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ISO/TS 16949:2009 BS EN ISO 14001:2004 QC 080000 IECQ HSPM

APPLICATION NOTES

- ▶ Time-of-Flight (ToF) Proximity Sensor
- ▶ 4424 1.00t
- ▶ 940nm VCSEL

Release Date: 03 January 2026 Version: A1.0

N0S68S42 (BC4424) ToF Proximity Sensor - Application Notes

B C 4 4 2 4 T o F S e n s o r

APPLICATIONS:

- Robot/AGV/Drone/UAV
- Laser Assisted Autofocus (AF)
- Distance Measurement
- Video Surveillance Equipment
- Gesture Control
- Body Gaming
- AI/ML-on-Edges
- Smart Lighting
- Collision Avoidance

BC4424 ToF Sensor

RoHS Compliant

FEATURES:

- **Package:** 4424 Integrated Miniature Module with:
  - ✓ 940nm VCSEL
  - ✓ VCSEL driver
  - ✓ Direct Time of Flight
  - ✓ RoHS 2.0 and REACH Compliant
  - ✓ Ranging sensor with advanced embedded micro controller
  - ✓ Advanced embedded optical cross-talk compensation to simplify cover glass selection
- **Interface:** I^2C (up to 1MHz)
- **Eye Safety:** Class 1
- **Measure Ranging Distance:** 20mm ~ 5m
- **Soldering methods:** Reflow soldering
- **MSL Level:** Level 3 acc. to J-STD 020

1. INTRODUCTION:

This product is an ultra-small sensor capable of handling gesture, object, behavior recognition, obstacle avoidance, and assisted focusing. Internally, it integrates a high-precision ToF chip, a Class 1 eye-safe VCSEL microlaser, advanced microlenses, and a control and processing unit.

This article primarily introduces how to correctly use the product.

2.1 APPLICATION CIRCUIT:

When designing the application circuit, please refer to the following diagram. Figure 1 shows the connection line for a single chip. The pins of the interface XSHUT/GPIO/SDA/SCL are connected to the host side using pull-up resistors. VDD is the power input terminal of the digital circuit, and VCSEL_VDD is the power input terminal of VCSEL.

To improve the accuracy of distance acquisition during device operation, it is recommended to use two power supplies to power VDD and VCSEL separately. C1 and C2 are bypass capacitors for the power supply, used to improve power supply stability.

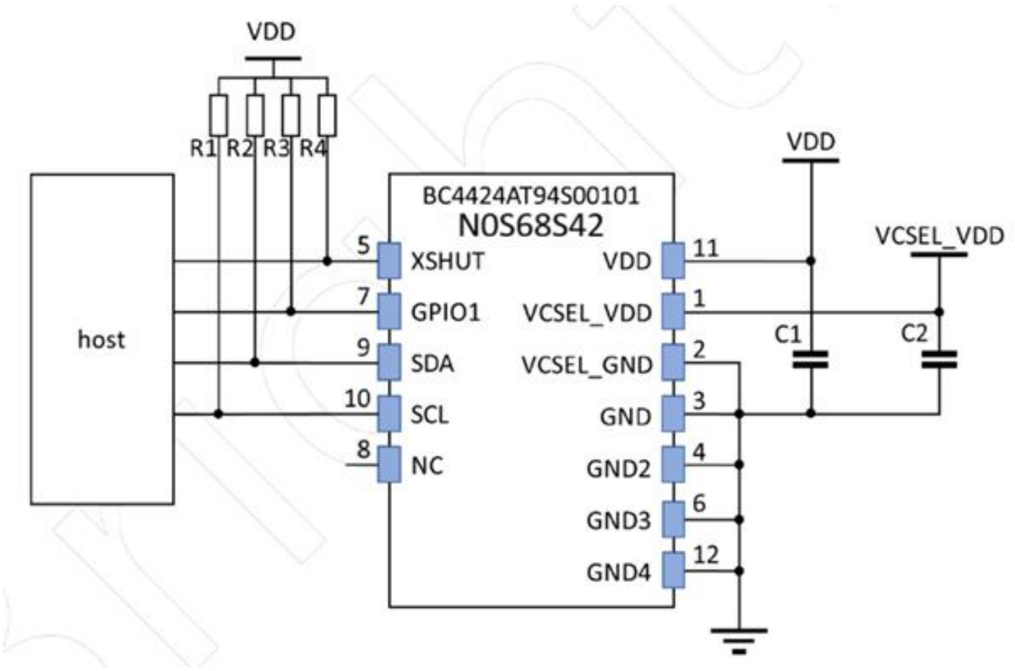


Figure 1: Typical Application Circuit

Lib ref.	Quantity	Position	Parameter	Tolerance
Capacitor	1	C1	4.7µF	±20%
Capacitor	1	C2	100nF	±20%
Resistor	2	R1, 42	1.5k-2.0k	5%
Resistor	2	R3, R4	10k	5%

Table 1: Component Reference Value

Notes:

a. The capacitor on the external power supply VDD should be placed as close as possible to the sensor pins PIN1 and PIN11, with the trace distance controlled within 3mm. The capacitor ground loop should be as short as possible, with a single-point ground loop of less than 3mm. Multiple grounding points should be used to ensure good connection between the chip and the copper ground, and to ensure a small ground loop.
b. The XSHUT pin needs to be connected to the HOST pin. If the state of the HOST pin is uncertain, a pull-up resistor with a resistance of 10KΩ is required.
c. If the user's device has a large parasitic capacitance, the pull-up resistor of IIC can be appropriately reduced to shorten the IIC waveform ramp-up time.
d. The power supply filter capacitor needs to be placed close to the chip pins.

