD: 1.6 to 3.5 V
Number of PINs	12 PIN
Interface	IIC: Max. 1MHz
Size	4.4 mm × 2.4 mm × 1 mm
Operating Temperature	-20 to 85 ℃
Storage Temperature	- 40 to 85 ℃

Table 1-1.Technical Specification

1.3 Applications

- Laser detection autofocus for smart projector
- 1D gesture recognition
- Robot obstacle avoidance and collision prevention
- Object detection in system standby mode
- Smart panel
- Smart security
- Smart bathroom
- AIoT and smart home
- Proximity and presence detection

2 Module Dimensions

The dimensions of NDS03 are shown below in *Figure 2-1.*

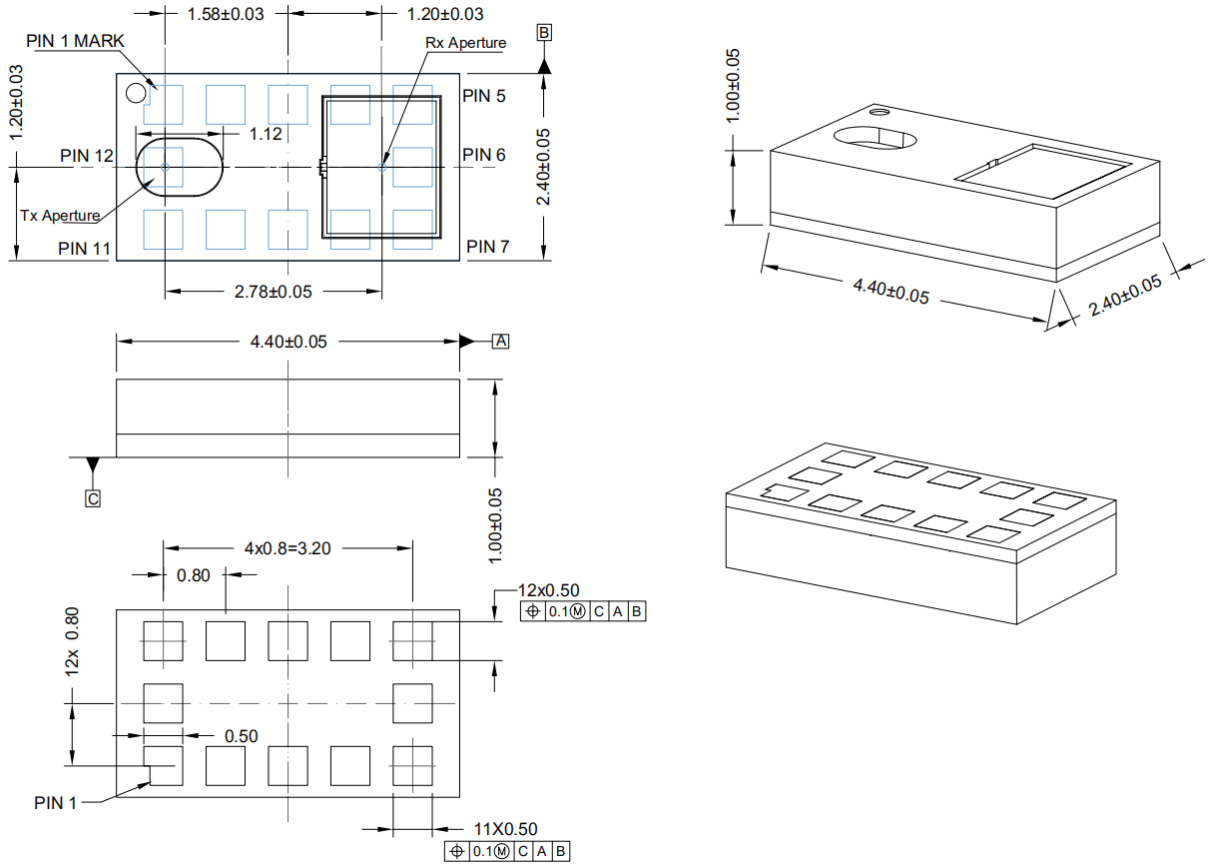


Figure 2-1. Module Dimensions

(All dimensions are in mm, unless otherwise stated.)

