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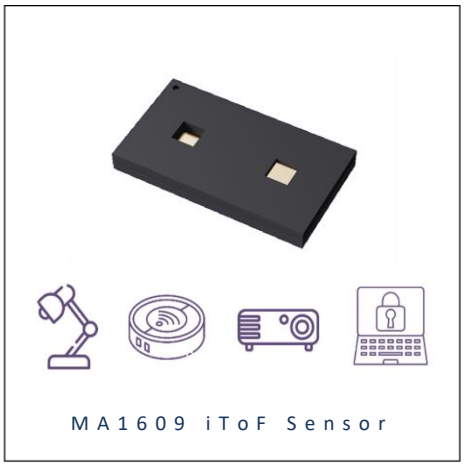
ISO/TS 16949:2009 BS EN ISO 14001:2004 QC 080000 IECQ HSPM

PRODUCT DATASHEET

- ► Time-of-Flight (ToF) Proximity Sensor
- ► 4x4 iToF 1609 1.66t
- ► 940nm VCSEL

Release Date: 09 September 2024 Version: A1.1

N0S67S37 (MA1609) ToF Proximity Sensor



MA1609 iToF Sensor

RoHS Compliant

FEATURES:

- **Package:** MA1609 Integrated Miniature Module with:
  - ✓ 940nm VCSEL
  - ✓ VCSEL driver
  - ✓ Ranging sensor with advanced embedded micro controller
  - ✓ Advanced embedded optical cross-talk compensation for simplify cover glass selection
- **Interface:** I^2C (up to 400KHz)
- **Eye Safety:** Class 1
- **Measure Ranging Distance:** 30cm~5.0m
- **Soldering methods:** Reflow soldering
- **MSL Level:** acc. to J-STD 020 Level 3

APPLICATIONS:

- Augmented Reality (AR)/Mixed Reality (MR)/Virtual Reality (VR)
- Robot/AGV/Drone/UAV
- Laser Assisted Autofocus (AF)
- Distance Measurement
- Video Surveillance Equipment
- Smart Lighting
- Collision Avoidance
- AI/ML-on-Edges

CHARACTERISTICS:

Maximum Ratings (T_a=25°C)

Parameter	Symbol	Ratings	Unit
Power Supply Voltage	V_{DD}	3.0~3.5	V
VCSEL_V_{DD}	$V_{DD(VCSEL)}$	3.3~4.5	V
SCL, SDA, XSHUT	$V_{I/O\ Terminal}$	-0.3~3.5	V
GND, GND2, GND3, GND4, VCSEL_GND	V_g	0.0	V
Operating Temperature	T_{OPR}	-20~+70	°C
Storage Temperature	T_{STG}	-40~+85	°C
Soldering Temperature [1]	T_{sol}	245	°C
Relative Humidity (non-condensing)	RH_{nc}	85	%
ESD withstand Voltage (HBM: JEDEC JS-001-2017)	$V_{ESD-HBM}$	2000	V
ESD withstand Voltage (CDM: JEDEC EIA/JESD22-C101F)	$V_{ESD-CDM}$	500	V

1. The reflow peak soldering temperature is specified according to IPC/JEDEC J-STD-020.
2. Exceeding the absolute maximum ratings specified in the table may result in permanent damage to the device, The ratings in the above table are provided for emphasis purposes only and do not reflect the normal operating conditions of the device. Long-term operation under conditions exceeding the absolute maximum ratings can have an impact on the device's reliability.

Current Consumption (T_a=25°C)

Parameter	Symbol	Ratings	Unit
Standby Mode Consumption (max.)	I_{SMC}	12	µA
Active Ranging Average Consumption (incl. VCSEL)	I_{AAC}	max.160	µA
Active Ranging Peak Consumption (incl. VCSEL)	I_{APC}	typ.1	A