2.2 POWER SUPPLY:

The N0S68S42/BC4424 requires a typical power supply voltage of 3.3V for both VDD and VCSEL. It is recommended to use different power supplies for VDD and VCSEL to ensure the stability of the digital VDD power supply and improve the stability of distance detection.

To ensure stable operation of the N0S68S42/BC4424, a 0.1uF bypass capacitor needs to be connected in parallel between VDD/VDD_VCSEL and GND. This capacitor should be placed as close to the N0S68S42/BC4424 as possible during PCB design.

2.3 LAYOUT:

The PCB layout of N0S68S42/BC4424 is shown in Figure 2, and the PCB package and pads dimensions of N0S68S42/BC4424 can be referenced in Figure 3.

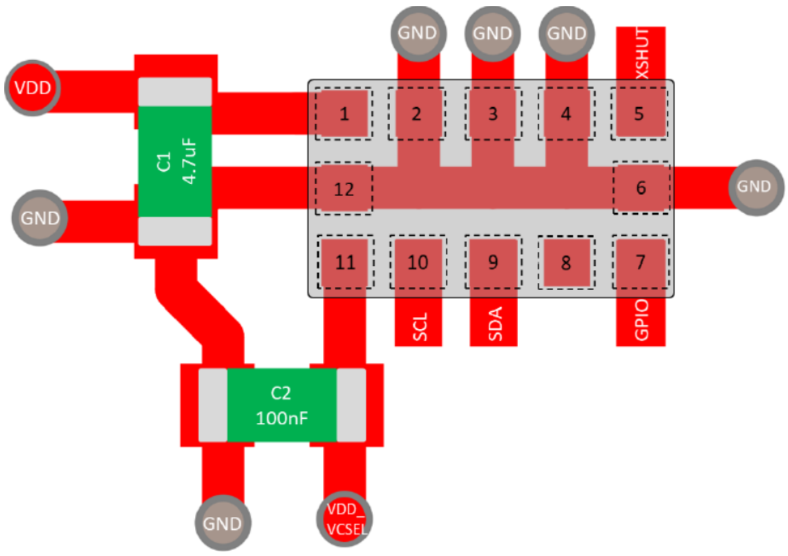


Figure 2: PCB Layout

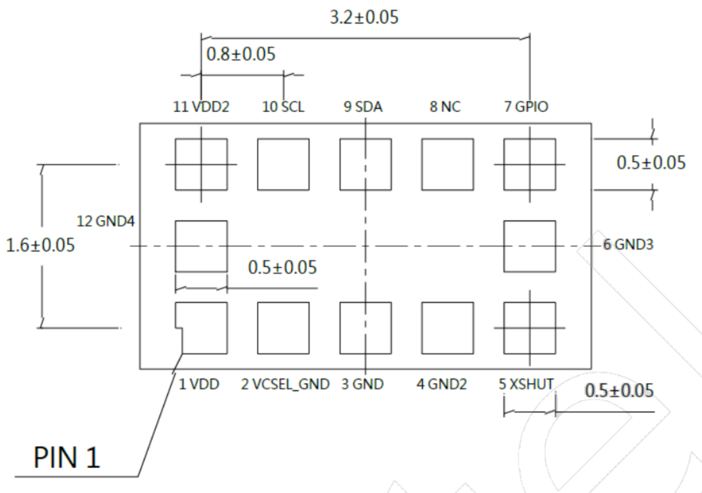


Figure 3: PCB Package

2.4 MULTI-DEVICE CONNECTION:

This product, N0S68S42/BC4424, can perform IIC address allocation and supports multiple N0S68S42/BC4424 connected to one IIC interface. The connection line is shown in Figure 4 below.

The N0S68S42/BC4424 can perform IIC address allocation during power-on initialization. The controller controls the power-on sequence of the N0S68S42/BC4424 by controlling the power-on sequence of XSTUT, and allocates new IIC addresses according to the power-on sequence. Subsequent control then uses these new IIC addresses to control multiple N0S68S42/BC4424 units.