3 3D Model View

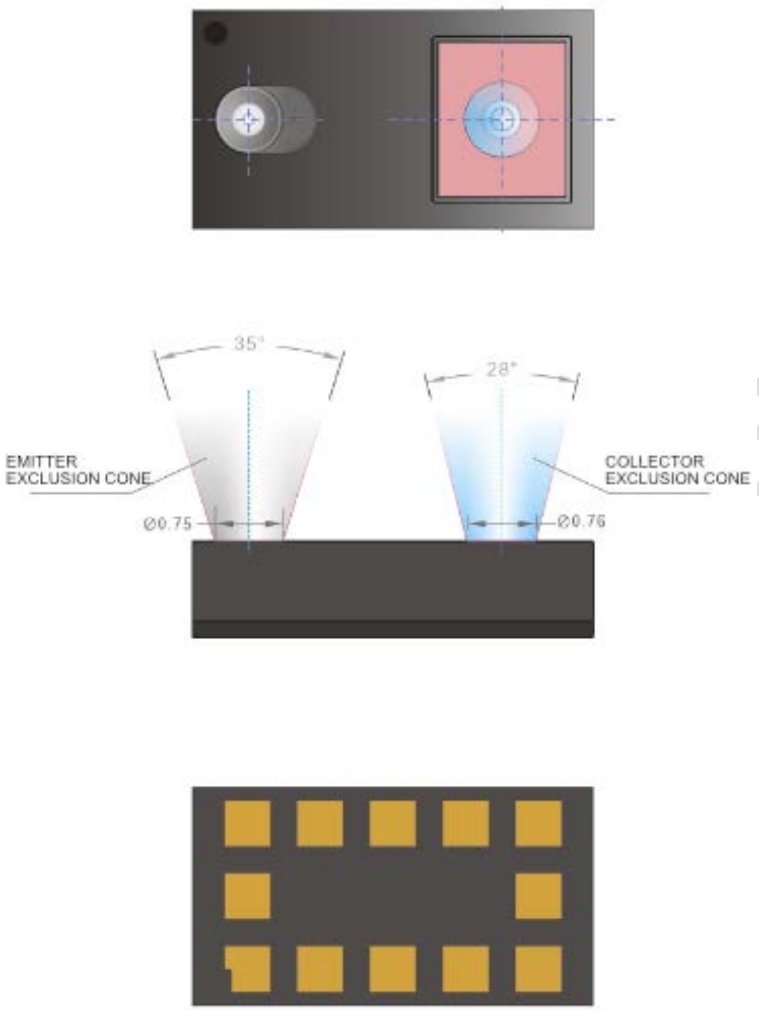


Figure 3-1. 3D Model Rendering of NDS03

Note

The hole diameter tolerance is ±0.05mm, and the angular tolerance is ±2°. The conical restriction areas, indicated in the diagrams for the emitter and collector, represent the minimum hole size that should be retained when using the module. This includes the silicone sleeve, bracket, and ink window opening. When designing these components, users should take into account assembly errors, machining tolerances, and other potential discrepancies to ensure that the restriction areas remain unobscured and uncovered.

4 Device Pinout

Figure 4-1 shows the pinout of the NDS03. The NDS03 pin numbers and signal descriptions are shown in Table 4-1.

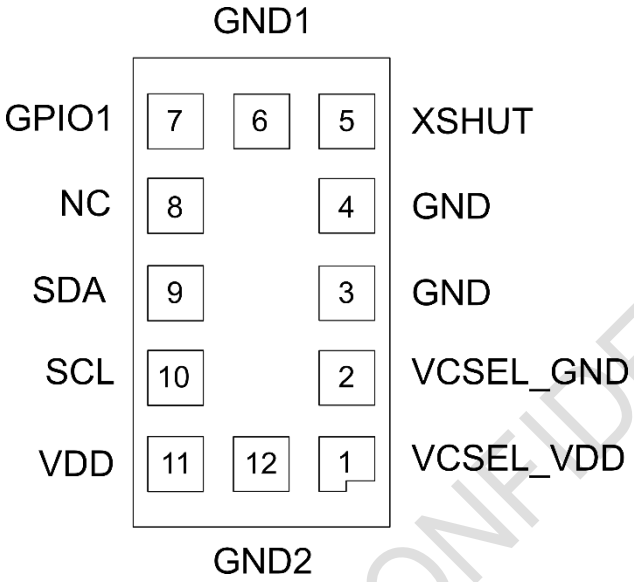


Figure 4-1. Pinout (Bottom View) of NDS03

Pin Number	Signal Name	Signal Type	Signal Description
1	VCSEL_VDD	VCSEL supply	2.7V to 3.5V power supply
2	VCSEL_GND	Ground	Connect to main ground
3	GND	Ground	Connect to main ground
4	GND	Ground	Connect to main ground
5	XSHUT	Digital input	Active low hardware reset/ standby more
6	GND1	Ground	Connect to main ground
7	GPIO1	Digital output	Interrupt output
8	NC	-	No connect
9	SDA	Digital I/O	IIC data line
10	SCL	Digital output	IIC clock line
11	VDD	Supply	2.7V to 3.5V power supply
12	GND2	Ground	Connect to main ground

Table 4-1. NDS03 pin numbers and signal descriptions

Note

- The XSHUT pin is an active-low input controlled by the host to enter these modes:
  - Low: Resets the sensor and initiates sleep mode.
  - High: Initiates or resumes the sensor's normal operation.
- The GPIO1 pin can be used as a data interrupt, with the high or low level of GPIO1 indicating whether the measurement data is ready.
- SDA, SCL, GPIO1 and XSHUT have no diode to any VDD supply. Therefore, even with VDD=0 V they do not block the interrupt line or I²C bus.

5 Functional Description

5.1 System Interface

A typical interface diagram using the NDS03 is shown below in Figure 5-1. This typical master-slave topography consists of a host (master) and the NDS03 (slave) communicate over an IIC interface. The host application controls the NDS03 sensor using NDS03 API commands to perform device initialization, ranging, polling, ranging mode configuration, and calibration functions. (For more details, please refer to the NDS03 SDK regarding the usage of the NDS03 API).

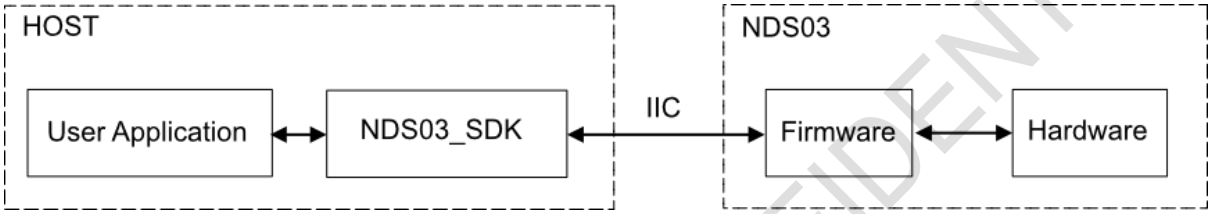


Figure 5-1. System Interface of NDS03

5.1.1 Firmware State Machine

A general firmware state machine description is shown in Figure 5-2.

