MA1609F94BL00 Datasheet

Time of Flight Sensor

1609 Series (940nm)

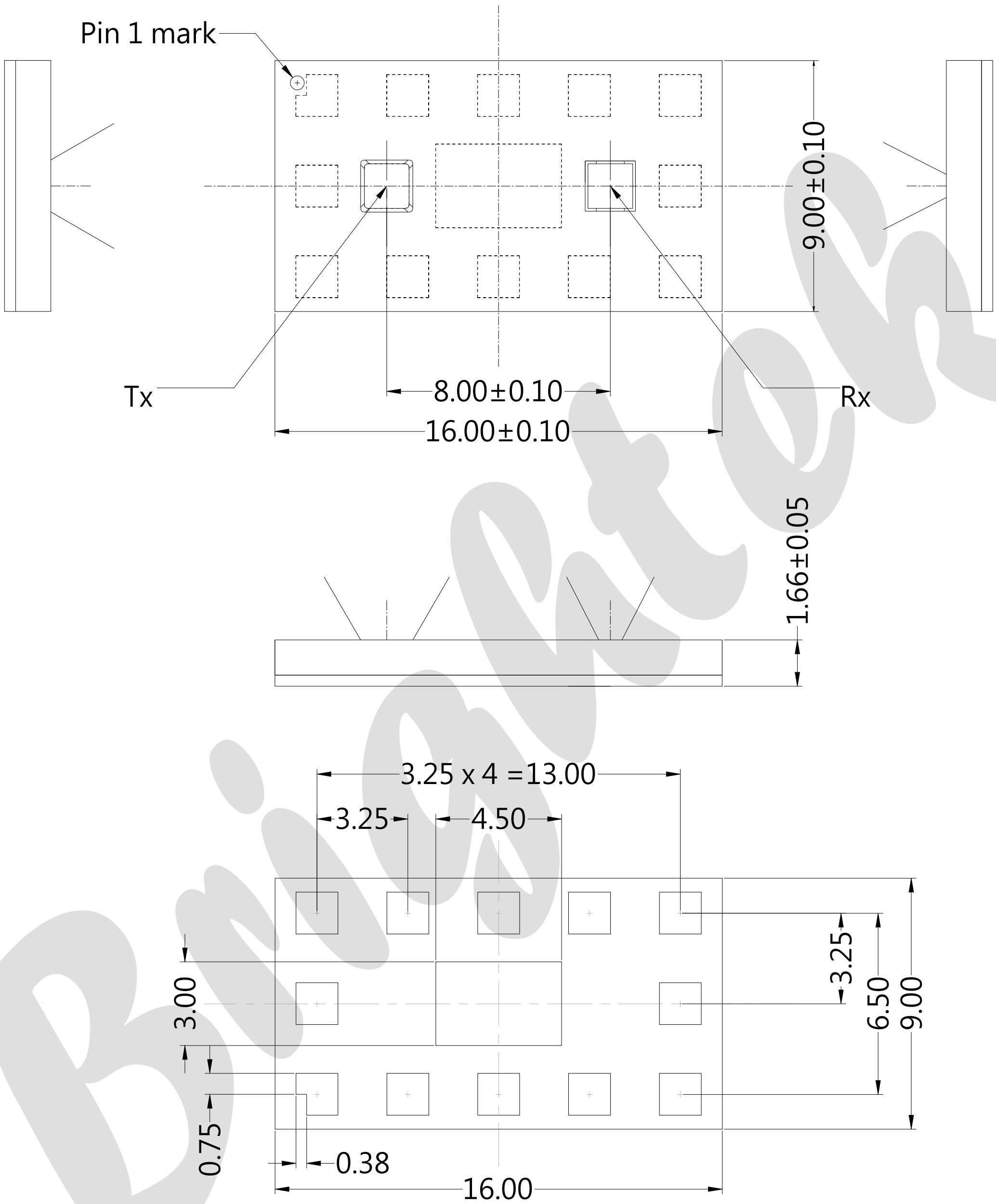
Applications

- Service robots
- Smart lighting
- Laser assisted autofocus (AF)
- Collision avoidance

Features

- Fully integrated miniature module
  - ✓ 940 nm VCSEL
  - ✓ VCSEL driver
  - ✓ Ranging sensor with advanced embedded micro controller
  - ✓ 16.00 x 9.00 x 1.66 mm
- I^2C interface (up to 400kHz)
- Class 1 Eye safety
- RoHS 2.0 and REACH compliant
- MSL 3 qualified according to J-STD 020
- Measure absolute distances up to 5m
- Advanced embedded optical cross-talk compensation for simplified cover glass selection.

