

Application Note 01
**Usage of MEMS Differential Pressure Sensor
(D6F-PH)**



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1. Outline

This application note is intended to demonstrate how to use and interface with Omron's MEMS differential pressure sensor(D6F-PH). It should be noted that this document is intended to supplement the datasheet, which should be referenced when using the sensor.

2. Structure

Fig.1 shows the internal cross-section view of the MEMS differential pressure sensor (D6F-PH). Air will flow from one inlet and out the other passing over the MEMS flow chip surface. The MEMS chip is able to measure the airflow as air passes over the chip. For more details on Omron's MEMS Flow sensor chip, please see the application note(MDMK-13-0153).

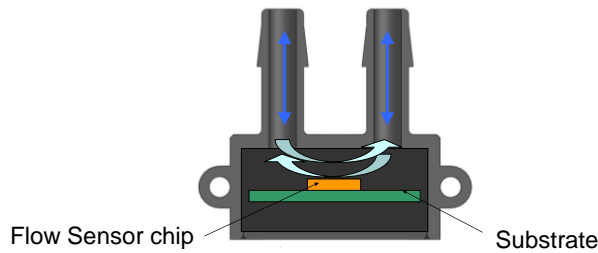


Fig.1 the internal cross-section view of MEMS differential pressure sensor (D6F-PH)