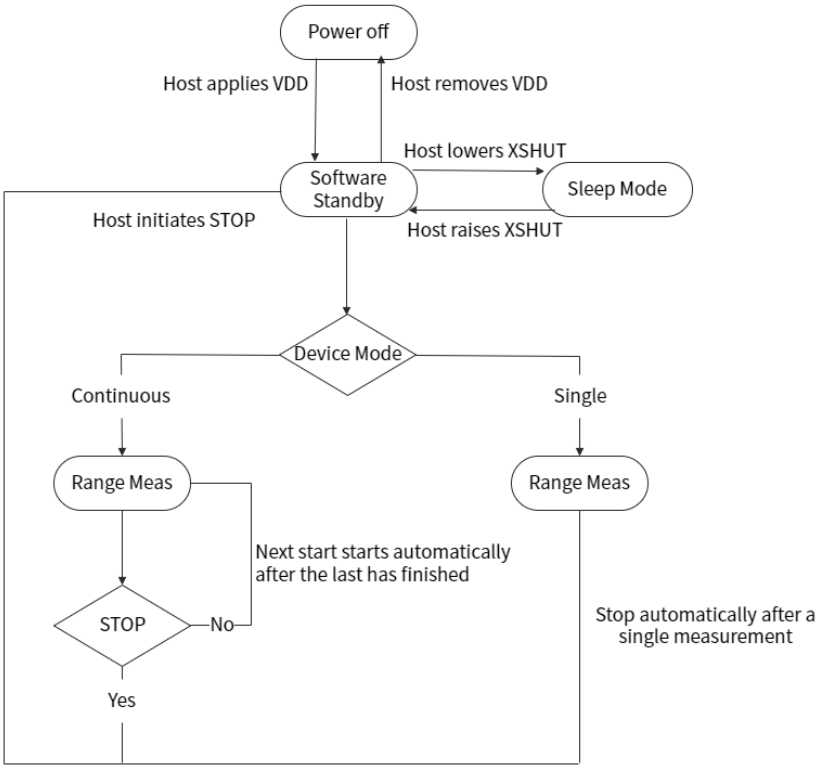


Figure 5-2. Firmware State Diagram

5.2 Ranging Modes

There are two primary device ranging operating modes in the NDS03_SDK.

- Single Ranging Mode

  Ranging is performed only once immediately after the API function is called. The system automatically returns to software standby mode.

- Continuous Ranging mode

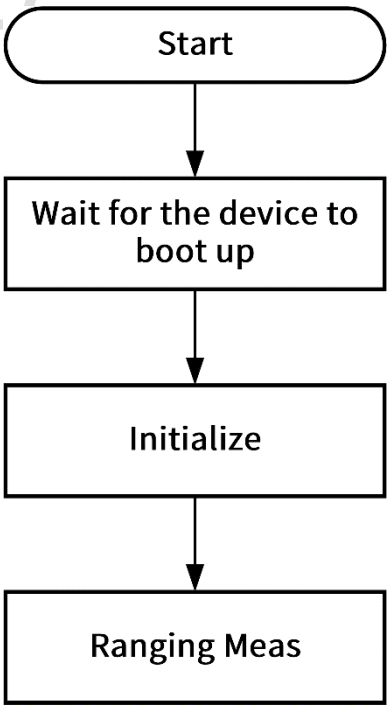
  Once a measurement is completed, the NDS03 system will automatically proceed to the next one. The NDS03 will return to ready state only when the host sends a command to stop continuous distance measurements (for detailed information, refer to the NDS03_SDK).

5.3 Multi-Object Functionality

The NDS03 module can simultaneously detect multiple objects within its field of view. The software driver can output up to four distances at the same time, indicating the positions of the target objects. For more details, please refer to the latest NDS03 SDK.

5.4 Typical Ranging Sequence

A typical ranging sequence from power-up to first measurement consists of the following phases.



5.4.1 Wait to Boot (Firmware Boot Phase)

Waiting to boot is a stage to detect whether the NDS03 module is ready through IIC. If a timeout occurs at this stage, it may be due to the following issues:

- A peripheral circuit error.
- Sensor damage caused by improper soldering or high reflow temperatures.
- A problem during the IIC read/write operation.

5.4.2 Range Measurement

This phase involves configuring the operating mode and initiating the range measurement operation. Users can configure the operating mode according to their needs. During the ranging process, values of 65500 or 65300 are considered invalid and must be filtered out.

5.5 Interrupt Functionality

The NDS03 module can be controlled via registers to implement interrupt-driven data reading functions, with two methods available: standard interrupt and threshold interrupt.

5.5.1 Standard Interrupt

By default, the GPIO1 pin is automatically pulled low after measurement is enabled, and pulled high again after the data is read. Users can use this pin as an interrupt pin. For more detailed information on functionality interfaces, please refer to the NDS03_SDK.

5.5.2 Threshold Interrupt

The threshold interrupt is categorized into a lower threshold and an upper threshold. When used in conjunction with the GPIO1 pin, these thresholds can enable interrupt functions that are triggered by different levels. For more detailed information on the functionality interfaces, please refer to the NDS03_SDK.

5.6 Power-Up Sequence

After supplying power to the VCSEL_VDD and VDD pins, ensure that the XSHUT pin is in a high state to enable IIC communication. The device then enters the pre-boot configuration stage, and after the firmware has started, it automatically proceeds to the initialization phase. Once initialized, the sensor transitions to the ready state and awaits further instructions. During the firmware startup, the device actively polls the IIC bus, and upon successful startup, it ceases polling. The complete power-up sequence for the NDS03, including these steps, is shown in Figure 5-4.

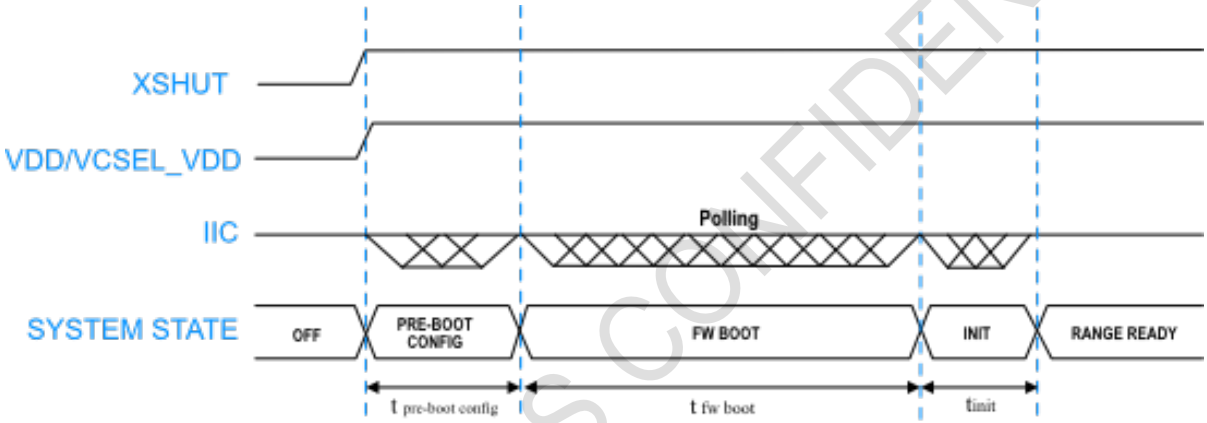


Figure 5-4. Power-Up Sequence for the NDS03

Parameter	Phase	Description
$t_{pre\text{-}boot\ config}$	VDD(H) - FW_Boot Start	Time from power-up to firmware boot start.
$t_{fw\ boot}$	FW_Boot - Start Init	Time from firmware boot to start of initialization
t_{init}	Time of initialization	Time required for initialization.