Dimensional Drawing



1. Dimensions are in millimeters.
2. Keep free of mechanical items which interfere with module operation in irradiate and receive area.

Device Pinout

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

Noted. 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.

Maximum Ratings

T_A : 25 °C

Parameter	Symbol	Rating	
VDD	V_{DD}	Min.	3.0 V
		Typ.	3.3 V
		Max.	3.5 V
VCSEL_VDD		Min.	3.4 V
		Typ.	3.6 V
		Max.	4.5 V
SCL,SDA,XSHUT	$V_{I/O\ terminal\ voltage}$	Min.	-0.3 V
		Max.	3.5 V
GND,GND2,GND3,GND4,VCSEL_GND	V_g	Max.	0.0 V
Storage temperature	T_{stg}	Min.	-40 °C
		Max.	85 °C
Soldering temperature	T_{sol}	Max.	245 °C
Relative Humidity (non-condensing)	RH_{nc}	Max.	85 %
ESD withstand voltage (HBM : JEDEC JS-001-2017)	$V_{ESD-HBM}$	Max.	2 kV
ESD withstand voltage (CDM : JEDEC EIA/JESD22-C101F)	$V_{ESD-CDM}$	Max.	500 V
Moisture sensitivity level	**MSL3**		

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.

MSL 3 : Under the conditions of ambient temperature below 30 degrees and relative humidity below 60%, the maximum operational lifespan of the device is 168 hours.

Recommended operating conditions

Parameter	Symbol		Rating
VDD	V_{DD}	Min.	3.0 V
		Typ.	3.3 V
		Max.	3.5 V
VCSEL_VDD	V	Min.	3.3 V
		Typ.	3.6 V
		Max.	4.5 V
Operating temperature	T_{op}	Min.	-20 °C
		Max.	70 °C

Current consumption

TA : 25°C

Parameter	Symbol		Values
Standby mode consumption	I_{SMC}	max.	12 µA
Active ranging average consumption (including VCSEL)	I_{AAC}	max.	420 mW
Active ranging peak consumption (including VCSEL)	I_{APC}	typ.	1 A

Digital input and output

Parameter	Symbol	Min.	Typ.	Max.	Unit
	XSHUT Pin				
Low level input voltage	VIL	-	-	0.3VDD	V
High level input voltage	VIH	0.52VDD	-	VDD	V
	I²C Interface (SDA/SCL)				
Low level input voltage	VIL	0	-	0.3VDD	V
High level input voltage	VIH	0.52 VDD	-	VDD	V
Low level output voltage (I_{OUT} = 4 mA)	VOL	-	-	0.14	V
Leakage current	IIL/IH	-	-	1	µA

Functional description

System function description

The system-level function description is shown in Figure 1 MA1690F94BL00 system function description. The client application program controls the MA1690F94BL00 sensor device by calling the API in the MA1690F94BL00_SDK. The SDK opens up functions such as device initialization, ranging and calibration PAI for users to call

