

LF2000 Series Liquid Flow Sensor I²C Interface Protocol

V 1.0.2

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1. Overview

This document specifies the commonly used I²C data communication protocols for the liquid flow sensor LF2000. This document will also review some I²C bus basics, but is not intended to give detailed descriptions on I²C bus specification. For detailed I²C bus specification, please refer to reference ^[1].

2. User Interface

2.1 Pin Definition

The pin layout and definition of LF2000 are shown in Figure 2.1 and Table 2.1 respectively.

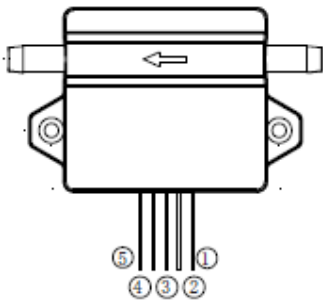


Figure 2.1: Pin layout.

Pin	Definition
1	SCL (I ² C clock)
2	GND (ground)
3	Vcc (DC supply)
4	Vout (analog voltage output)
5	SDA (I ² C data)

Table 2.1: Pin definition.

2.2 Pin Description

Serial Data (SDA) Pin

Serial Data Line (SDA) is bidirectional data line, SDA requires a pull-up resistor connected with VCC and it is on board already.

Serial Clock Line (SCL)

Serial Clock Line (SCL) is used to synchronize all data transferred over the I2C bus. The required pull-up resistor is also on board.

Power supply (VCC)

VCC range: $3.6V \leq VCC \leq 6.0V$

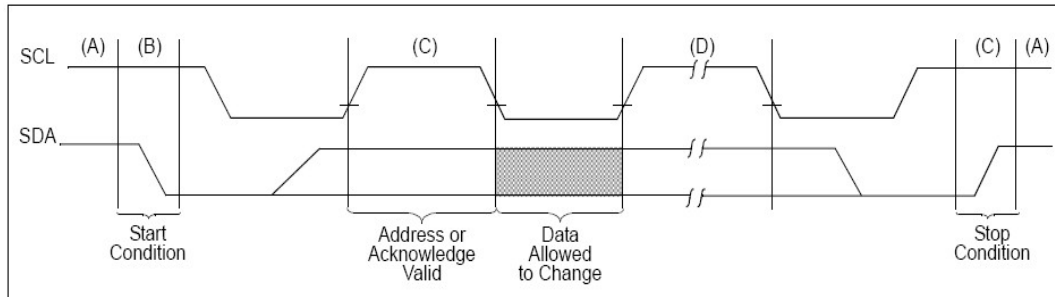
3. Bus Properties

I²C bus protocols are defined as the following:

- The data transfer can be started only when the bus is idle.

- During data transfer, the series data line (SDA) must be kept steady whenever the series clock line (SCL) is high. When the series clock line is high, a change of the series data line from high to low or from low to high will be treated as a start condition or a stop condition.

Following figure shows the bus timing diagram:



3.1 Bus Idle (A)

Both the series data line and the series clock line are high.

3.2 Start Condition (B)

When SCL is high, a change of SDA from high to low represents a start condition that initiates data transfer. A start condition must present before any data transfer commands can be executed.

3.3 Stop Condition (C)

When SCL is high, a change of SDA from low to high represents a stop condition that ceases data transfer. All the data transfer commands must be accomplished before a stop condition presents.

3.4 Data (D)

After the start condition, the series data line must be kept steady when the series clock line is high.

The series data line can change during the period when the series clock line is low, and each data bit must correspond to a clock pulse.

Each data transfer will begin with a start condition and cease after a stop condition. Every byte put on the series data line must be 8 bits long. The number of bytes that can be transmitted per transfer is unrestricted. Each byte has to be followed by an Acknowledge bit. The number of data bytes between a start condition and a stop condition will be decided by the bus master.