XSHUT Pin Digital Input and Output

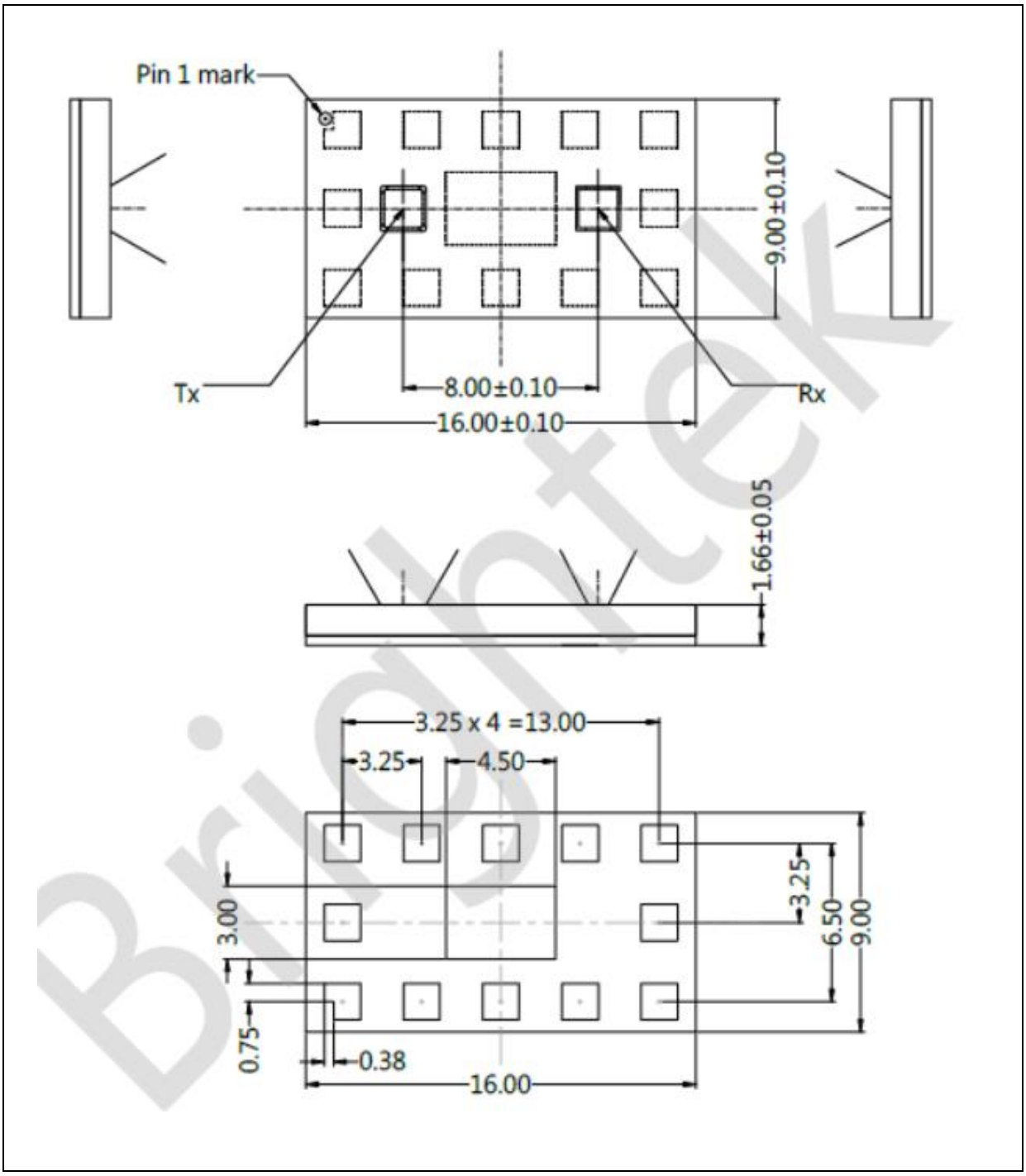
Parameter	Symbol	Values			Unit
		Min.	Typ.	Max.	
Low Level Input Voltage	V_{IL}	---	---	0.3 V_{DD}	V
High Level Input Voltage	V_{IH}	0.52 V_{DD}	---	V_{DD}	V

I^2C Interface (SDA/SCL) Digital Input and Output

Parameter	Symbol	Values			Unit
		Min.	Typ.	Max.	
Low Level Input Voltage	V_{IL}	0	---	0.3 V_{DD}	V
High Level Input Voltage	V_{IH}	0.52 V_{DD}	---	V_{DD}	V
Low Level Output Voltage (I_{OUT}=4mA)	V_{OL}	---	---	0.14	V
Leakage Current	$V_{IL/IH}$	---	---	1	µA

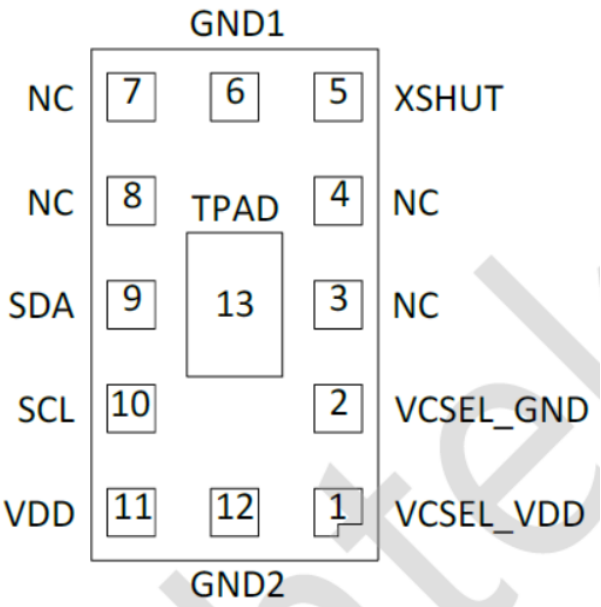
OUTLINE DIMENSION:

Package Dimension:



1. All dimensions are in millimetre (mm).
2. Tolerance ±0.1mm, unless otherwise noted.
3. Keep free of mechanical items which interfere with module operation in irradiate and receive area.