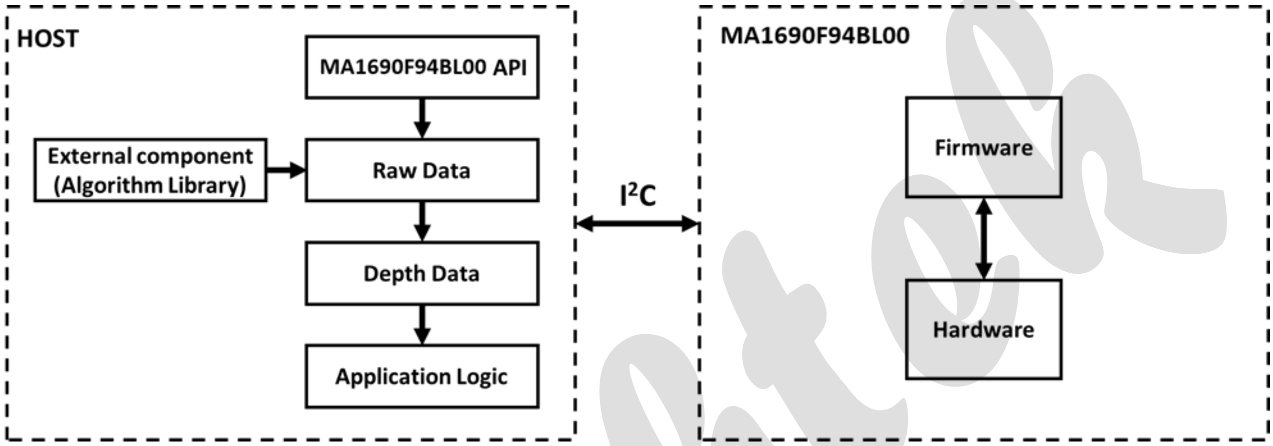


Figure 1 MA1690F94BL00 system function description

Firmware state machine description

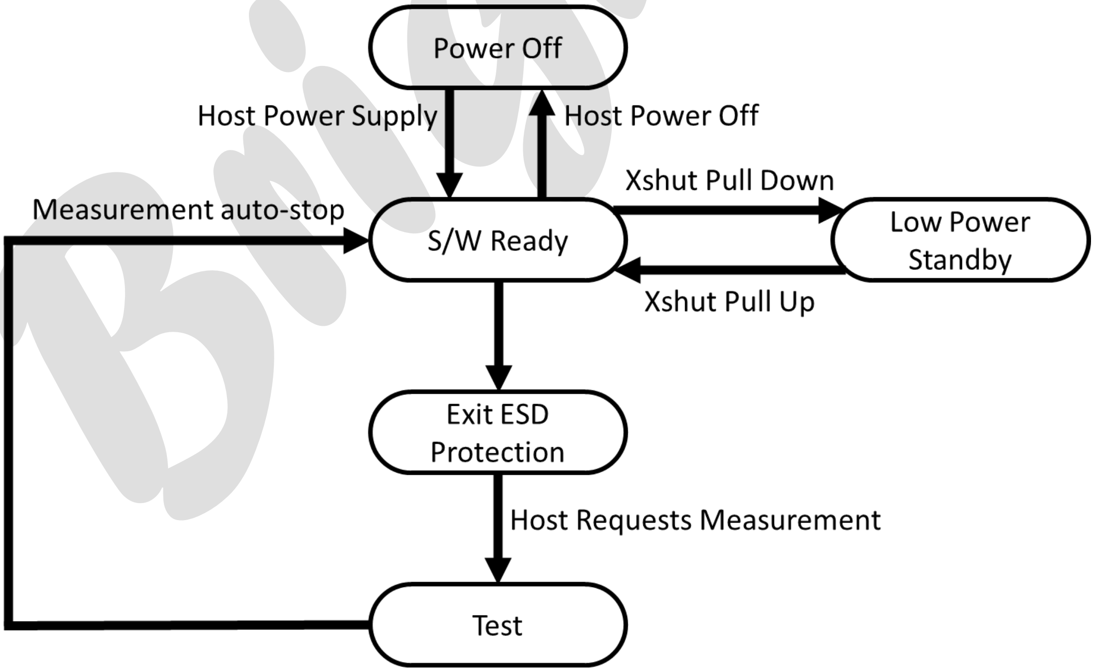


Figure 2 MA1690F94BL00 Firmware state machine

Typical ranging flow

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

- Waiting for device to start
- Initializing sensor devices
- Ranging

Waiting for 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 I2C read/write program. Please capture the waveform for analysis.

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.

Power-up sequence

After supplying power to VDD/VCSEL_VDD, ensure that the XSHUT pin is in a high state to enable normal I2C 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 I2C, and once successful, the polling is terminated.