5.7 Sleep Mode

NDS03 has a low-power sleep mode to reduce power consumption when the sensor is not in use.

5.7.1 Enter Sleep Mode

There are two ways to enter standby mode.

- HW: Pull the XSHUT pin low to reset the sensor and standby mode.
- SW: Writing a specific register through the IIC and the sensor will enter the standby mode. (For more details, please refer to NDS03_SDK)

5.7.2 Exit Sleep Mode

There are two ways to exit standby mode:

- HW: Raise the XSHUT pin and the sensor will resume normal operation.
- SW: Writing a specific register through the IIC and the sensor will exit the standby mode. (For more details, please refer to NDS03_SDK)

6 IIC Interface

The IIC bus is composed of a serial data line (SDA) and a serial clock line (SCL), supporting multiple slave devices, each identified by its device address. The IIC bus of the NDS03 operates at a maximum speed of 1 MHz and uses a device address of 0x5C.

To initiate data transmission, the host sends a start signal, followed by the 7-bit device address and 1-bit read and write (R/W) control bit, as shown in Figure 6-1. When the R/W control bit is 0, the master writes to the slave; when it is 1, the master reads from the slave.

MSB LSB

1	0	1	1	1	0	0	R/W

Figure 6-1.IIC Device Address Format

The data transmission waveform is depicted in Figure 6-2. The slave is connected to the bus using an open-drain configuration. Both SDA and SCL lines should be pulled up to a positive supply voltage with pull-up resistors. The signal lines are actively driven low by the devices. A high condition is achieved when the lines are not actively driven, allowing the pull-up resistors to pull the signal lines high. When no data is being transmitted, both signal lines go high.

Two signal conditions indicate the start and stop of data transmission:

- Start Condition: with SCL high, pull SDA low to generate a start signal. After the slave detects the start signal, it is ready to receive data.
- Stop Condition: after the acknowledge, hold SCL and SDA high to generate a stop signal.

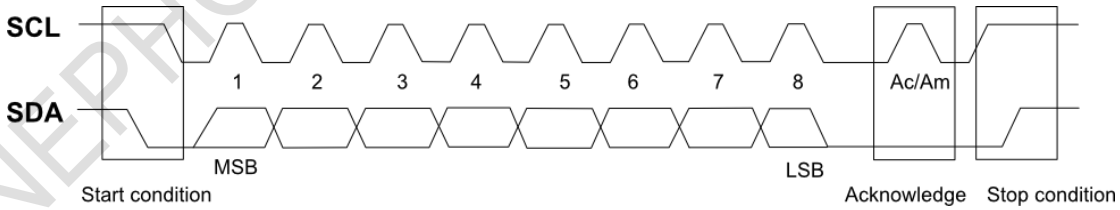


Figure 6-2. Data Transfer Protocol

During data transmission, the SDA is allowed to change the data bits being transmitted when the SCL is low. When SCL is high, SDA must remain stable, effectively transmitting one bit of data per clock cycle. At the end of the 8th clock cycle, the master releases the SDA line and waits for the slave to respond. In the 9th clock cycle, the slave pulls SDA low to acknowledge receipt of the data

packet. If no ACK is received, the host detects this as a failed transmission. The host signals the end of transmission by setting both SDA and SCL high after the acknowledgment.

After sending the start bit, the host transmits the first byte, which consists of a 7-bit device address followed by a 1-bit R/W control bit. Upon receiving an acknowledgment from the slave, the host proceeds to send the register address. Once an acknowledgment for the address is received, the host writes the content to that address. A typical data write operation is shown in Figure 6-3.

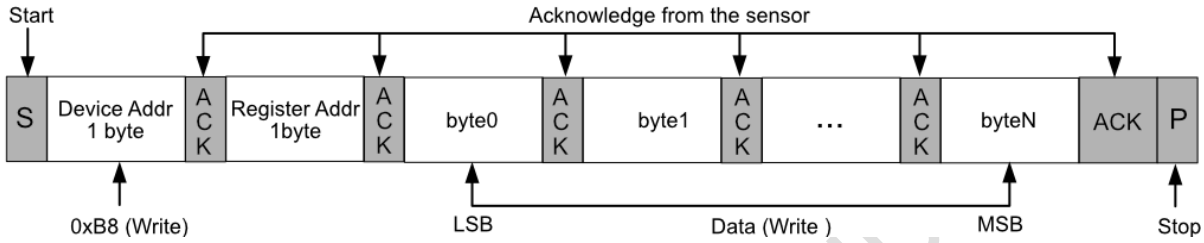


Figure 6-3. Data Format (Write Operation)

In the read timing sequence, after the device address (write command) and the register address have been sent, a start signal is sent again, followed by the device address with the read command bit set. Then, the data is read, as illustrated in Figure 6-4.

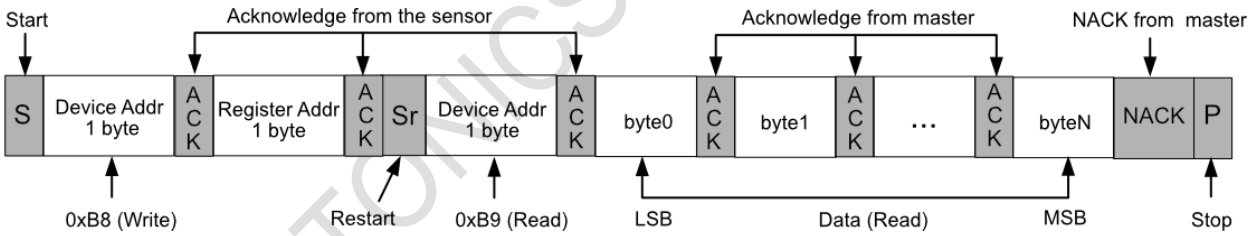


Figure 6-4. Data Format (Read Operation)

6.1 IIC Interface-Timing Characteristics

Timing characteristics are shown in the tables below. Please refer to the figure below for an explanation of the parameters used. Timings are given for all process, voltage, and temperature (PVT) conditions.