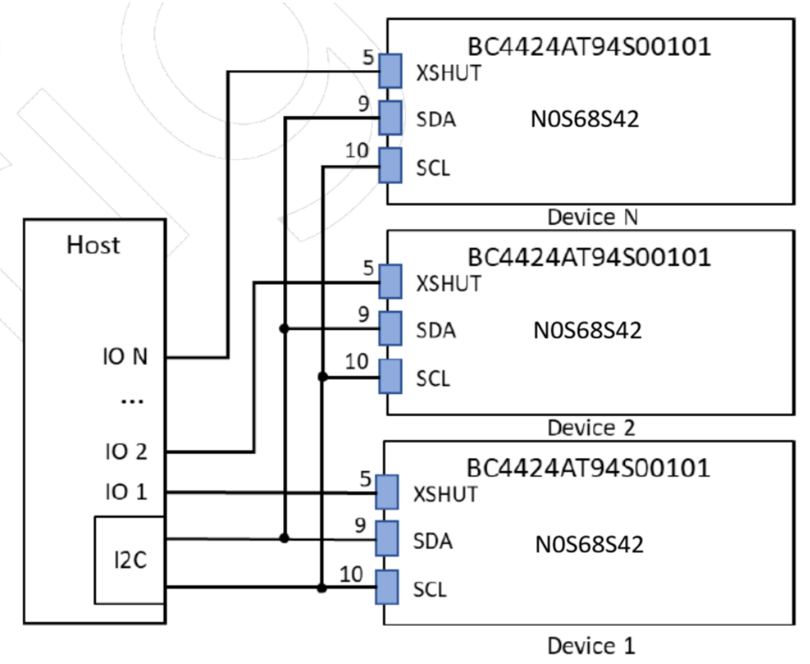


Figure 4: Multi-Device Connection

2.5 MICROCONTROLLERS:

This product supports 3.3V I/O level signal input for both the controller and the FPGA.

Known controller models that can control this product:

1. NXP® S32K144 S32K116
2. STMicroelectronics® STM32F103 STM32F407

Note: This product does not restrict the brand of controller; a suitable controller can be selected according to the communication requirements and rules of the LED.

3.1 EXAMPLE OF BASIC OPERATING SEQUENCE:

The following is the procedure for distance detection using the N0S68S42/BC4424.

Setup Phase:

a. Power on the N0S68S42/BC4424 and wait for it to stabilize (~1ms);

b. Set XSHUT to high;
c. Wait for the N0S68S42/BC4424 to start;
d. Initialize the N0S68S42/BC4424 and set a new IIC address (if there is only one N0S68S42/BC4424, the address does not need to be changed).

Main Loop:
a. Acquire distance data using single distance detection/continuous distance detection.

Standby Mode:
a. Set XSHUT to low, and the N0S68S42/BC4424 enters low-power mode.

Shutdown Phase:
a. Set XSHUT to low level; b. Disconnect N0S68S42/BC4424 from power supply.

3.2 DEVICE STATES:

Figure 5 simply illustrates the status changes of the N0S68S42/BC4424 device:

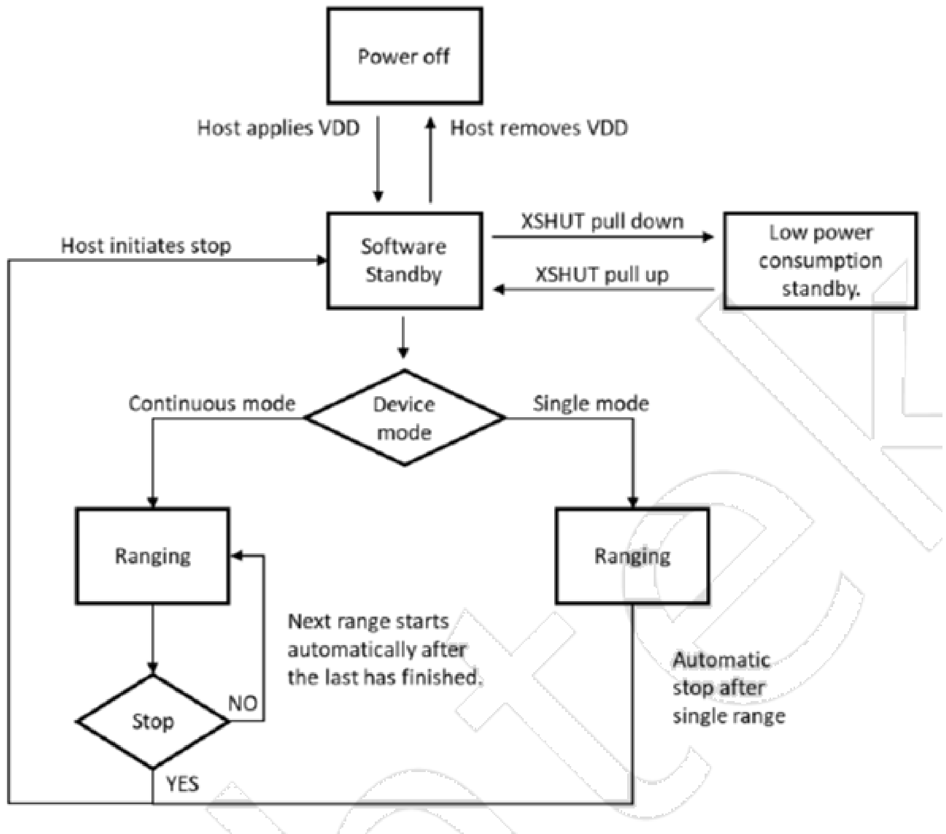


Figure 5: Device State Diagram

3.3 WORKING MODE:

The N0S68S42/BC4424 has two operating modes.