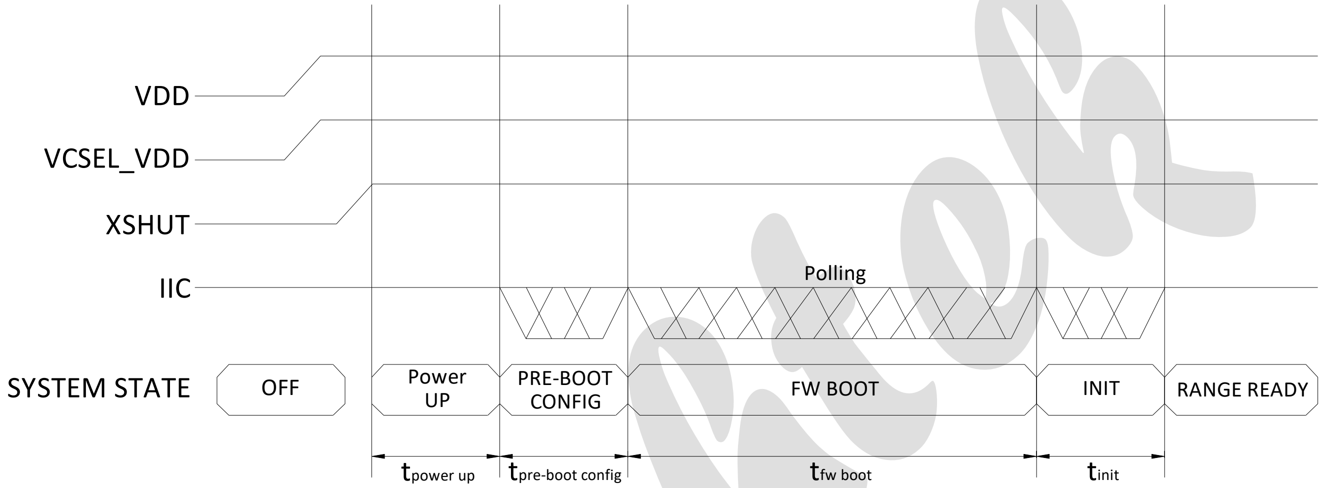


Figure 3 The Power-up Sequence

Note:

- **$t_{pre\text{-}boot\ config}$**: The 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.

Standby mode

MA1690F94BL00 features a standby mode, which significantly reduces power consumption of the sensor when it is in standby mode.

Entering standby mode

- Hardware mode: Pulling the XSHUT pin of MA1690F94BL00 low puts the sensor into standby mode.
- Software mode: TBD

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)

Control interface

I²C timing

The I²C bus consists of two lines, the data line SDA and the clock line SCL. The MA1690F94BL00 operates as a slave device with the device address of 0x5B. The I²C bus speed for the MA1690F94BL00 is 400 KHz.

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.

1	0	1	1	0	1	1	R/W

Figure 4 MA1690F94BL00 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.

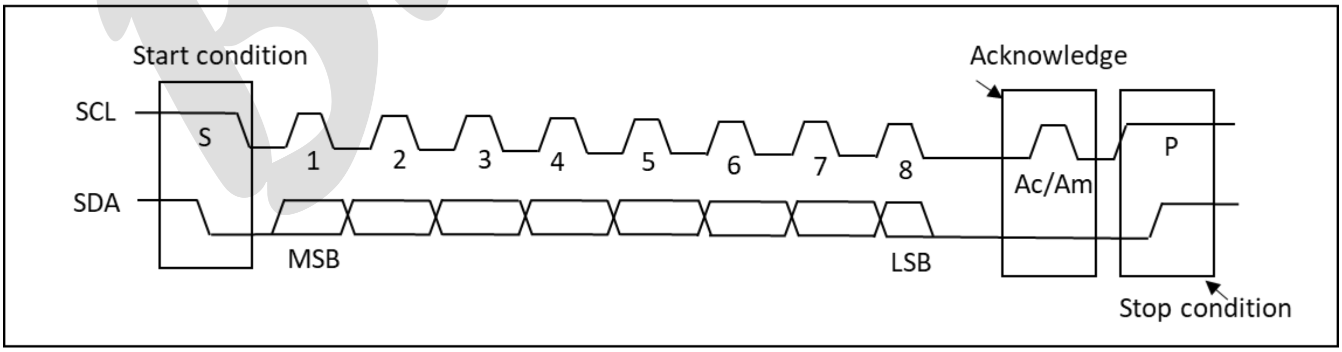


Figure 5 Data Transfer Protocol

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.

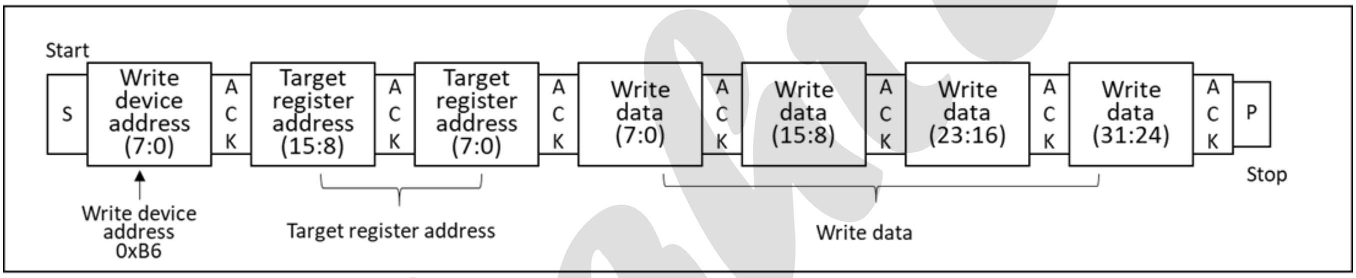


Figure 6 MA1690F94BL00 Data Format (Write)

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.