Symbol	Parameter	Min.	Typ.	Max.	Unit
F_{IIC}	Operating frequency	0	-	1000	kHz
t_{LOW}	Clock pulse width low	0.5	-	-	μs
t_{HIGH}	Clock pulse width high	0.26	-	-	μs
t_{SP}	Pulse width of spikes which are suppressed by the input filter	-	-	50	ns
t_{BUF}	Bus free time between transmissions	0.5	-	-	μs
$t_{HD.STA}$	Start hold time	0.26	-	-	μs
$t_{SU.STA}$	Start set-up time	0.26	-	-	μs
$t_{HD.DAT}$	Data in hold time	0	-	0.9	μs
$t_{SU.DAT}$	Data in set-up time	50	-	-	ns
t_R	SCL/SDA rise time	-	-	120	ns
t_F	SCL/SDA fall time	-	-	120	ns
$t_{SU.STO}$	Stop set-up time	0.26	-	-	μs
$C_{i/o}$	Input/output capacitance (SDA)	-	-	10	pF
C_{in}	Input capacitance (SCL)	-	-	4	pF
C_L	Load capacitance	-	140	550	pF

Table 6-1. IIC Interface - Timing Characteristics

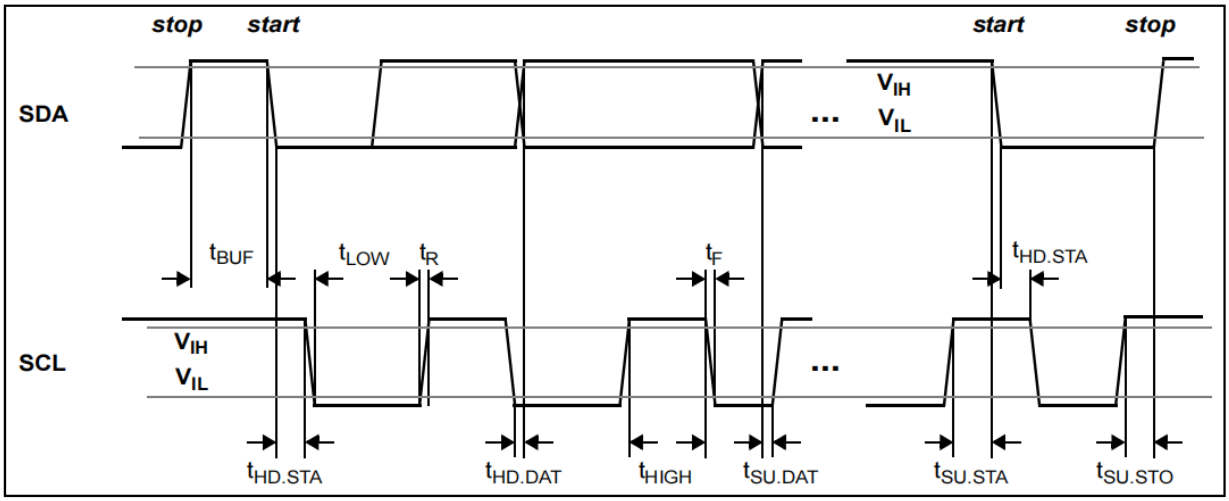


Figure 6-5. IIC Timing Characteristics

7 Ranging Performance

7.1 Measurement Conditions

- Target used are Grey (18%), White (90%)
- Target size：at least 2m x 2m (90%), 1.6m x 1.5m(18%)
- Offset calibration done at 50 cm from sensor.
- Nominal voltage (3.3 V) and temperature (25°C).
- Indoor: Target are performed in the 145lux daylight target illumination, no infrared.
- High Ambient Light: A halogen lamp is used to simulate an outdoor lighting environment of 5000 lux, and the ambient light is applied to the target reflection card, not as direct illumination of the module.
- The specified target fills 100 % of the field of view of the device. (FOV=25°).
- All ranging tests are performed without cover window.
- The sensor relies on default calibration data.
- The longest single measurement time is 33 ms.

7.2 Maximum Ranging Distance

Target Reflectance	Indoor	High Ambient Light
90%	5000 mm	1000 mm
18%	2800 mm	1000 mm

Table 7-1. Maximum Ranging Distance

Note

- Maximum range capability is based on a 90% detection rate.
- Detection rate is a statistical value indicating the worst-case percentage of measurements that return a valid ranging. For example, taking 1000 measurements with 90% detection rate gives 900 valid distances. The 100 other distances may be outside the specification.

7.3 Ranging Distance and Accuracy

Target Reflectance	Range Distance(mm)	Indoor	High Ambient Light
90%	20-500	±10 mm	±15 mm
	>500	±2 %	±5 %
18%	20-250	±10 mm	±15 mm
	>250	±4 %	±5 %

Table 7-2. Ranging Distance and Accuracy

Note

Ranging accuracy figures are based on 2.0 sigma i.e. 95% of measurement are within the specified range.

8 Electrical Characteristics

8.1 Absolute Maximum Ratings

Parameter	Min.	Typ.	Max.	Unit
VCSEL_VDD，VDD	-0.3	-	3.6	V
IOVDD	-0.3	-	3.6	V
SCL，SDA，XSHUT and GPIO1	-0.3	-	3.6	V
Storage Temperature	-40	-	85	℃
Relative Humidity (no condensation)	-	-	85	%
Moisture Sensitivity	MSL 3			-

Table 8-1. Absolute Maximum Ratings for the NDS03

Note

- Stresses exceeding those listed in Table 8-1 may cause permanent damage to the device. Note that these are stress ratings only, the device's functional operation at these or any other conditions beyond those specified in the operational sections is not guaranteed. Furthermore, prolonged exposure to conditions at the absolute maximum ratings may affect device reliability.
- MSL 3：If the sensor is removed from the vacuum package (Ambient temperature < 30°C, Relative humidity < 60%), the max floor life is 168 hours before a pre-bake is recommended.