3. Dimensions

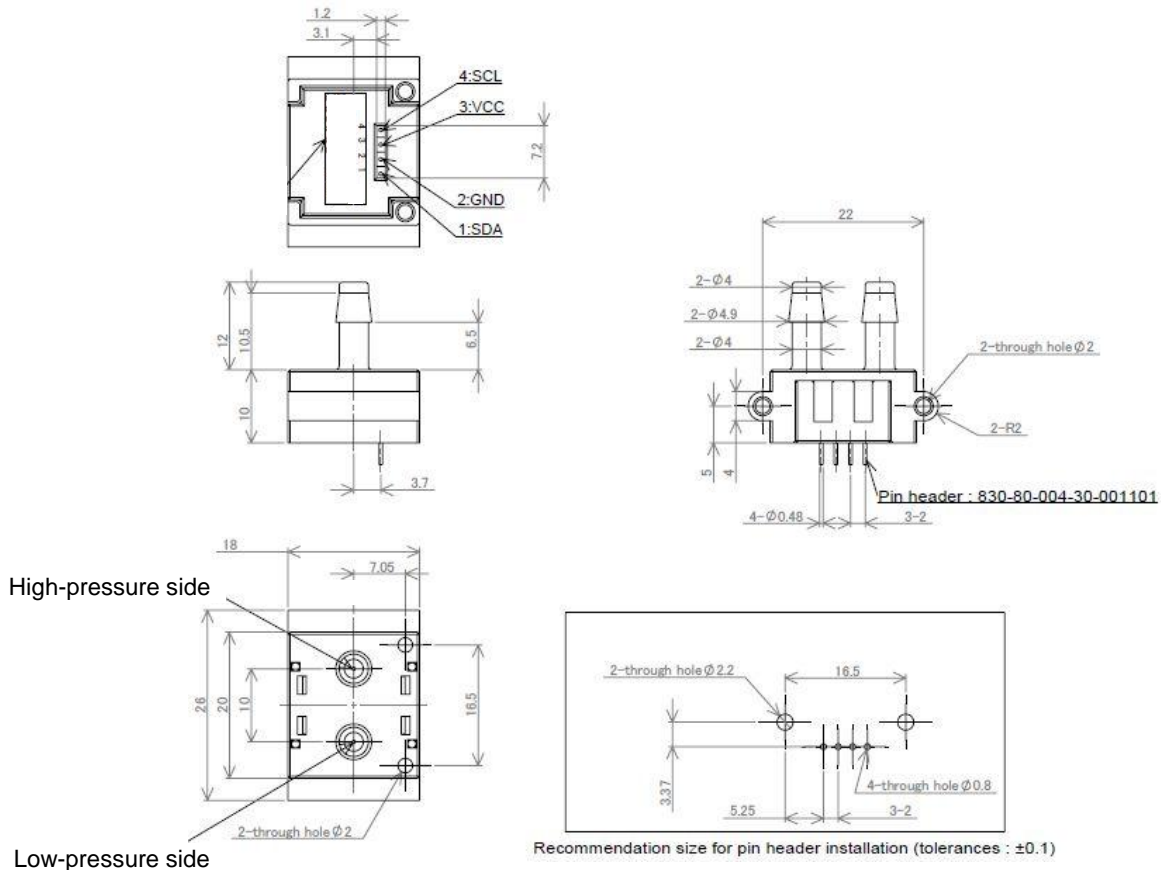


Fig.2 Outline dimensions of D6F-PH

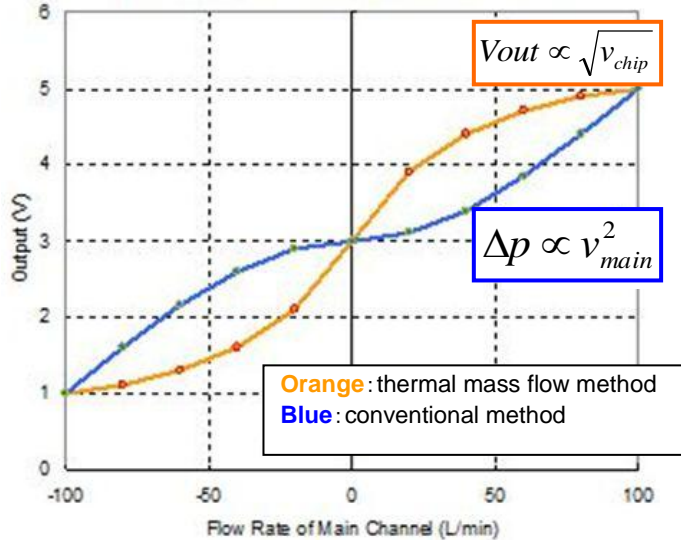
Please refer to Section 6: Usage about bypass tube connection and electrical connection.

4. Principle of Pressure detection

By using a thermal mass flow sensor, Omron's MEMS differential pressure sensor can detect fine changes in differential pressure. For more detailed information, please refer to Application Note (MDMK-13-0153).

5. Features of Product

By using a thermal mass flow method, Omron's MEMS differential pressure sensor is more sensitive compared with that of a conventional (capacitive) differential pressure sensor in the low-pressure range.



Thermal mass flow method

The output of Omron's sensor is proportional to the square root of the gas flow rate through the sensor chip surface.

Conventional method

The output of a conventional sensor is proportional to the square of the gas flow velocity through the main channel.

Fig. 3 Comparison with conventional method and thermal mass flow method

Table1. Specifications of D6F-PH□□□□

Item	Description				
	Min	Typ	Max	Unit	Note
Range of Differential Pressure	-50	-	50	Pa	D6F-PH0505AD3
	0	-	250	Pa	D6F-PH0025AD1
	-500	-	500	Pa	D6F-PH5050AD3
Resolution	-	12	-	bit	
Zero point accuracy (Note)	-0.2	-	+0.2	Pa	
Span accuracy (Note)	-3	-	+3	%R.D.	
Span shift by Temperature	-0.5	-	+0.5	%R.D.	With respect to a change of 10 degC
Response Time	-	33	50	msec	12bit Resolution
Ambient Operating Temp	-20	-	80	degC	without freezing and condensation
Ambient Storage Temp	-40	-	80	degC	without freezing and condensation
Ambient Operating Humidity	35	-	85	%RH	without freezing and condensation
Ambient Storage Humidity	35	-	85	%RH	without freezing and condensation
Supply Voltage	2.3	3.3	3.6	VDC	
Current Consumption	-	-	6	mA	Vcc=3.3V, 25degC
Frequency of SCL	-	-	400	kHz	FAST Mode

(Note) Span accuracy and zero point accuracy are the independence errors, and are not satisfied at the same time.

6. Usage

6-1. Recommended tube connection method of D6F-PH

When connecting the D6F-PH sensor in a bypass configuration, the sensor is able to detect fine pressure changes. This is achieved by providing an orifice in the main, which generates a small pressure change before and after the orifice. The D6F-PH will be connected to the bypass flow path from the pressure port which is provided before and after the orifice.