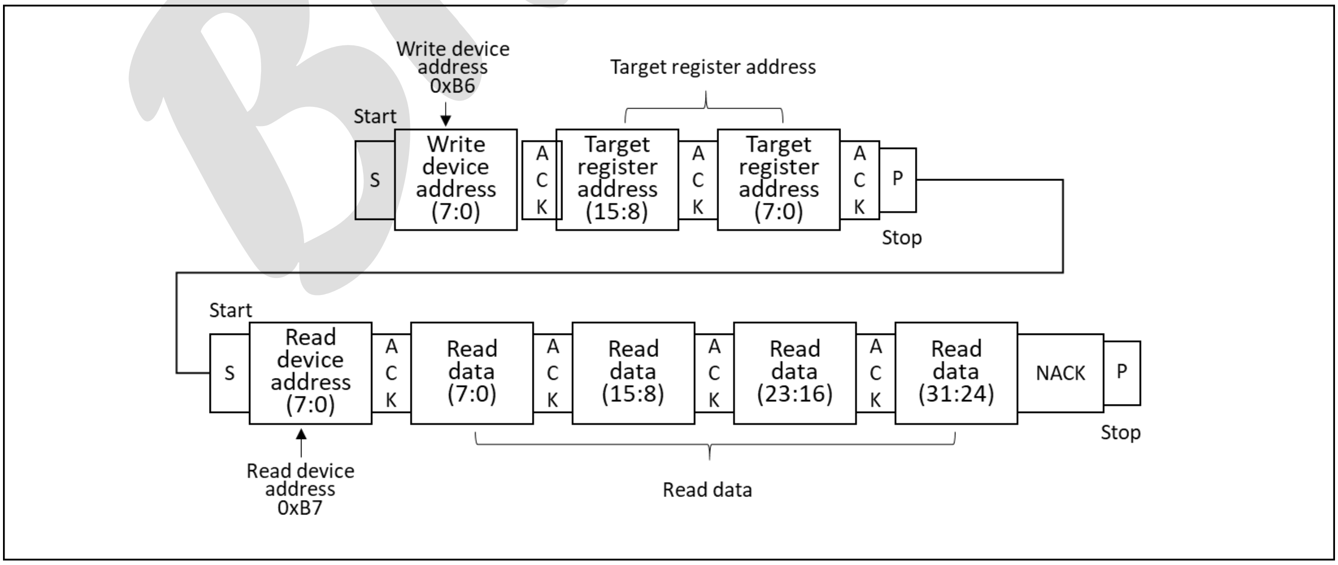


Figure 7 MA1690F94BL00 Data Format (Read)