PIN CONFIGURATION:



Pin number	Signal name	Signal type	Signal description
1	VSCEL_VDD	VCSEL Power Supply	Power Supply Input (3.3V~4.5V)
2	VSCEL_GND	Ground	Grounding
3	NC	-	No Connected Pin
4	NC	-	No Connected Pin
5	XSHUT	Digital Input	The reset input terminal of the hardware standby mode is effective when the level is low.
6	GND1	Ground	Grounding
7	NC	-	No Connected Pin
8	NC	-	No Connected Pin
9	SDA	Data	I^2C Data Line
10	SCL	Clock	I^2C Clock Line
11	VDD	Power Supply	Power Supply Input (3.0V~3.5V)
12	GND2	Ground	Grounding
13	TPAD	Ground	Thermal Pad

The XSHUT digital input pin controls the sensor's entry into low-power mode. After the sensor is powered on, the input level of the XSHUT pin needs to be pulled high, and the sensor enters the working mode.

- When the input level is low, the sensor resets and enters the low-power standby mode.
- When the input level is high, the sensor wakes up from the standby mode.

1. Function Description:

1.1 System Function Description:

The system-level function description is shown in Figure 1 N0S67S37 system function description. The client application program controls the N0S67S37 sensor device by calling the API in the N0S67S37_SDK. The SDK opens up functions such as device initialization, ranging and calibration PAI for users to call.