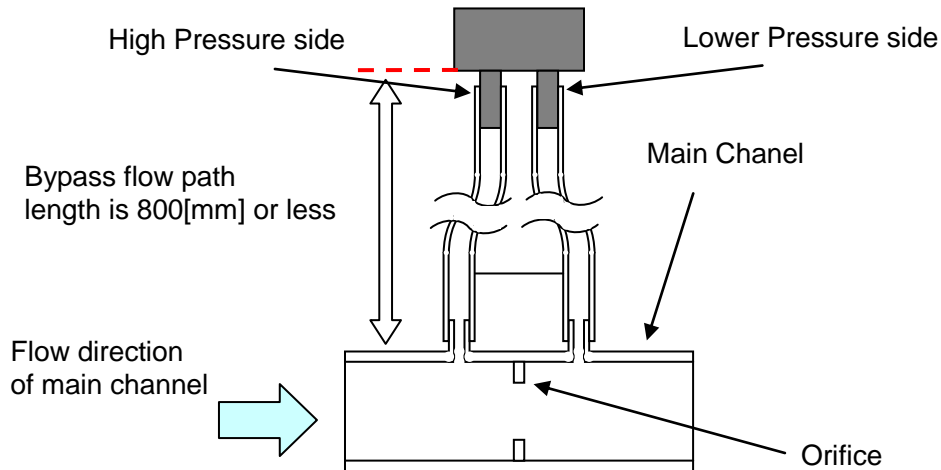


Fig. 4 Recommended tube connection method of D6F-PH

Here, the inner diameter of the bypass tube which is connected to the D6F-PH is 4[mm] and its length is 800[mm] or less.

6-2. Electrical connection method of D6F-PH

For the I2C output, the D6F-PH will require a pull-up resistor to each clock line(SCL) and data line (SDA). A pull-up resistor of 2.2[kΩ] (recommended value) should be implemented between the Vcc as shown in Fig.5. In addition, please adjust the pull-up resistor's value depending on the transfer rate of SCL and the I2C wire length.

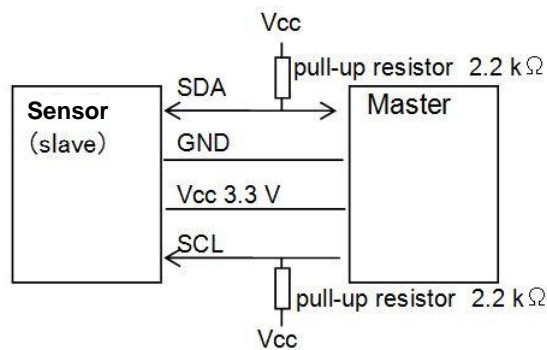


Fig. 5 Electrical connection method of D6F-PH

7 Specification of Communication

7-1. Outline of I2C Interface

Table2. Basic functions of I2C communication

Item	Descriptions
Communication method	I2C
SCL Frequency	Max 400kHz (Fast Mode)
Output format	Binary data (Upper byte, Lower byte)
Slave Address	1101100b or 0x6C

* Please note that the slave address is 7bits.

Interface Configuration Register

The memory and register access are controlled by writing to the interface configuration registers.

Various internal registers

In case access to internal registers are needed, the target register's address needs to be set to the Interface Configuration Register (address:00h and 01h).

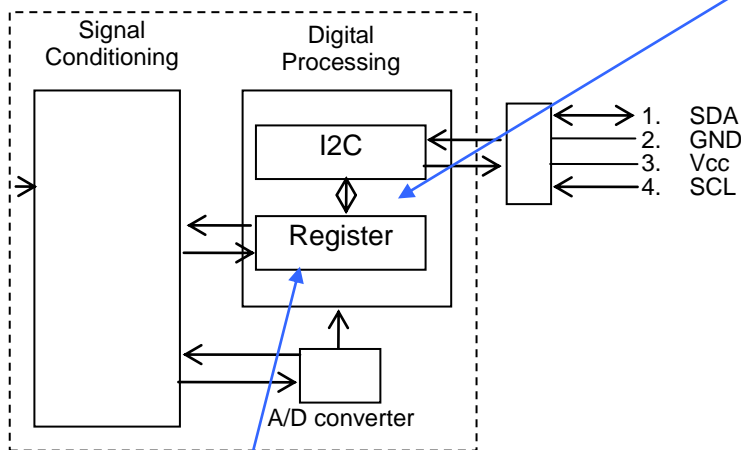


Table3. Interface Configuration Register

Configuration Address	Function
00h	Access Address 1
01h	Access Address 2
02h	Serial Control
03h	Write Buffer 0
04h	Write Buffer 1
05h	Write Buffer 2
06h	Write Buffer 3
07h	Read Buffer 0
08h	Read Buffer 1
09h	Read Buffer 2
0Ah	Read Buffer 3
0Bh	Initialize
0Dh	Power sequence