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

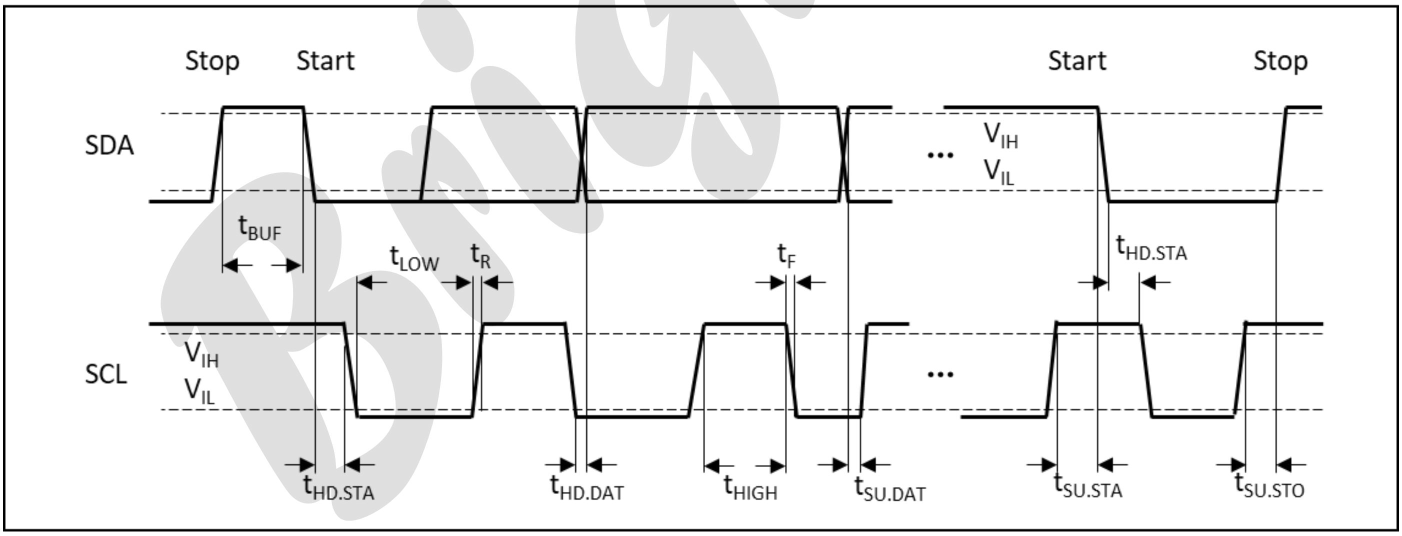


Figure 8 I²C Timing Characteristics

Performance

The 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°).
- Pixel count: 4 x 4.
- 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.

Ranging Distance & Accuracy

Target reflectivity	Condition	Ranging distance	Ranging accuracy
White card (90%) & Gray card (18%)	Fluorescent light & Darkroom	10~20cm	±1cm
		>20cm	±4%
	5Klux~100Klux	10~30cm	±1.5cm
		>30cm	±5%