8.2 Recommended Operating Conditions

Parameter	Min.	Typ.	Max.	Unit
Voltage (VCSEL_VDD, VDD)	2.7	3.3	3.5	V
Voltage (IOVDD)	1.6	-	3.5	V
Temperature (normal operating)	-20	-	85	℃

Table 8-2. Recommended Operating Conditions

8.3 ESD

Parameter	Specification	Conditions
Human Body Model (HBM)	JEDEC JS-001-2017	±2 KV,1.5 KΩ,100 pF
Charge Device Model (CDM)	JEDEC EIA/JESD22-C101F	±500 V

Table 8-3. ESD Performance

8.4 Interface Electrical Characteristics

Position	Symbol	Parameter	Min.	Typ.	Max.	Unit
GPIO1 / XSHUT	V_{IL}	Low level input voltage	-	-	0.3VDD	V
	V_{IH}	High level input voltage	0.52 VDD	-	VDD	V
	V_{OL}	Low level output voltage (I_{OUT}=4mA)	-	-	0.14	V
	V_{OH}	High level output voltage (I_{OUT}=4mA)	VDD-0.5	-	-	V
IIC Interface (SDA/SCL)	V_{IL}	Low level input voltage	-	-	0.3VDD	V
	V_{IH}	High level input voltage	0.52 VDD	-	VDD	V
	V_{OL}	Low level output (I_{OUT}=4mA)	-	-	0.14	V

Table 8-4. Interface Electrical Characteristics

8.5 Power Consumption

Device Mode	Min.	Typ.	Max.	Unit
Hardware sleep mode	-	20	30	μA
Software sleep mode	-	15	20	μA
Average current (including VCSEL, 30Hz@5m)	-	-	35	mA

Table 8-5. Power Consumption (25℃ ,both VDD and VCSEL_VDD are 3.3 V)

9 Application Schematic

9.1 Recommended Application Schematic

Caution

- The filtering capacitors for both VDD and VCSEL_VDD should be positioned as close as possible to PIN11 and PIN1, respectively, and should have a short ground path to ensure a minimal ground loop.
- The XSHUT pin needs to be connected to the HOST. A 10KΩ pull-up resistor can guarantee the pin is in the proper state. The recommended power supply for the XSHUT pull-up is the same as the module power supply.
- GPIO1 should be left unconnected if not used.

The application schematic of NDS03 is shown in the Figure 9-1.

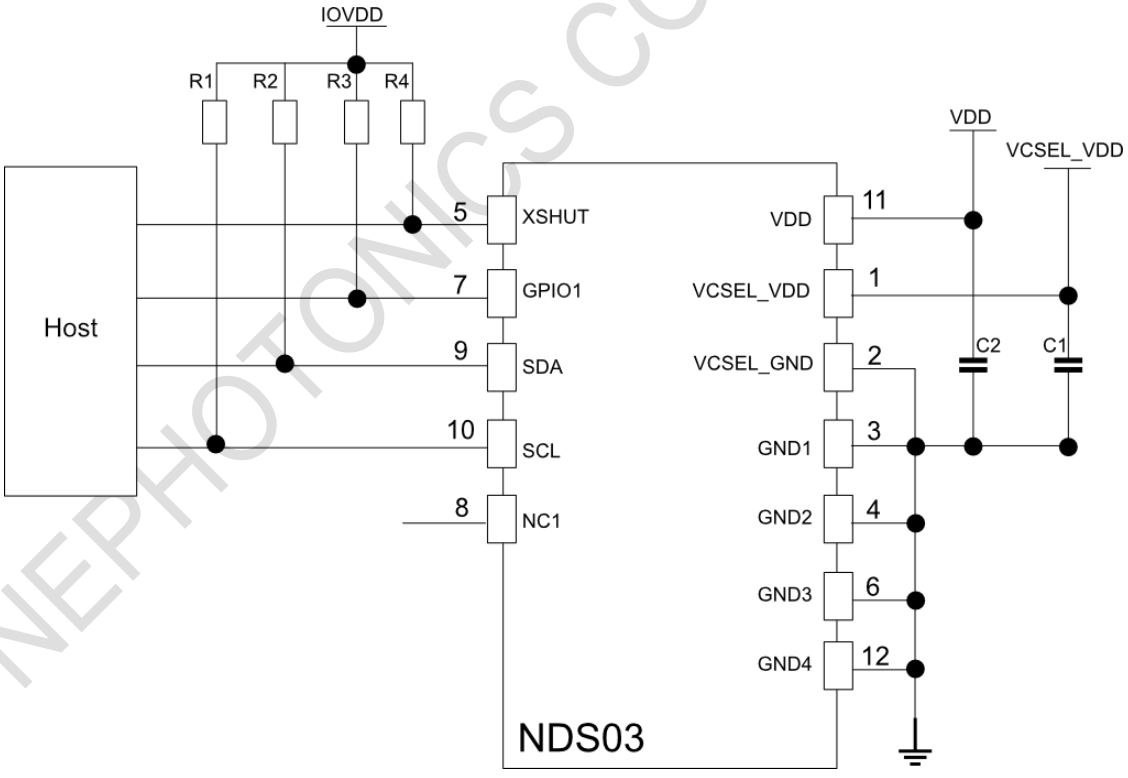


Figure 9-1. Recommended Application Schematic Diagram for NDS03

Recommended values and tolerances are shown in the table below.

Component	Qty.	Designator	Parameter	Tolerance
Chip capacitor	1	C1	4.7μF	±20%
Chip capacitor	1	C2	100 nF	±20%
Chip resistor	2	R1 / R2	1.5k ~ 2.0K	±5%
Chip resistor	2	R3 / R4	10K	±5%

Table 9-1. Recommended Application Circuit Components for the NDS03

Note

If the parasitic capacitance of the user's device is large, the pull-up resistance on the IIC bus can be appropriately reduced to decrease the rise time of the IIC waveform.

9.2 PCB Solder Pad Dimensions

The recommended solder pad dimensions of NDS03 are shown in Figure 9-2.