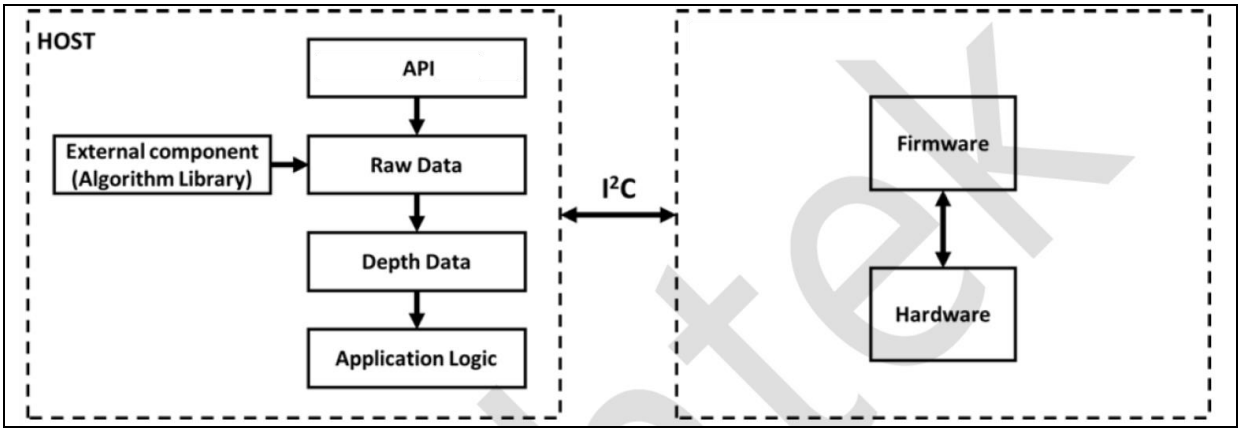


Figure 1. System Function Description

1.2 Firmware State Machine Description:

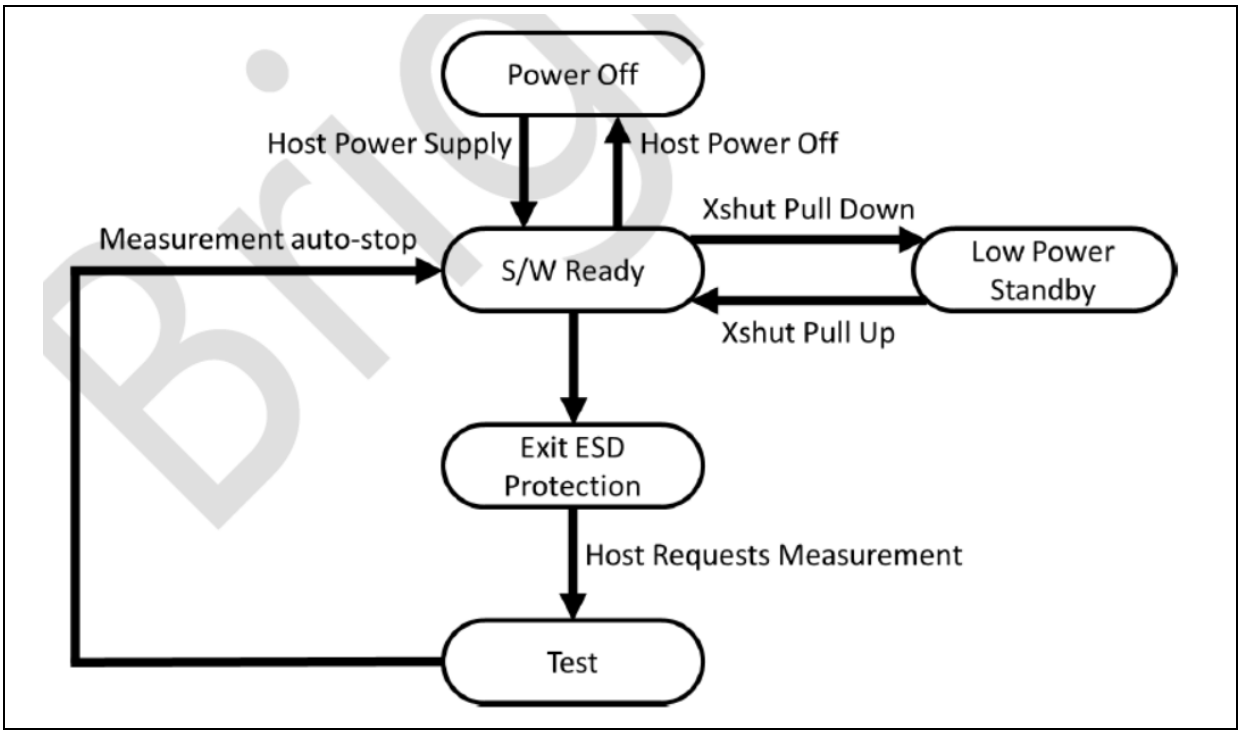


Figure 2. Firmware State Machine

1.3 Typical Ranging Flow:

A typical complete measurement process consists of the following three stages:

- Waiting for the device to start
- Initialize sensor device
- Ranging

1.3.1 Wait for the device to start

This stage is a phase where the device readiness is detected through I_2C. If there is a timeout during this stage, it could be due to the following issues:

- The error in the peripheral circuit.
- Welding issues, such as poor soldering or excessive temperature, resulting in sensor damage.
- There are issues with the I^2C read/write program. Please capture the waveform for analysis.

1.3.2 Ranging

This stage is the beginning of the distance measurement phase. During distance measurement, when the target object or sensor is in motion, the depth data obtained may contain invalid values of 65500 or 65300. Users are advised to filter out these values.

Note: If the sensor consistently outputs a depth measurement of 65300 when the target object is not too far away, please check the soldering or the layout of the external micro-circuit to ensure compliance with the standards.

1.4 Power Sequence:

After supplying power to VDD / VCSEL_VDD, ensure that the XSHUT pin is in a high state to enable normal I^2C communication. Subsequently, the device enters a pre-boot configuration phase, waiting for the firmware to start automatically and enter the initialization stage. Once initialization is complete, it transitions to a ready state, waiting to receive distance measurement commands. During the firmware startup phase, the device is polled through I^2C, and once successful, the polling is terminated.

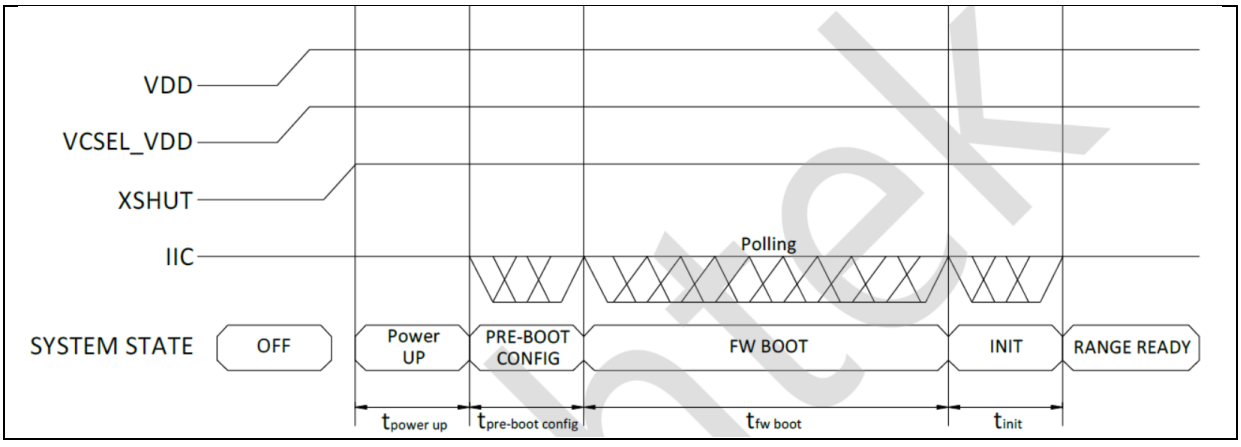


Figure 3. Power-On Sequence

Note:

- $t_{pre\text{-}boot\ config}$: pre-boot configuration time for the sensor.
- $t_{fw\ boot}$: The firmware startup time for the sensor.
- t_{init}: The initialization time for the sensor.

1.5 Standby Mode:

N0S67S37 features a standby mode, which significantly reduces power consumption of the sensor when it is in standby mode.