Application circuit

Application circuit diagram

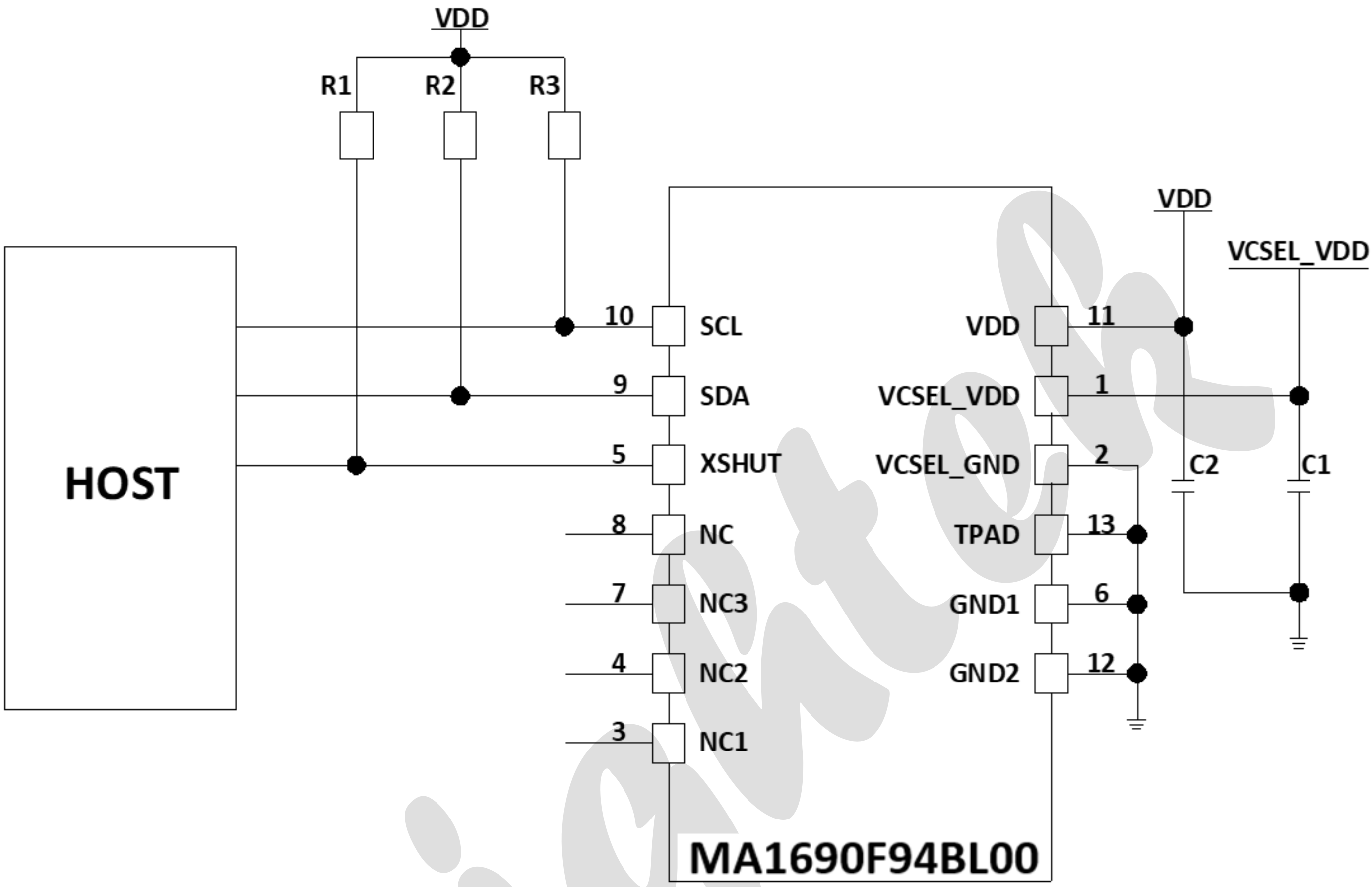


Figure 9 Application circuit diagram

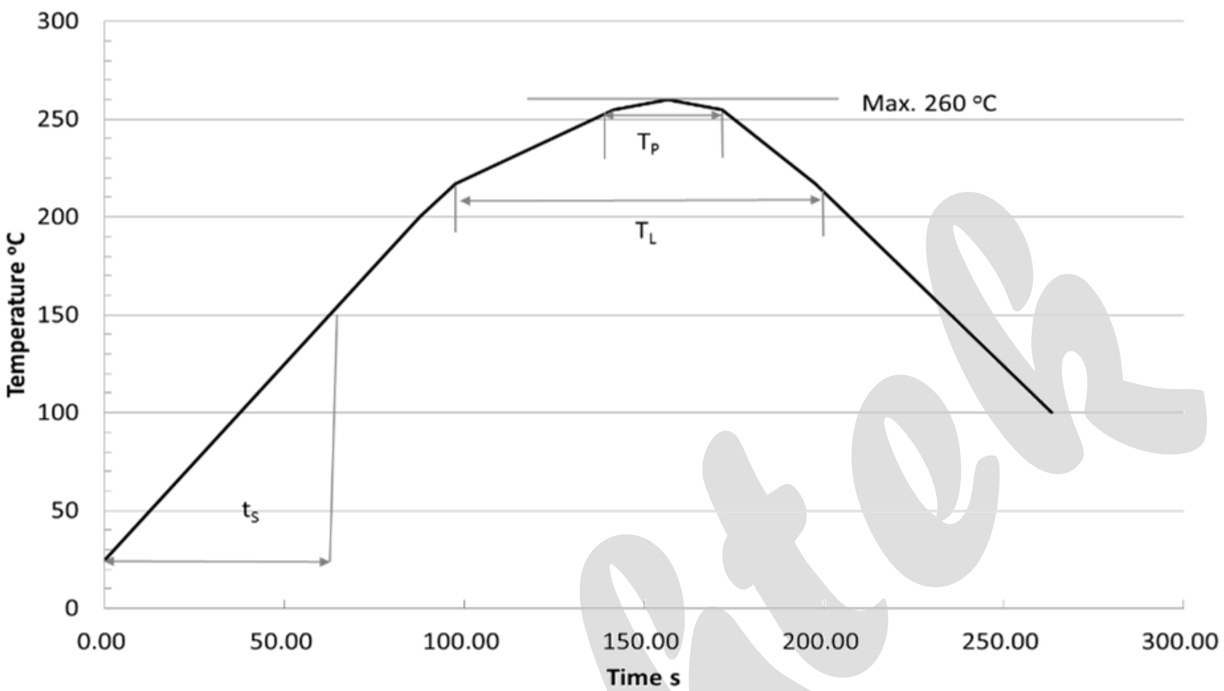
Lib ref.	Quantity	Position	Parameter	Tolerance
Capacitor	1	C1	4.7μF	±20%
Capacitor	1	C2	0.1μF	±20%
Resistor	1	R1	10K	±5%
Resistor	2	R2 、R3	1.5K~2k	±5%