Device Mode:

- Single Measurement Mode: After one measurement is completed, the N0S68S42/BC4424 system automatically returns to the software-ready state.
- Continuous Measurement Mode: After one measurement is completed, the N0S68S42/BC4424 system automatically performs the next measurement. The N0S68S42/BC4424 will only return to the software-ready state when the host actively calls the BC4424_StopMeasurement function in the BC4424_SDK to stop the measurement.

Measurement Mode:

The measurement mode is a configurable option within the operating mode, with the default being Normal mode. Customers can configure this mode according to their needs.

- Normal Measurement Mode: The default measurement mode, offering stable distance measurement and high accuracy.
- Fast Measurement Mode: Fast measurement mode operates at a higher frequency, but measurement accuracy may be slightly reduced.

3.4 TYPICAL RANGING FLOW:

A typical complete measurement process includes the following three stages:

a. Waiting for the device to start
b. Initializing the sensor device
c. Measurement

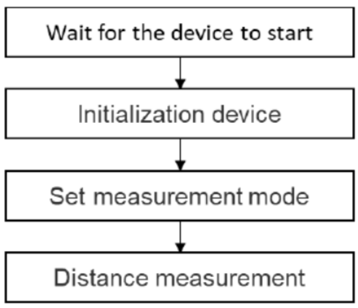


Figure 6: Typical Ranging Flow

Start and Initialization:

This stage is for checking the device's readiness via IIC. If it times out and returns at this stage, the following issues may be the cause:

a. External circuit error.
b. Soldering problem, such as a cold solder joint or overheating causing sensor damage.
c. Problem with the IIC read/write program; please capture and analyze the waveform.

Distance Measurement:
This stage includes configuring the working mode and starting distance measurement. Users can configure the working mode according to their needs. During distance measurement, if the target object or sensor is moving, the measured depth data may contain invalid values such as 65500 or 65300. Users need to filter these values.

Note:
If the sensor consistently outputs a depth of 65300 even when the target object is not too far away, please check whether the soldering or the layout of the external circuitry meets the standards.

3.5 INTERRUPT FUNCTION:

The N0S68S42/BC4424 can be controlled via registers to implement interrupt data reading, with two modes: normal interrupt and threshold interrupt.

General Interruption:
By default, the GPIO pin automatically goes low after a measurement is completed and automatically goes high after data is read. Users can use this pin as an interrupt pin.

After starting a measurement by calling BC4424_StartMeasurement in the BC4424_SDK, the GPIO pin will go high when the N0S68S42/BC4424 sensor completes a measurement. It will not go low until the user calls BC4424_GetRangingData in the BC4424_SDK to read the data. Users can use this pin as a trigger pin for interrupting data reading.

Threshold Interruption:
Threshold interrupts are divided into low-threshold and high-threshold types, and can be implemented using GPIO1 to trigger interrupts at different thresholds. For detailed function interfaces, please refer to the BC4424 SDK.

3.6 IIC ADDRESS SETUP:

The default IIC address of the N0S68S42/BC4424 is 0x5C, but the IIC address can be modified. This can be done by modifying the IIC data of BC4424_Dev_t using the SDK and calling the BC4424_InitDevice function.

Modifying the IIC addresses of multiple N0S68S42/BC4424s allows control of the XSTUT pin, which controls the power-on sequence of the devices, and then the IIC addresses are modified sequentially.

3.7 POWER-ON SEQUENCE:

After powering on VDD/VCSEL_VDD, the XSHUT pin must be pulled high for normal IIC communication. The device then enters the pre-boot configuration phase, waiting for firmware startup before automatically entering the initialization phase. After initialization, it enters the ready state, waiting to receive ranging commands. IIC only participates from the pre-boot configuration phase to the initialization phase. During the firmware startup phase, the device polls via IIC; polling ends upon successful startup.

The power-on timing sequence of N0S68S42/BC4424 is shown in the following diagram:

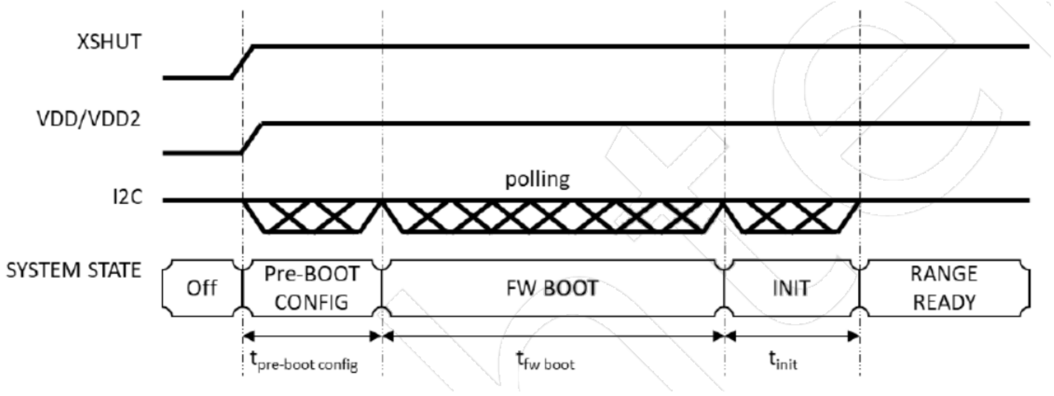


Figure 7: Power-On Sequence

Note:

a. $t_{pre\text{-}boot\ config}$ specifies the time from sensor power-on to pre-boot configuration, with a maximum of 1.2ms.
b. $t_{fw\ boot}$ specifies the sensor firmware boot time, with a maximum of 9ms.
c. t_{init} specifies the sensor initialization time, with a maximum of 0.8ms.