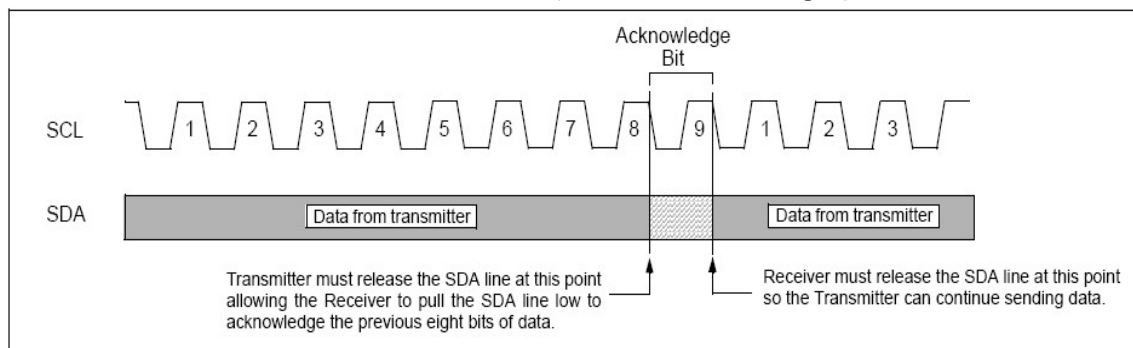
3.5 Acknowledge Bit

If the slave exists on the bus then it will respond with acknowledge (ACK) bit (active low for acknowledged) for that address. The master must provide an extra SCL pulse for each ACK bit.

The address and the data bytes are sent most significant bit first. The start bit is indicated by a high-to-low transition of SDA with SCL high; the stop bit is indicated by a low-to-high transition of SDA with SCL high.

If the master wishes to read from the slave then it repeatedly receives a byte from the slave, the master sending an ACK bit after every byte but the last one (See figure below). (In this situation, the master is in the master receive mode and the slave is in the slave transmit mode.)

The master then ends transmission with a stop bit, or it may send another start bit if it wishes to retain control of the bus for another transfer (a "combined message").



4 Device Address

The I²C interface of the LF2000 sensor adopts the slave-master mode with transfer rate 10kbit/s ~ 20kbit/s, making it easy to establish connection and simplify the commands. The slave address is always an even number between 02h and FEh, i.e., totally there are 128 available slave addresses. Multiple LF2000 board can be configured as a single-master multi-slave bus for multi-device communication, provided that each board (i.e., slave board) has a unique address. The default address is 02h.

5 Commands

The LF2000 sensor uses a communication mode based on the command Interpretation mechanism. The data accesses are accomplished through various commands. A proper command consists of a command code and none, one or multiple command values. If a command has only a command code without any command value, it is called a "pure" command;

otherwise, it is called a “compound” command. The most significant byte of the command code is utilized to indicate the command is a “read” command (80h) or a “write” command (00h). An entire command must be continuously transmitted into the sensor under inquiry within a frame (between a start bit and a stop bit); otherwise, an error may occur.

The following commands are supported:

Table 5.1 LF2000 Sensor I²C Command List

Number	Command	Description	Read ¹	Write ²	Write Verification ³	Comment
1	01H	Read Instant Flow Rate	⊙			
2	02H	Read Positive Flow Rate	⊙			
3	03H	Read Negative Flow Rate	⊙			
4	04H	Set/Retrieve Sensor Working Mode	⊙	⊙		
5	05H	Set/Retrieve Filter Depth	⊙	⊙		
6	06H	Set/Retrieve Sensor Serial Number	⊙	●	※	
7	07H	Set/Retrieve Maximum Flow Value	⊙	●	※	
8	08H	Set/Retrieve Sensor's I ² C Address	⊙	⊙		

Note:

- 1) “⊙” stands for the command open to the public
- 2) “●” stands for the command only used by the manufacturer
- 3) “※” stands for the command requires verification of keyword before the write operation, similar to input a protection code.
- 4) If a command is not included in above table, it may cause unknown error.

5.1 Read Instant Flow Rate (Command Code: 81h=01h+80h)

5.1.1 Procedure

This command is a “pure” command (which has no command values). The procedure is as follows:

- 1) The master sends a start bit;
- 2) The master sends “slave address + write bit”, and the slave acknowledges;
- 3) The master sends the command code “81h”, and the slave acknowledges;
- 4) The master sends a re-start bit;
- 5) The master sends “slave address + read bit”, and the slave acknowledges;
- 6) The slave returns the 1st byte of the instant flow rate, and the master acknowledges;
- 7) The slave returns the 2nd byte of the instant flow rate, and the master acknowledges;
- 8) The slave returns the 3rd byte of the instant flow rate, and the master acknowledges;
- 9) The slave returns the 4th byte of the instant flow rate, and the master doesn't

acknowledge;

- 10) The master sends a stop bit.

5.1.2 Explanation

This command is used for enquiring real-time flow rate. It is a 32-bit floating-point number. When the number is positive, the flow is in positive direction; when the number is negative, the flow is in the opposite direction. The flow rate is calculated as follows.

$$\begin{aligned} \text{The flow rate} = & (\text{the 1st byte}) * 16777216 + \\ & (\text{the 2nd byte}) * 65536 + \\ & (\text{the 3rd byte}) * 256 + \\ & (\text{the 4th byte}) / 1000 \end{aligned}$$

The unit of the flow rate is mL/min.