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

Reflow Soldering Profile

Product complies to MSL Level 3 acc. to JEDEC J-STD-020E

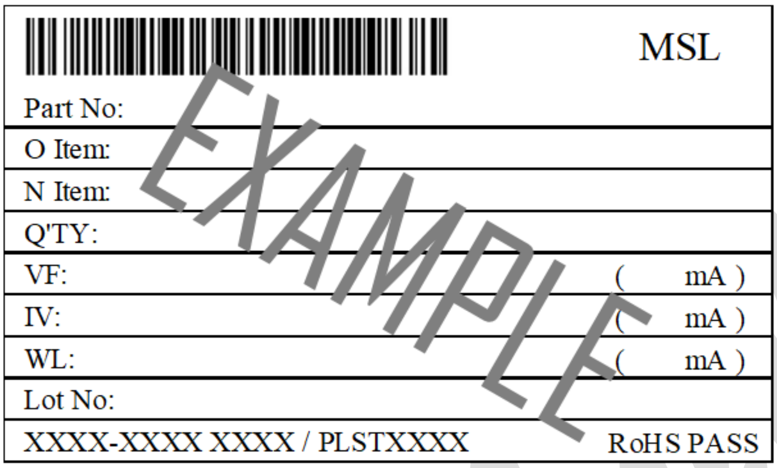
Pb free Reflow Profile



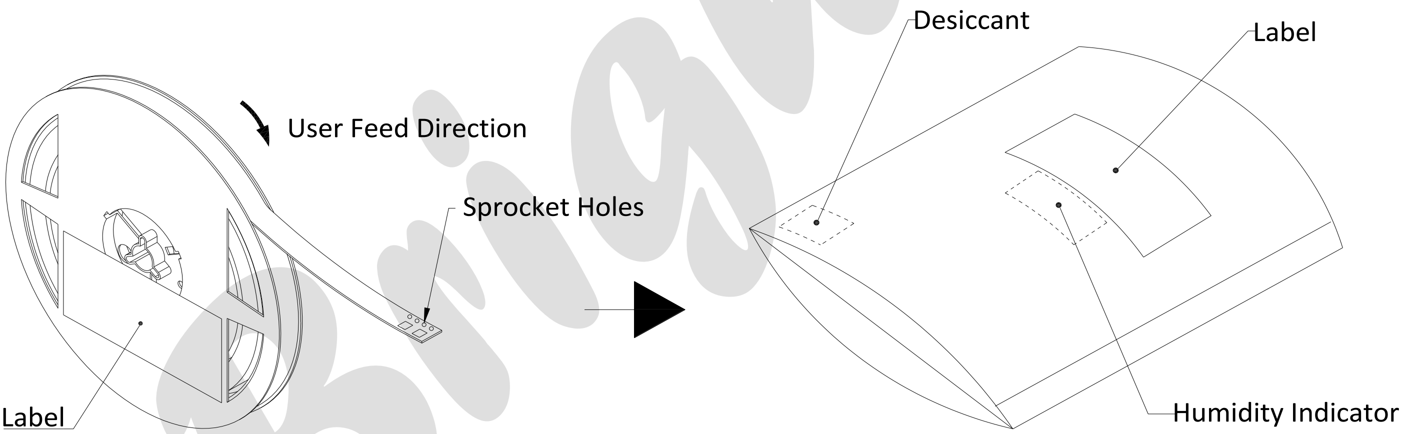
Profile Feature	Symbol	Pb-Free (SnAgCu) Assembly			Unit
		Minimum	Recommendation	Maximum	
Ramp-up rate to preheat 25 °C to 150 °C			2	3	K/s
Time t_S T_{Smin} to T_{Smax}	t_S	60	100	120	s
Ramp-up rate to peak T_{Smax} to T_P			2	3	K/s
Liquidus temperature	T_L		217		°C
Time above liquidus temperature	t_L		80	100	s
Peak temperature	T_P		245	260	°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

1. Do not stress the silicone resin while it is exposed to high temperature.
2. The reflow process should not exceed 3 times.

Barcode-Product-Label (BPL)



Dry Packing Process and Materials



1. Moisture-sensitive product is packed in a dry bag containing desiccant and a humidity card according JEDEC-STD-033.

Disclaimer

1. BRIGHTEK reserves the right(s) on the adjustment of product material mix for the specification.
2. The product meets BRIGHTEK published specification for a period of one year from date of shipment.
3. The graphs shown in this datasheet are representing typical data only and do not show guaranteed values.
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