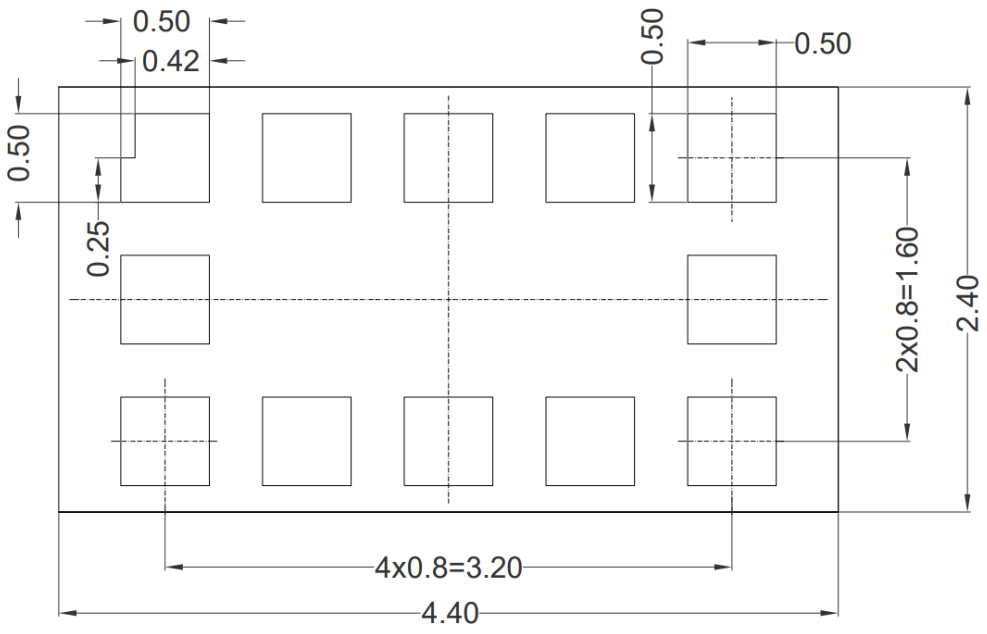


Figure 9-2. Recommended Solder Pad Dimensions (Top View)

(All dimensions are in mm, unless otherwise stated.)

10 Packaging

The details packaging of NDS03 is shown in the figure below.

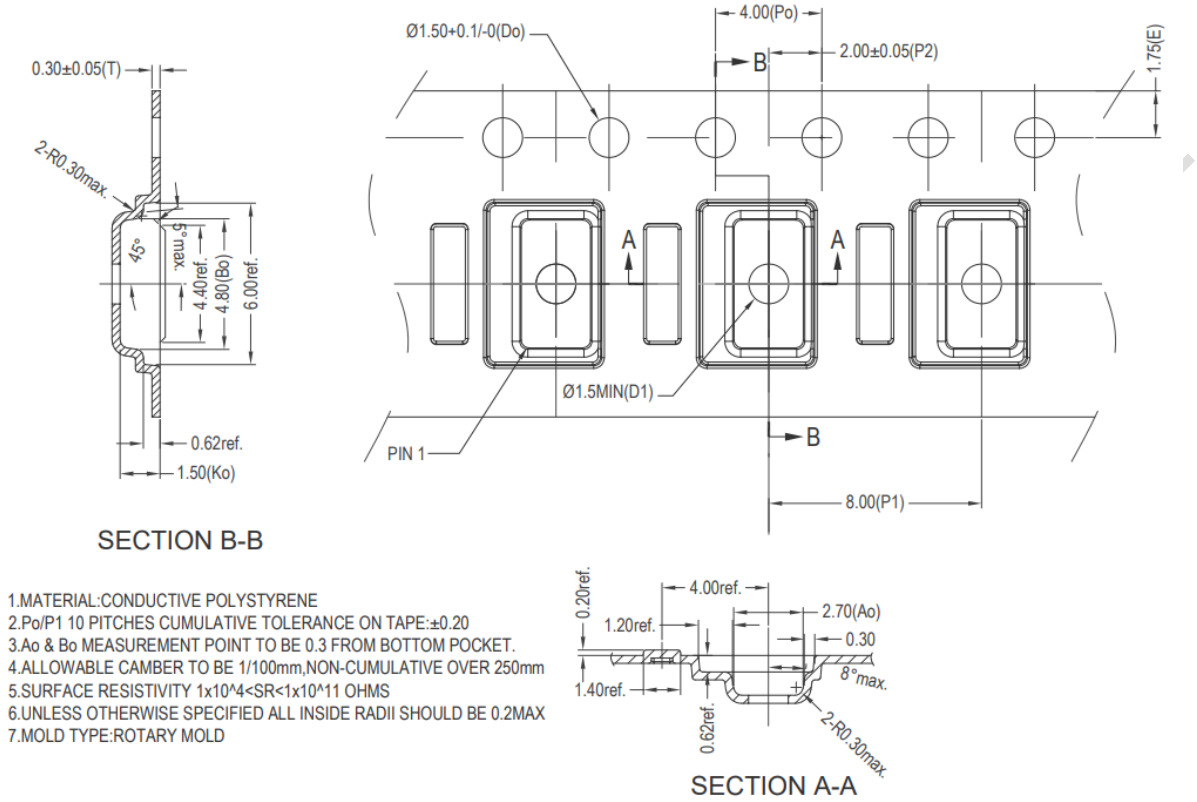


Figure 10-1. Packaging of the NDS03

11 Soldering & Storage Information

11.1 Pre-Processing Before SMT

Caution

- Before proceeding with Surface Mount Technology (SMT) assembly, the NDS03 module requires pre-baking to remove moisture. The recommended parameters for this pre-baking process are a temperature of 60°C maintained for a duration of 8 hours.
- The NDS03 module is classified with an MSL-3 moisture sensitivity level. If removed from vacuum packaging and stored in a workshop environment with a temperature below 30°C and humidity below 60% for a period exceeding 168 hours, the module must be baked again to remove moisture.