1.5.1 Entering standby mode:

- Hardware mode: Pulling the XSHUT pin of N0S67S37 low puts the sensor into standby mode.
- Software mode: TBD.

1.5.2 Wake up device:

- If hardware standby mode is used, the sensor can be awakened by pulling the XSHUT pin to a high logic level
- If software standby mode is used, the awakening operation is to be determined (TBD).

2. Control Interface:

2.1 I²C Timing:

The I²C bus consists of two lines, the data line SDA and the clock line SCL. The N0S67S37 operates as a slave device with the device address of 0x5B. The I²C bus speed for the N0S67S37 is 400KHz.

During data transmission, the host initiates the communication by sending a start signal. Following that, it sends the 7-bit device address and a single read/write control bit (R/W) in a sequence from high to low. When the R/W control bit is 0, it indicates that the host is performing a write operation to the slave device. When the R/W control bit is 1, it indicates that the host is performing a read operation from the slave device. The host then waits for a response from the slave device, as shown in Figure 4, which illustrates the device address format.

Figure 4. Address: 0x5b

As shown in Figure 5, the slave device is connected to the bus using an open-drain structure. Both SCL and SDA lines require pull-up resistors. Therefore, when the bus is idle, both lines are at a high logic level. However, when any device pulls the line low, it will cause the bus to be pulled low.

- Start bit: when SCL is at high level, pull SDA down to generate start signal. After the slave detects the start signal, it shall be accurate ready to receive data. The data transmission state is from the start signal to the stop signal, which is completed by the bidirectional data line SDA.
- Stop bit: when SCL is high level, pull SDA high to generate end signal. After the slave detects the end signal, stop receiving data.

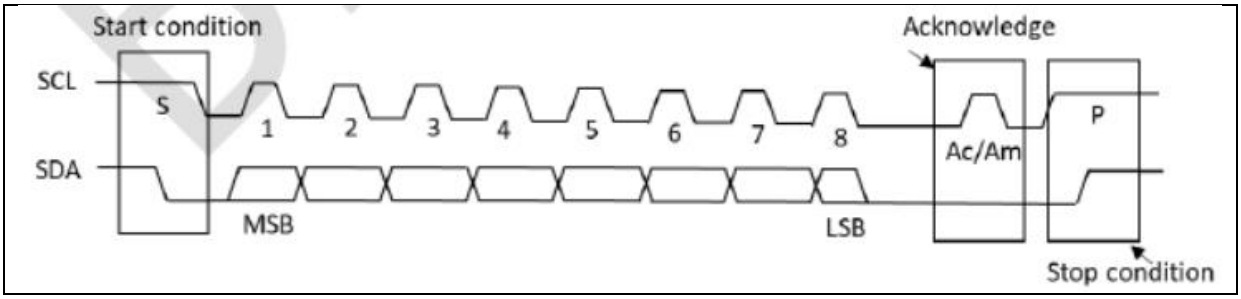


Figure 5. Data Transfer Protocol

During data transmission, when SCL is low, SDA is allowed to change its data bit. When SCL is high, SDA is required to remain stable, effectively transmitting 1 bit of data per clock cycle.

At the end of the eighth clock cycle, the master releases SDA to allow the slave to respond. On the ninth clock cycle, the slave pulls SDA low to acknowledge. If, during the ninth clock cycle, SCL is high and SDA is not detected as low, it is considered a non-acknowledgment, indicating a failed data transmission. At the end of the ninth clock cycle or when the current transmission is complete, the slave releases SDA to allow the master to continue transmitting data. If the master sends a stop signal, the transmission is ended.

After the start bit is initiated, the first byte is sent, which consists of the 7-bit device address and a single read/write control bit. Upon receiving the correct acknowledgment from the slave, the master proceeds to send the word address. Once the correct acknowledgment from the slave is received, the master can then write the desired content to that address.

The typical write data transmission format is illustrated in Figure 6, which shows the data transmission format for writing.

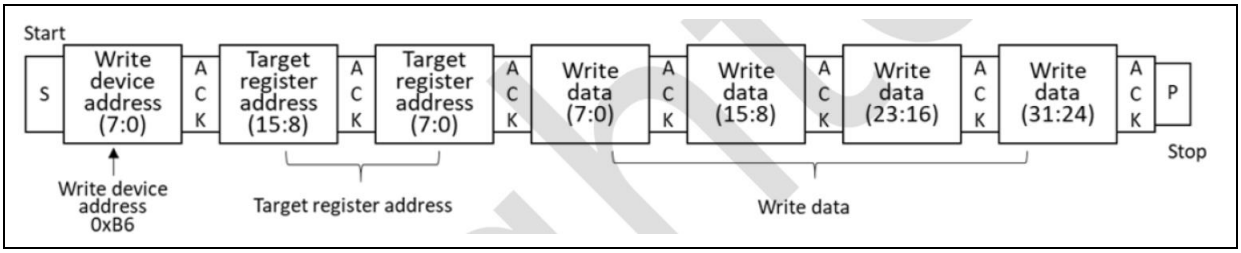


Figure 6. Data Format (Write)

For the read timing sequence, after sending the device address (write command) and word address, a repeated start signal, and device address (read command) are sent. Following that, the data can be read, as shown in Figure 7, which illustrates the data format for reading.