Table4. Internal Register Map

Address	Register name	Descriptions
D040h	SENS_CTRL	Sensor Control Register
D046h	FLAGS	Flag Register
D049h	INT_CTRL	CRC Calculation Control
D051h	COMP_DATA1_H	Compensated Flow rate Register
D052h	COMP_DATA1_L	
D061h	TMP_H	Internal Temperature Register
D062h	TMP_L	
D065h	REF_FLOW1_H	Sensor Reference Flow Register
D066h	REF_FLOW1_L	
D067h	THRESH_FLOW1_H	Sensor Threshold Flow Register
D068h	THRESH_FLOW1_L	

7-2. Interface Configuration Registers

The memory and registers access are controlled by writing to the interface configuration registers.

Table5. Interface Configuration Register Map

Configuration Address	Function	Note
00h	Access Address 1 (Upper byte)	Upper byte of first Access Address
01h	Access Address 2 (Lower byte)	Lower byte of first Access Address
02h	Serial Control	Write / Read Access Control
03h	Write Buffer 0	Data to be written at Address
04h	Write Buffer 1	Data to be written at Address + 1
05h	Write Buffer 2	Data to be written at Address + 2
06h	Write Buffer 3	Data to be written at Address + 3
07h	Read Buffer 0	Data read from Address
08h	Read Buffer 1	Data read from Address + 1
09h	Read Buffer 2	Data read from Address + 2
0Ah	Read Buffer 3	Data read from Address + 3
0Bh	Initialize	
0Dh	Power Sequence	Hardware reset control

Upper byte: bit[15:8] of 16bit data, Lower byte: bit[7:0] of 16bit data

7-2-1. Access Address Registers (00h – 01h)

The access address registers are used to access internal register blocks including sensor register map, ADC register map, and internal memory. It specifies the data transfer start address with auto increment for multiple byte data transfer.

Table6. Access Address Register

Address	MSB D7	D6	D5	D4	D3	D2	D1	LSB D0
00h	A15	A14	A13	A12	A11	A10	A9	A8
01h	A7	A6	A5	A4	A3	A2	A1	A0

7-2-2. Serial Control Register (02h)

Table7. Serial Control Register (02h)

The serial control register contains various bits to modify the behavior of the serial access.

Address	MSB D7	D6	D5	D4	D3	D2	D1	LSB D0
02h	D_byte_ cnt[3]	D_byte_ cnt[2]	D_byte_ cnt[1]	D_byte_ cnt[0]	Req	R_WZ	Acc_ctl2 [1]	Acc_ctl2 [0]

- Acc_ctl2 [1 : 0] – Access Control bits
0 0 = 16bits address (A15-A0) access (internal ROM and registers)

0 1 = 8bits address (A7-A0) access and used to access MCU internal 256 byte dual port RAM.

1 0 = reserved

1 1 = reserved

- R_WZ – Read or Write access select bit
 - 0 = Write Access
 - 1 = Read Access
- Req- Request bit
 - 0 = the previous request is done
 - 1 = new request. After the serial bus bridge controller finishes a request, it will clear Req to 0. For write requests the bridge controller moves the data in write data buffers to the location pointed by access address. For read requests the bridge controller stores the read data into data buffer.
- D_byte_cnt3 [3:0]
 - Transfer data byte count. It only supports 1, 2, 3, 4 data byte transfer.

7-2-3. Write Buffer Registers (03h – 06h)

There are four write data buffer registers at address: 03h – 06h. To perform a write, the host can either use a single command or perform separate writes to the following addresses.

The host can write to sensor register map in single byte transfer:

The host can burst write data start from address = 00h with following data byte, A[15:8], A[7:0], 18h, data[0].

Or the host can do four serial bus writes and write one data byte into serial bus register with the following steps.