11.2 Soldering Information

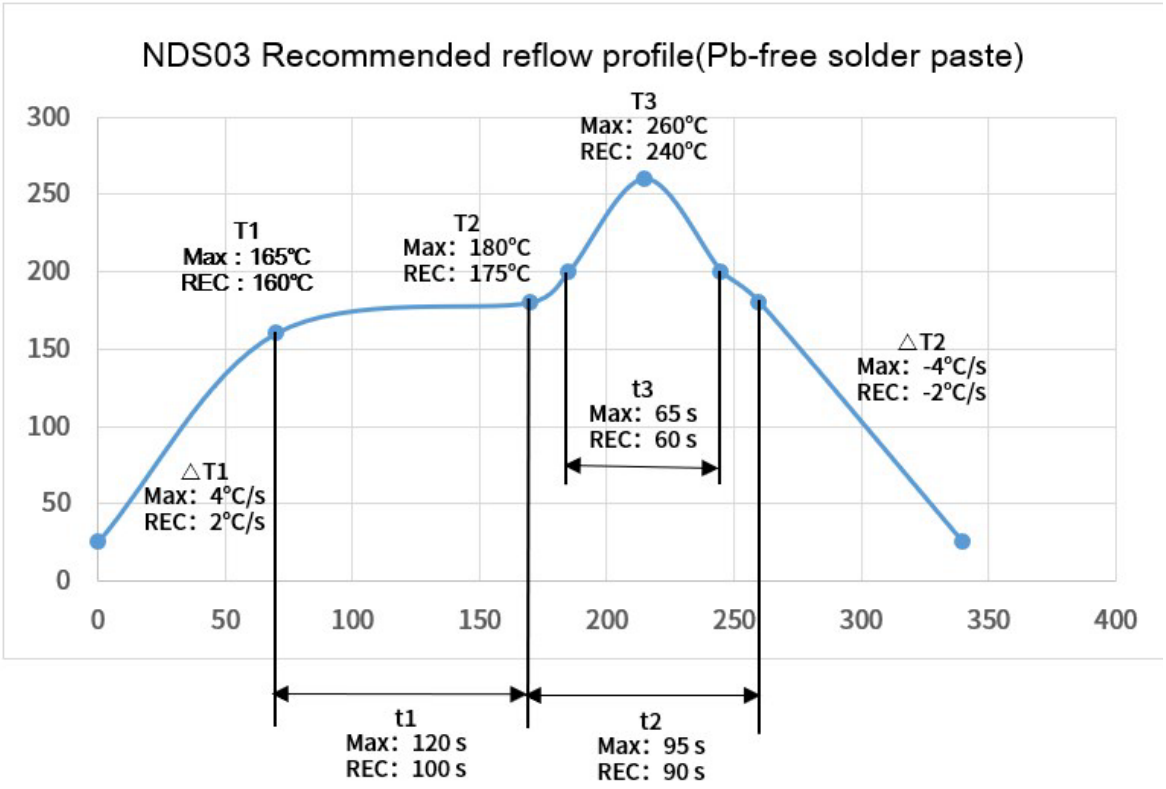


Figure 11-1. Recommended Reflow Profile for the NDS03

The value range and recommended value (Pb-free solder paste) for the solder profile of NDS03 are shown in Table 11-1. Customers will have to tune the reflow profile depending on the PCB, solder paste, and material used. The recommended peak temperature range of reflow profile is 240°C, with the maximum not exceeding 245°C.

Parameters	Recommended	Max.	Unit
Heating: Maximum temperature (T1)	160	165	°C
Heating: Ramp up (△T1)	2	4	°C /s
Constant: Maximum temperature (T2)	175	180	°C
Constant: Time (t1)	100	120	s
Reflow: Maximum temperature (T3)	240	245	°C
Reflow: Time (t2)	90	95	s
Temperature>200℃: Time (t3)	60	65	s
Ramp down (△T2)	-2	-4	°C /s

Table 11-1. Recommended Reflow Profile (Pb-free solder paste)

Caution

The recommended peak temperature range for the reflow profile is 240°C, with a maximum not exceeding 245°C, as described in Table 11-1. If, for any reason, a customer needs to use a reflow profile that differs from this recommendation—particularly if the peak temperature exceeds 240°C—the customer must qualify this new profile at their own risk. In any case, the profile must adhere to the maximum profile limits outlined in Table 11-1.

11.3 Storage Conditions

The NDS03 module has a storage temperature range from -40°C to 85°C and is classified at a Moisture Sensitivity Level (MSL) of 3.

12 Laser Safety Considerations

NDS03 contains the VCSEL, advanced micro lens and corresponding drive circuit. The laser output is designed to remain within Class-1 laser safety limits under all reasonably foreseeable conditions including single faults in compliance with IEC/EN 60825-1:2014. The laser output will remain within Class-1 limits if the NEPHOTONICS recommended device settings are used and the operating conditions specified are respected, such as the system does not include any additional lenses for concentrating the laser beam, and the parameters cannot be set beyond the recommended operating conditions. The laser output power must not be increased by any means and no optics should be used with the intention of focusing the laser beam. Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

13 Caution

- The filtering capacitors for both VDD and VCSEL_VDD should be positioned as close as possible to PIN11 and PIN1, respectively, and should have a short ground path to ensure a minimal ground loop.
- The XSHUT pin needs to be connected to the HOST. A 10KΩ pull-up resistor can guarantee the pin is in the proper state. The recommended power supply for the XSHUT pull-up is the same as the module power supply.
- GPIO1 should be left unconnected if not used.
- Before proceeding with Surface Mount Technology (SMT) assembly, the NDS03 module requires pre-baking to remove moisture. The recommended parameters for this pre-baking process are a temperature of 60°C maintained for a duration of 8 hours.
- The NDS03 module is classified with an MSL-3 moisture sensitivity level. If removed from vacuum packaging and stored in a workshop environment with a temperature below 30°C and humidity below 60% for a period exceeding 168 hours, the module must be baked again to remove moisture.
- The recommended peak temperature range for the reflow profile is 240°C, with a maximum not exceeding 245°C, as described in Table 11-1. If, for any reason, a customer needs to use a reflow profile that differs from this recommendation—particularly if the peak temperature exceeds 240°C—the customer must qualify this new profile at their own risk. In any case, the profile must adhere to the maximum profile limits outlined in Table 11-1.

14 Ordering Information

The ordering information of NDS03 is shown in Table 14-1.

Part Number	Package	Packing	Minimum Order Quantity
NDS03-CV1C	OLGA	Tape and reel	1K

Table 14-1. Ordering Information

Revision History

Version	Changes	Date
V1.0	Initial Version.	26-Oct-2022
V1.1	Updated ranging performance, PIN description, power-consumption, standby mode description.	27-March-2024
V1.2	Updated content of SMT, ranging performance, power consumption, and the voltage range.	20-May-2024
V1.3	Updated ranging performance, power-consumption, and voltage range.	10-July-2024

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