5.2 Read Positive Flow Rate (Command Code: 82h=02h+80h)

5.2.1 Procedure

This command is a “pure” command (which has no command values). The procedure is as follows:

- 1) The master sends a start bit;
- 2) The master sends “slave address + write bit”, and the slave acknowledges;
- 3) The master sends the command code “82h”, and the slave acknowledges;
- 4) The master sends a re-start bit;
- 5) The master sends “slave address + read bit”, and the slave acknowledges;
- 6) The slave returns the 1st byte of the positive direction flow rate, and the master acknowledges;
- 7) The slave returns the 2nd byte of the positive direction flow rate, and the master acknowledges;
- 8) The slave returns the 3rd byte of the positive direction flow rate, and the master acknowledges;
- 9) The slave returns the 4th byte of the positive direction flow rate, and the master doesn't acknowledge;
- 10) The master sends a stop bit.

5.2.2 Explanation

This command is used for enquiring current positive direction flow rate. It is a 32-bit floating-point number. The number is always positive. When the flow is in the opposite direction, the value is 0.

5.3 Read Negative Flow Rate (Command Code: 83h=03h+80h)

5.3.1 Procedure

This command is a “pure” command (which has no command values). The procedure is as follows:

- 1) The master sends a start bit;
- 2) The master sends “slave address + write bit”, and the slave acknowledges;
- 3) The master sends the command code “83h”, and the slave acknowledges;
- 4) The master sends a re-start bit;
- 5) The master sends “slave address + read bit”, and the slave acknowledges;
- 6) The slave returns the 1st byte of the positive direction flow rate, and the master acknowledges;
- 7) The slave returns the 2nd byte of the positive direction flow rate, and the master acknowledges;
- 8) The slave returns the 3rd byte of the positive direction flow rate, and the master acknowledges;
- 9) The slave returns the 4th byte of the positive direction flow rate, and the master doesn’t acknowledge;
- 10) The master sends a stop bit.

5.3.2 Explanation

This command is used for enquiring current negative direction flow rate. It is a 32-bit floating-point number. The number is always positive, equal to the absolute value of the negative direction flow rate. When the flow is in the positive direction, the value is 0.

5.4 Retrieve Sensor Working Mode (Command Code: 84h=04h+80h)

5.4.1 Procedure

This command is a “pure” command (which has no command values). The procedure is as follows:

- 1) The master sends a start bit;
- 2) The master sends “slave address + write bit”, and the slave acknowledges;
- 3) The master sends the command code “84h”, and the slave acknowledges;
- 4) The master sends a re-start bit;
- 5) The master sends “slave address + read bit”, and the slave acknowledges;
- 6) The slave returns the working mode, and the master doesn’t acknowledge;
- 10) The master sends a stop bit.

5.4.2 Explanation

This command is used for enquiring the sensor’s working mode. There are three modes for the sensor: positive direction (00h), negative direction (01h), and bi-direction (02h). When sensor is under positive mode, only positive direction flow rate can be read, and negative direction flow rate is always 0; and vice versa for the negative direction. When sensor is in bi-direction mode, flow rate of both directions can be read.

5.5 Set Sensor Working Mode (Command Code: 04h=04h+00h)

5.5.1 Procedure

This command includes command values. The command values have to be between 00h~FFh. The procedure is as follows:

- 1) The master sends a start bit;
- 2) The master sends “slave address + write bit”, and the slave acknowledges;
- 3) The master sends the command code “04h”, and the slave acknowledges;
- 4) The master sends “working mode”, and the slave acknowledges;
- 5) The master sends a stop bit.

5.5.2 Explanation

This command is used for setting the sensor’s working mode.

5.6 Retrieve Filter Depth (Command Code: 85h=05h+80h)

5.6.1 Procedure

This command is a “pure” command (which has no command values). The procedure is as follows:

- 1) The master sends a start bit;
- 2) The master sends “slave address + write bit”, and the slave acknowledges;
- 3) The master sends the command code “85h”, and the slave acknowledges;
- 4) The master sends a re-start bit;
- 5) The master sends “slave address + read bit”, and the slave acknowledges;
- 6) The slave returns the filter depth, and the master does not acknowledge;
- 7) The master sends a stop bit.