3.8 STANDBY MODE:

The N0S68S42/BC4424 has a standby mode, which can significantly reduce the power consumption of the N0S68S42/BC4424 sensor.

Enter Standby Mode:

- Hardware-based standby mode: Pull the BC4424 XSHUT pin low to enter standby mode.
- Software-based standby mode: Send an IIC command to enter standby mode (see BC4424_SDK for details).

Wake Up:

- To wake up the sensor from standby mode using hardware, simply pull the XSHUT pin high.
- To wake up the sensor from standby mode using software, send an IIC command to exit standby mode (see BC4424_SDK for details).

3.9 IIC INTERFACE:

The N0S68S42/BC4424 uses IIC as its control interface. The IIC interface has two signals: the serial data line (SDA) and the serial clock line (SCL). Each device connected to the bus uses a unique device address and a simple master-slave relationship.

In this control system, the N0S68S42/BC4424 acts as a slave device, with a default device address of 0x5C. The maximum supported IIC bus speed on the N0S68S42/BC4424 is 1MHz. The slave device uses an open-drain connection to the bus. Both SCL and SDA require pull-up resistors, so both lines are high when the bus is idle.

As shown in Figure 8, the data transmission protocol uses an open-drain structure connected to the bus. Both SCL and SDA require pull-up resistors. Therefore, when the bus is idle, both lines are high. When either device outputs a low level, the bus will be pulled low.

- Start Bit: When SCL is high, SDA is pulled low, generating a start signal. After detecting the start signal, the slave device prepares to receive data. The data transmission state is from the start signal to the stop signal, completed by the bidirectional data line SDA.

- Stop Bit: When SCL is high, SDA is pulled high, generating a stop signal. After detecting the stop signal, the slave device stops receiving data.

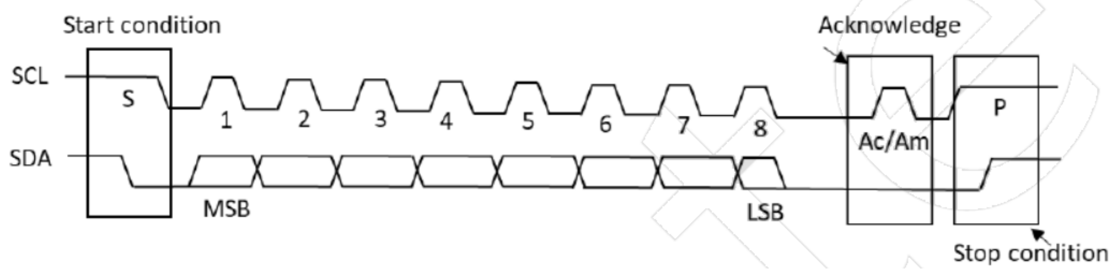


Figure 8: IIC Data Transfer Protocol

Device Address:
The default 7-bit IIC device address of the N0S68S42/BC4424 is 0x5C. During IIC read and write operations, the device address needs to be shifted left by 1 bit and then combined with the previous read/write bit (0: write operation, 1: read operation) to form an 8-bit read/write address, as shown in Figure 9, which illustrates the device address format.

1	0	1	1	1	0	0	R/W

Figure 9: Device Address

Write Data:
The write operation format is shown in Figure 10, the IIC write operation format.

a. The Host generates a start signal.
b. The device address 0x5C is left-shifted by 1 bit and written to 0, i.e., 0xB8 (1 Byte), onto the IIC SDA data line.
c. The Host receives an acknowledgement from the slave device.
d. The slave device's destination register address (1 Byte) is written onto the IIC SDA data line, sending 8 bits (1 Byte) of data at a time.
e. The Host receives one acknowledgement from the slave device.
f. The data to be sent (N Bytes) is written onto the IIC SDA data line, sending 8 bits (1 Byte) of data at a time.
g. The Host receives one acknowledgement from the slave device.
h. The Host generates a stop signal.

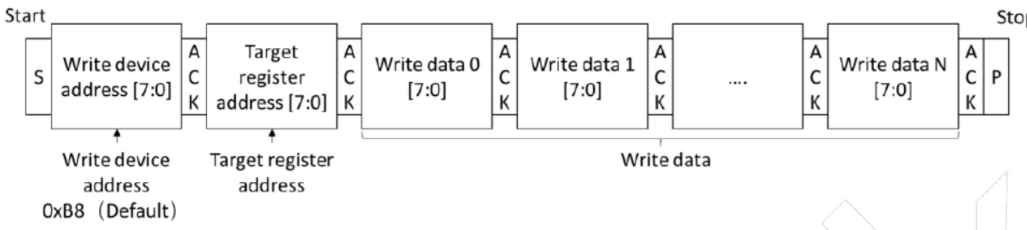


Figure 10: Write Data Format

Read Data:
The read operation format is shown in Figure 11, the IIC read operation format.