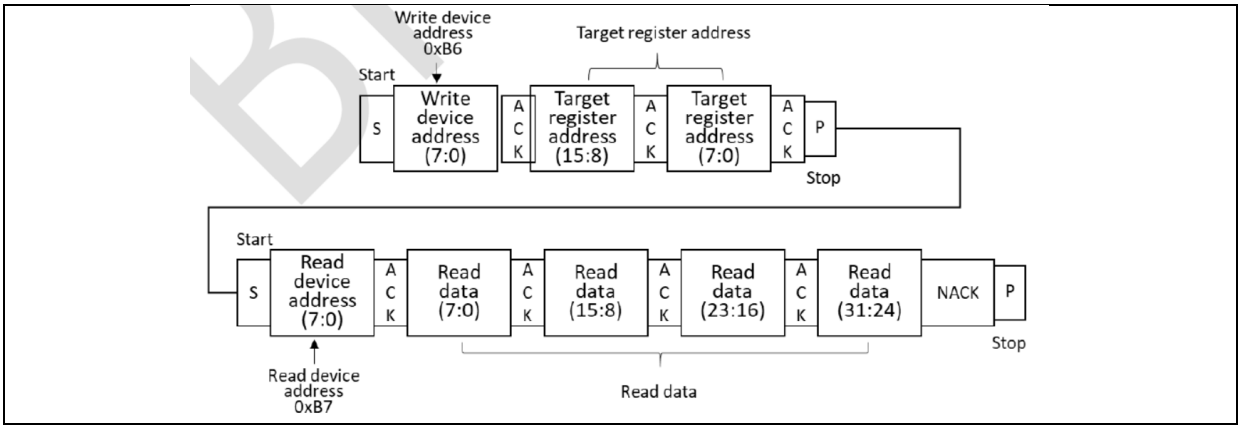


Figure 7. Data Format (Read)

2.2 I²C Interface – Timing Characteristics:

Timings are given for all PVT conditions.

Symbol	Parameter],\	Min.	Typ.	Max.	Unit
F_{IIC}	Operating frequency (standard and fast modes)	0	-	400	kHz
t_{LOW}	The width of the SCL low-level pulse	1.71	-	1.74	μs
t_{HIGH}	The width of the SCL high-level pulse	810	-	904	ns
t_{SP}	The input filter suppresses peak pulse widths.	-	330	-	ns
t_{BUF}	The bus idle time between transmissions	2.6	-	29	μs
$t_{HD.STA}$	Start signal hold time	-	825	-	Ns
$t_{SU.STA}$	Repeated start signal setup time	0.63	-	2.83	μs
$t_{HD.DAT}$	Data hold time	57	-	870	Ns
$t_{SU.DAT}$	Data setup time	0.82	-	2.1	μs
t_R	SCL/SDA rise time	216	-	334	Ns
t_F	SCL/SDA fall time	4	-	6	Ns
$t_{SU.STO}$	End signal setup time	700	760	-	ns
$C_{i/o}$	Input/output capacitance (SDA)	-	5.5	-	pF
C_{in}	Input capacitance (SCL)	-	4.5	-	pF
C_L	Load capacitance	-	125	400	pF

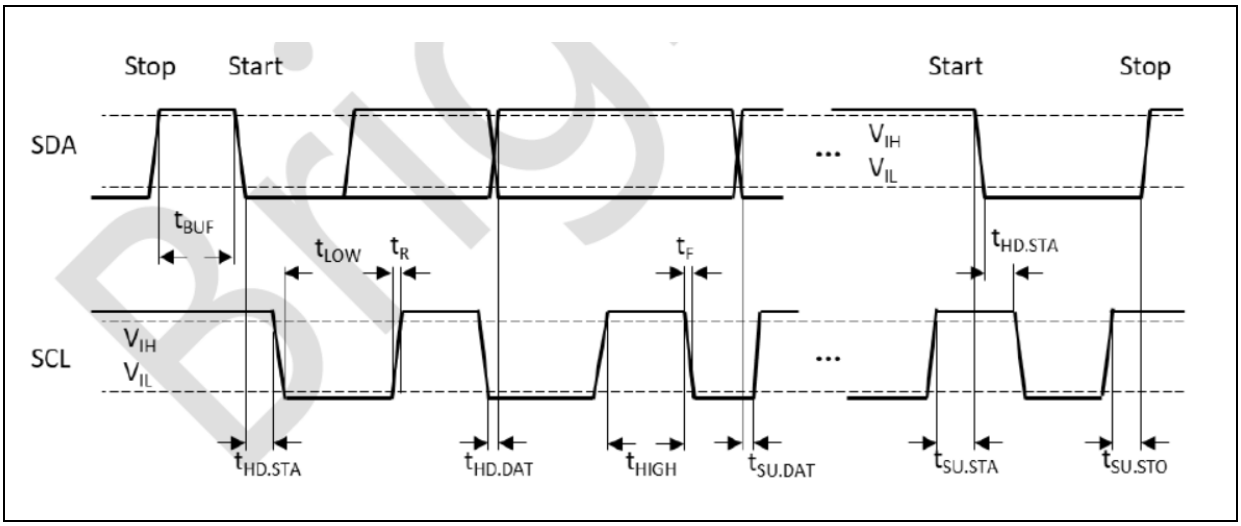


Figure 8. I²C Timing Characteristics

3. Performance:

Measurement conditions for ranging:

- Using target reflectivity: White (90%), Gray (18%).
- Using target reflector size: Larger than 0.53m*0.53m (90%), 1.5m & 1.6m (18%).
- Indoor: Under ambient lighting conditions of no strong light, white LED at 145 lux.
- Outdoor: Simulating outdoor lighting conditions of 5Klux, 50Klux, and 100Klux using halogen lamps, with ambient light applied to the target reflection card, excluding direct module illumination.
- Operating voltage: 3.3V.
- All distances are measured within the full coverage field of view (FOV=20°x20°).
- Measurements exclude the cover plate.
- Distance measurements are frequency calibrated.
- Accuracy calculations are based on the average of 20 distance measurements, while precision calculations utilize the mean square deviation of 20 distance measurements.
- Pixel count: 4 x 4 ； Pixel Area Schematic diagram:

Corner	Boundary	Boundary	Corner
Boundary	Center	Center	Boundary
Boundary	Center	Center	Boundary
Corner	Boundary	Boundary	Corner

3.1 Ranging Distance & Accuracy

Target reflectivity	Condition	Ranging distance	Ranging accuracy
White card (90%)	Fluorescent light & Darkroom	30~50 cm	±3 cm
		>50 cm	±5 %
	50Klux~100Klux	30~50 cm	±3.5 cm
		>50 cm	±5 %