5.6.2 Explanation

This command is used for retrieving the sensor’s filter depth. The value of the filter depth is between 00h~FFh. When filter depth is equal or less than 2, no filtering is applied. The larger the filter depth value is, the more stable the measurement (readings of flow rate from I²C) is, but the response time is slower. The filter depth will not affect the response time of the analog output.

5.7 Set Filter Depth (Command Code: 05h=05h+00h)

5.7.1 Procedure

This command includes command values. The command values have to be between 00h~FFh. The procedure is as follows:

- 1) The master sends a start bit;
- 2) The master sends “slave address + write bit”, and the slave acknowledges;
- 3) The master sends the command code “05h”, and the slave acknowledges;
- 4) The master sends “filter depth”, and the slave acknowledges;
- 5) The master sends a stop bit.

5.7.2 Explanation

This command is used for setting the sensor’s filter depth.

5.8 Retrieve Series Number (Command Code=86h=06h+ 80h)

5.8.1 Procedure

This command is a “pure” command (which has no command values). The procedure is as follows:

- 1) The master sends a start bit;
- 2) The master sends “slave address + write bit”, and the slave acknowledges;
- 3) The master sends the command code “86h”, and the slave acknowledges;
- 4) The master sends a re-start bit;
- 5) The master sends “slave address + read bit”, and the slave acknowledges;
- 6) The slave returns the 1st byte of the series number, and the master acknowledges;
- 7) The slave returns the 2nd byte of the series number, and the master acknowledges;
-
- 8) The slave returns the 11th byte of the series number, and the master acknowledges;
- 9) The slave returns the 12th byte of the series number, and the master doesn't acknowledge;
- 10) The master sends a stop bit.

5.8.2 Explanation

This command is used for enquiring the series number of the current flow sensor. The series number is unique for each flow sensor, and consists of 12 alphabets and/or numeric numbers. The series number can serve as the manufacturer ID number for checking its factory default parameter settings.

5.9 Retrieve Maximum Flow Rate (Command Cod= 87h=07h+80h)

5.9.1 Procedure

This command is a “pure” command (which has no command values). The procedure is as follows:

- 1) The master sends a start bit;
- 2) The master sends “slave address + write bit”, and the slave acknowledges;
- 3) The master sends the command code “87h”, and the slave acknowledges;
- 4) The master sends a re-start bit;
- 5) The master sends “slave address + read bit”, and the slave acknowledges;
- 6) The slave returns the 1st byte of the positive direction flow rate, and the master acknowledges;
- 7) The slave returns the 2nd byte of the positive direction flow rate, and the master acknowledges;
- 8) The slave returns the 3rd byte of the positive direction flow rate, and the master

acknowledges;

- 9) The slave returns the 4th byte of the positive direction flow rate, and the master doesn't acknowledge;
- 10) The master sends a stop bit.

5.9.2 Explanation

This command is used for enquiring maximum flow rate of the sensor. It returns 4-byte hexadecimal number, which represents a 32 bit floating-point number as the maximum flow rate. The default maximum flow rate is 1000 mL/Hr.

5.10 Read I²C Address (Command Code= 88h=08h+80h)

5.10.1 Procedure

This command is a “pure” command (which has no command values). The procedure for reading I²C address of the flow sensor is as follows:

- 1) The master sends a start bit;
- 2) The master sends “slave address + write bit”, and the slave acknowledges;
- 3) The master sends the command code “88h”, and the slave acknowledges;
- 4) The master sends a re-start bit;
- 5) The master sends “slave address + read bit”, and the slave acknowledges;
- 6) The slave returns the I²C address, and the master doesn't acknowledge;
- 7) The master sends a stop bit.

5.10.2 Explanation

This command is used for enquiring the I²C address. For detailed discussions on I²C address, please refer to Section 4.

5.11 Set I²C Address (Command Code= 08h=08h+00h)

5.11.1 Procedure

This command includes command values. The command values have to be an even number between 02h~FEh, which represent the sensor's I²C address. The procedure is as follows:

- 1) The master sends a start bit;
- 2) The master sends “slave address + write bit”, and the slave acknowledges;
- 3) The master sends the command code “08h”, and the slave acknowledges;

- 4) The master sends I²C address, and the slave acknowledges;
- 5) The master sends a stop bit.

5.11.2 Explanation

This command is used for setting the I²C address. For detailed discussions on I²C address, please refer to Section 4.

Reference

1. THE I2C-BUS SPECIFICATION VERSION 2.1, Philips Semiconductors, JANUARY 2000.