a. The Host generates a start signal.
b. The device address 0x5b is left-shifted by 1 bit and written to the IIC SDA data line as 0xB8 (1 Byte).
c. The Host receives an acknowledgement from the slave device.
d. The slave device's destination register address (2 Bytes) is written to the IIC SDA data line. The Host receives an acknowledgement from the slave device every 8 bits (1 Byte) of data sent.
e. The Host generates a stop signal.
f. The Host generates a start signal.
g. The device address 0x5b is left-shifted by 1 bit and written to the IIC SDA data line as 0xB9 (1 Byte).
h. The Host receives an acknowledgement from the slave device.
i. The Host reads the slave device data (4 Bytes) through the IIC SDA data line. For the first 3 bytes, the Host generates an acknowledgement every 8 bits (1 Byte) of data sent.
j. After receiving the last byte, the Host generates a NACK signal.
k. The Host generates a stop signal.

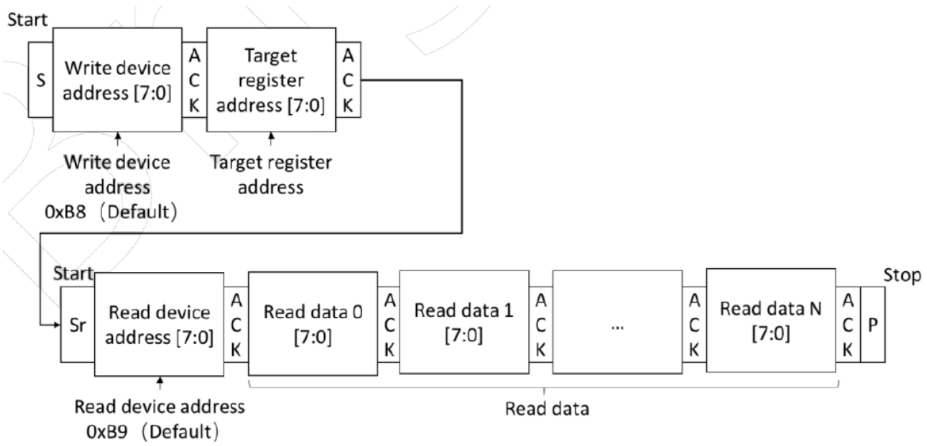


Figure 11: Read Data Format

Note:
Before the host reads data from the IIC SDA, it is recommended to delay for about 10µs to prevent data reading failure.

4.1 COVER GLASS INSTALLATION CROSS TALK:

When applying this technology, a cover plate needs to be added to protect the N0S68S42/BC4424. When adding a protective cover plate, crosstalk issues need to be considered.

As shown in Figure 12, crosstalk occurs because the IR emitted light is reflected back and forth by the cover plate before entering the receiver. Excessive crosstalk can lead to errors in distance detection. Therefore, measures to reduce crosstalk must be taken when adding the cover plate.

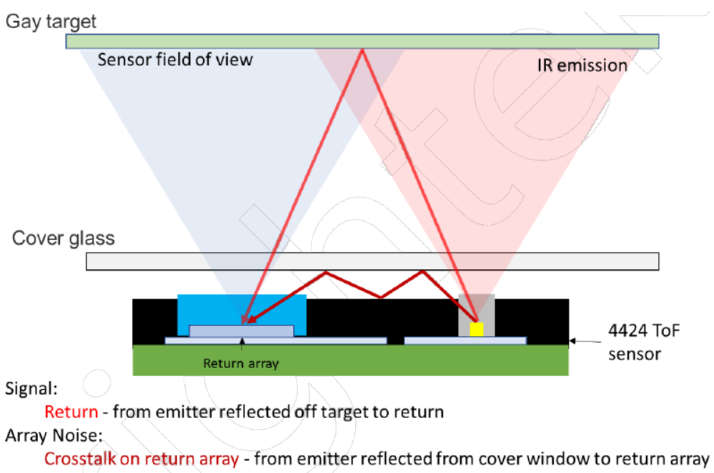


Figure 12: BC4424 Cross Talk

4.2 INSTALLATION REQUIREMENTS OF COVER GLASS:

To reduce crosstalk interference, as shown in Figure 13, the following requirements must be met:

a. N0S68S42/BC4424 should be placed as close as possible to the cover plate, with a maximum distance E of 1mm between N0S68S42/BC4424 and the cover plate.
b. The maximum thickness T of the cover plate should be 1mm.
c. The cover plate must have an infrared (940nm) transmittance of at least 90%.
d. The cover plate should be parallel to the transmitting and receiving surfaces of N0S68S42/BC4424.