4. Application Circuit:

Application circuit diagram

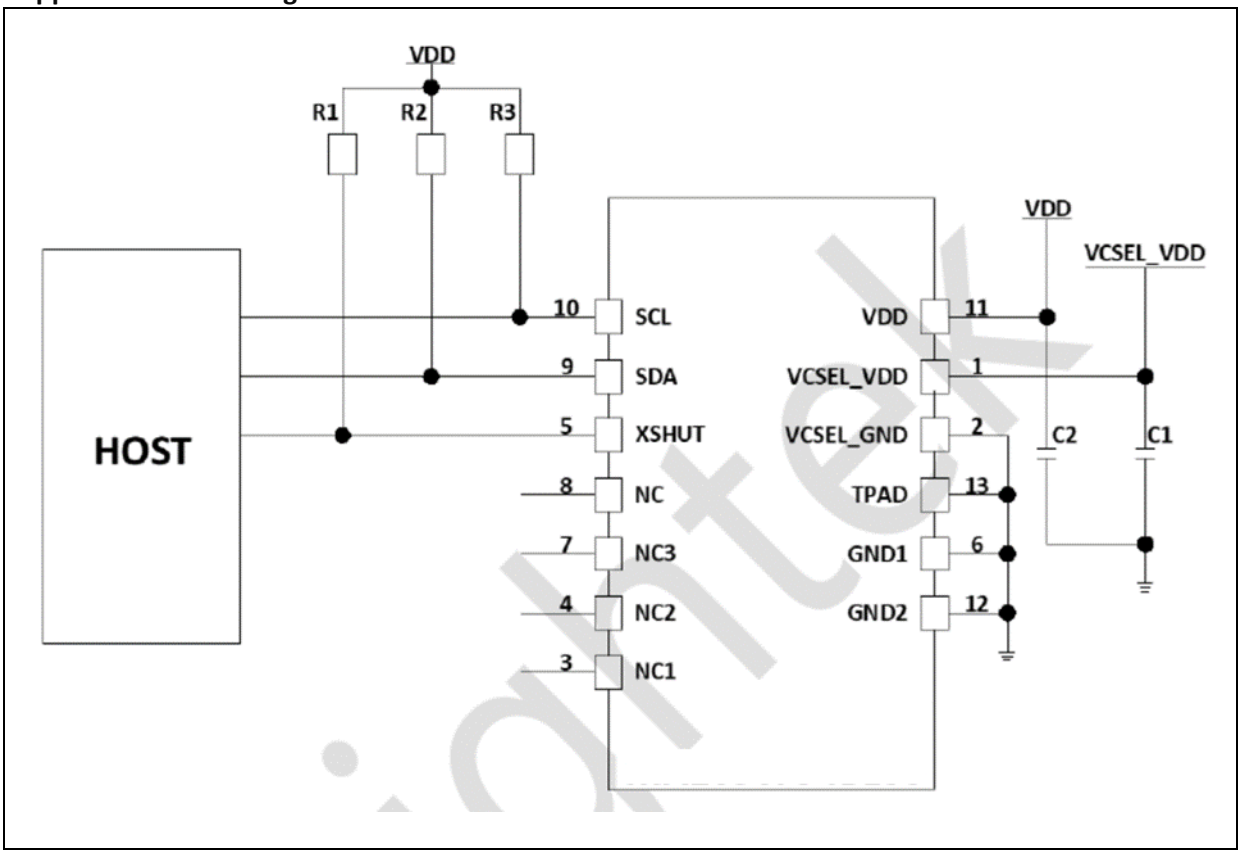


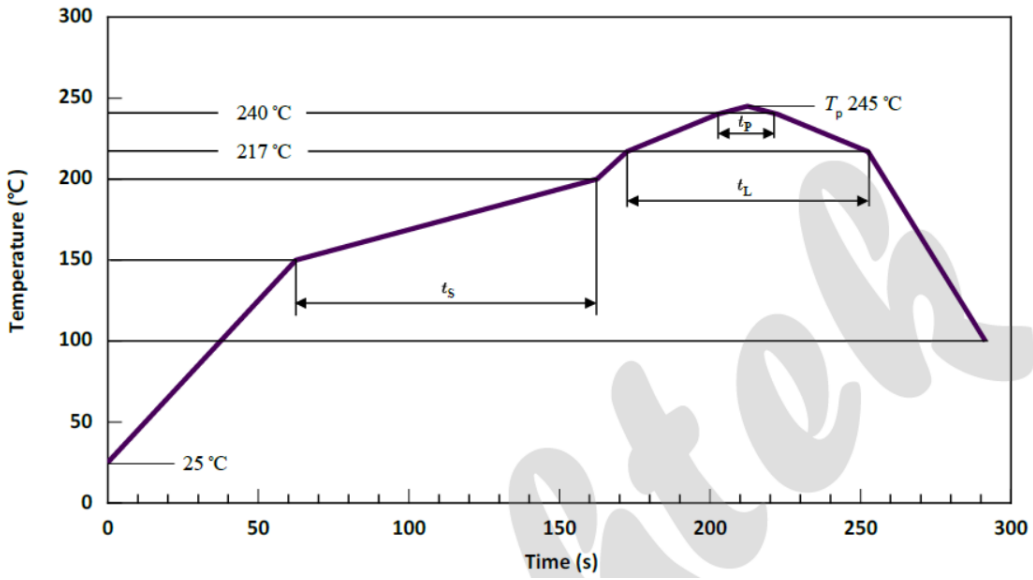
Figure 9. Application circuit diagram

Lib ref.	Quantity	Position	Parameter	Tolerance
Capacitor	1	C1	4.7μF	±20%
Capacitor	1	C2	0.1μF	±20%
Resistor	1	R1	10K	±5%
Resistor	2	R2、R3	1.5K~2k	±5%

Note: If the parasitic capacitance of the user's device is relatively large, the I^2C pull-up resistors can be reduced to decrease the rise time of the I^2C waveform.

RECOMMENDED SOLDERING PROFILE:

Lead-free Solder IR Reflow:



Profile Feature	Symbol	Pb-Free (SnAgCu) Assembly			Unit
		Minimum	Recommendation	Maximum	
Ramp-up rate to preheat 25 °C to 150 °C			2	3	K/s
Time ts T_{Smin} to T_{Smax}	t_S	60	100	120	s
Ramp-up rate to peak T_{Smax} to T_P			2	3	K/s
Liquidus temperature	T_L		217		°C
Time above liquidus temperature	t_L		80	100	s
Peak temperature	T_P			245	°C
Time within 5 °C of the specified peak temperature TP - 5 K	T_P	10	20	30	s
Ramp-down Rate T_P to 100 °C			3	4	K/s
Time 25 °C to T_P				480	s

Note:

1. We recommend the reflow temperature 240°C (±5°C). The maximum soldering temperature should be limited to 245°C.
2. Maxima reflow soldering: 3 times.
3. Before, during, and after soldering, should not apply stress on the components and PCB board.

PRECAUTIONS OF USE:

Storage:

It is recommended to store the products in the following conditions:

- Humidity: 60% R.H. Max.
- Temperature: 5°C~30°C (41°F ~86°F).

Shelf life in sealed bag: 12 months at 5°C~30°C and <60% R.H.

Once the package is opened, the products should be used within 1 week. Otherwise, they should be kept in a damp-proof box with descanting agent stored at R.H.<10% and apply baking before use.

ESD (Electrostatic Discharge):

Static Electricity or power surge will damage the LED. Use of a conductive wrist band or anti-electrosatic glove is recommended when handing the LED all time. All devices, equipment, machinery, work tables, and storage racks must be properly grounded.

REVISION RECORD:

Version	Date	Summary of Revision
A1.0	13/08/2024	Datasheet set-up.
A1.1	09/09/2024	Update ranging distance.