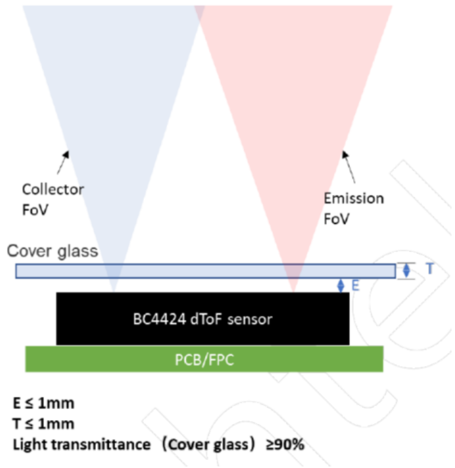


Figure 13: Installation of Cover Glass

4.3 CROSS TALK CALIBRATION:

The N0S68S42/BC4424 supports crosstalk calibration. After the cover plate is correctly installed, crosstalk calibration is required to improve the measurement accuracy of the N0S68S42/BC4424.

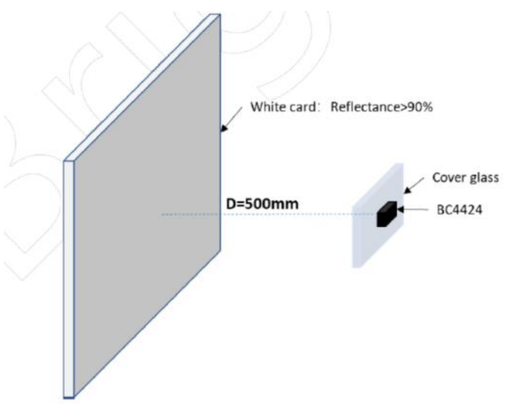


Figure 14: Cross Talk Calibration

As shown in Figure 14 above, during crosstalk calibration, the transmitting and receiving surfaces of the N0S68S42/BC4424 must be parallel to the white card. The distance between the N0S68S42/BC4424 and the white card must be 500mm. The reflectivity of the white card must be greater than or equal to 90%.

The crosstalk calibration process is shown in Figure 15 below. First, place the N0S68S42/BC4424 at a distance of 500mm from the white card. Then, use the function BC4424_XtalkCalibration() to perform calibration. Finally, wait for completion and determine whether it was successful.

Note:

a. If calibration fails, check if the cover plate is installed correctly.
b. Calibration only needs to be performed once. The calibration data will be saved in N0S68S42/BC4424 and will not be lost upon power-on.

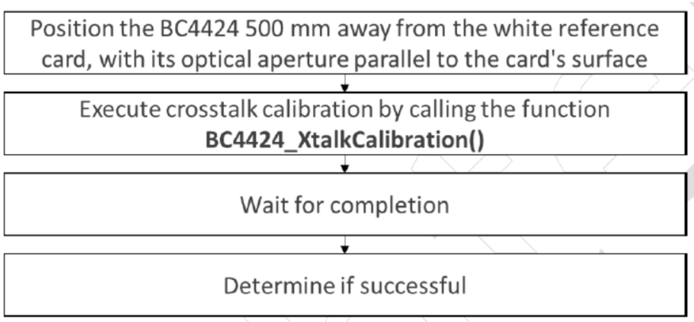


Figure 15: Cross Talk Calibration Flow

4.4 CONFORMAL COATING:

N0S68S42/BC4424 can be coated with a protective film for moisture-proofing, mildew-proofing, and salt spray protection. The protective film must have a light transmittance greater than 90%, and the combined thickness of the protective film and the cover film must be less than 1 mm.

After applying the protective film, a crosstalk calibration is also required.

5.1 OFFSET CALIBRATION:

Distance offset is characterized by the average offset (the center deviation between the measured value and the actual distance). See the figure below:

Figure 16: Range Offset

For optimal performance, it is recommended to perform offset calibration at the factory, with a calibration distance of 10 cm. The following factors should be considered during offset calibration:

- Power supply voltage and temperature.
- Protective cover glass on top of the N0S68S42/BC4424 module.

5.2 OFFSET CALIBRATION FLOW:

As shown in Figure 17, when performing offset calibration, it is necessary to ensure that the transmitting and receiving surfaces of N0S68S42/BC4424 are parallel to the white card, and the distance between N0S68S42/BC4424 and the white card is equal to the set value (the default value is 500mm). The reflectivity of the white card is required to be greater than or equal to 90%.

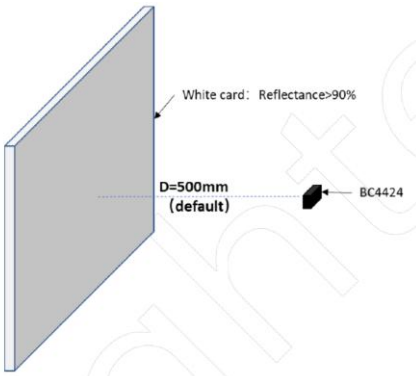


Figure 17: Offset Calibration

The crosstalk calibration process is shown in Figure 18 below. First, place the N0S68S42/BC4424 at a distance of XX mm from the white card (default 500 mm). Then, use the function BC4424_OffsetCalibration() to perform calibration. Finally, wait for the process to complete and determine whether it was successful.

Note:
If calibration fails, check if the distance is accurate?

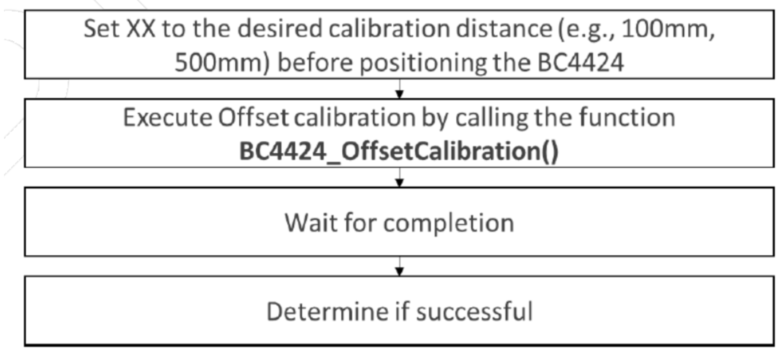


Figure 18: Offset Calibration Flow

6.1 SDK – SYSTEM FUNCTION:

The system-level functional description is shown in Figure 19, which illustrates the system functional description of N0S68S42/BC4424. The user application controls the N0S68S42/BC4424 sensor device by calling the APIs in the N0S68S42/BC4424 SDK. This SDK provides APIs for device initialization, ranging, ranging mode configuration, and calibration, which are available for user access.

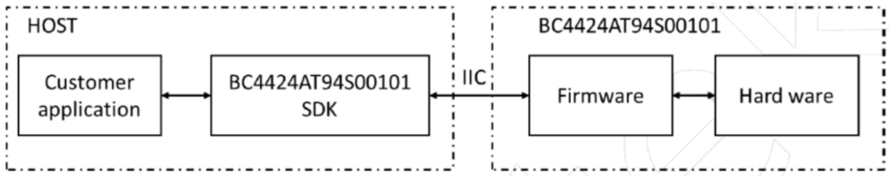


Figure 19: System Function

Q&A:

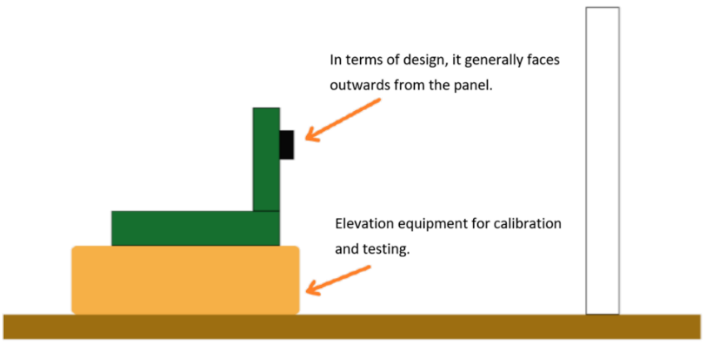
Q1: Does the integration time change with each measurement, or is it a fixed value after being set?

A: Because of the automatic exposure function, the integration time will change with the measurement distance or the reflectivity of the object.

Q2: We are currently measuring distances within 300mm, and the specifications state that the error within 300mm is 10mm. However, in our actual measurements, when the offset is calibrated to 150mm, the error exceeds 10mm within 100mm.

A: Sources of error:
- Incorrect calibration environment
- Incorrect testing environment
- Problems with PCB circuit design (e.g., placement of external capacitors)

Regarding points 1 and 2 above, it is necessary to ensure that there are no reflective objects other than the measurement target within the light-receiving area of the 4424 during calibration; otherwise, it will affect the accuracy of the measurement.



When designing the PCB circuit, it is important to note that the capacitor on the external power supply VDD should be placed as close as possible to the sensor pins PIN1 and PIN11, with the trace distance controlled within 3mm. The capacitor ground loop should be as short as possible, with a single-point ground loop of less than 3mm. Multiple grounding points should ensure good connection between the chip ground and the copper ground to ensure a small ground loop.

Q3: Upon entering sleep mode, the ammeter reading drops from 26mA to 4mA, indicating successful sleep mode entry. Exiting sleep mode, however, results in the ammeter still showing 4mA, preventing exit. We need to complete the "Device Restart," "Read Device ID," and "Device Boot" steps according to the flowchart before the ammeter reading returns to 26mA. Therefore, is this process repeated every time we exit sleep mode?

A: Test data is as follows: Device current:

a. Xshut low: 308uA
b. Xshut high: 429uA
c. Operating state: 26.7mA
d. Software sleep: 2.826mA
e. Software sleep wake-up: 428uA

Regardless of the method used to enter sleep mode, it is equivalent to a module reset. After waking up, booting is a necessary action. The data above also shows that the software sleep wake-up state is consistent with the state after Xshut is high.

Q4: What is crosstalk calibration?

A: When a cover plate is added to the N0S68S42/BC4424, most of the infrared light emitted by the VCSEL will pass through the cover plate and be reflected back by the object being measured, thus being received by the sensor. A small portion of the infrared light is reflected back by the cover plate and then received by the sensor, interfering with ranging.

Therefore, crosstalk refers to the interference caused by this small portion of infrared light, and crosstalk calibration is designed to reduce the ranging error caused by this. We also recommend that customers perform crosstalk calibration after installing the cover plate. For specific crosstalk calibration procedures, please refer to our calibration manual.

REVISION RECORD:

Version	Date	Summary of Revision
A1.0	17/05/2025	First issued.