- Write A[15:8] to address = 00h of interface configuration registers.
 - Write A[7:0] to address = 01h of interface configuration registers.
 - Write data[0] to address = 03h of interface configuration registers.
 - Write 18h to address = 18h of interface configuration registers.(1byte, new request, write)
- [Note] Read Serial Control register(02h). If Req = 0 (02h[3]), controller is finished with write.

7-2-4. Read Buffer Registers (07h – 0Ah)

There are four read data buffer registers at address: 07h – 0Ah. To perform a read, the host can either use a single streaming command or perform separate commands to the following addresses. After the read request is done by the internal serial bus bridge controller, the Req bit is cleared to 0 and read data is stored in rd_buf1 – rd_buf4 (address = 07h – 0Ah).

For single byte read request the host can burst write A[15:8], A[7:0], 1Ch at start address = 00h. The host needs to read the command register until the Req bit is cleared to 0, then read “read data buffer” for read data at address = 07h.

The host can perform a single byte read by individually programming the following registers.

- Write A[15:8] to address = 00h of interface configuration registers.
 - Write A[7:0] to address = 01h of interface configuration registers.
 - Write 1Ch to address = 02h of interface configuration registers.(1byte, new request, read)
- [Note] Read address = 02h. If Req = 0 (02h[3]), controller is finished with read data[0] from address = 07h.

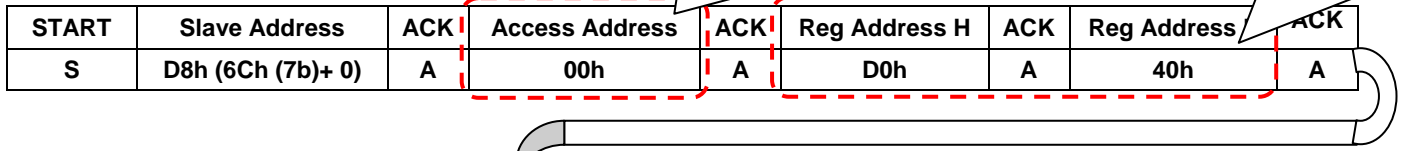
7-2-5. Example of I2C Access Commands

I2C Command Examples

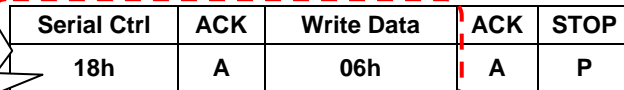
•I2C command: I2C write

Start address of serial configuration registers.

Address to be set to 00h/01h of serial configuration registers.

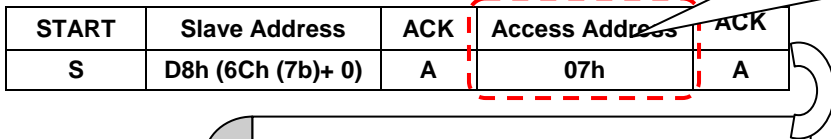


Data to be set to 02h/03h of serial configuration registers.

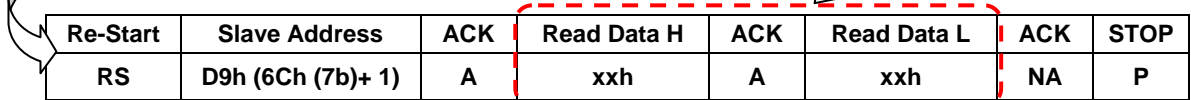


•I2C command: I2C read

Start address of serial configuration registers (Read Buffer 0)



This data will be stored in serial configuration register "07h" & "08h". (Read Buffer 0 / Read Buffer 1)



7-3. Description of Registers

The internal memory and registers of the sensor module can be accessed via the interface configuration registers.

7-3-1. Sensor Control (D040h)

Table8. SENS_CTRL

Address	MSB D7	D6	D5	D4	D3	D2	D1	LSB D0
D040h						MS	DV_PWR[1]	DV_PWR[0]
Write Access	None	None	None	None	None	Host & MCU	Host & MCU	Host & MCU
Default	0	0	0	0	0	0	0	0

- DV_PWR[1 : 0] – Main Device power mode setting
 - 0 0 = Standby – All blocks are powered down.
 - 1 0 = MCU on – Used when only MCU is required. Basic analog and memories are powered on and MCU clock is running.

Note : This register should not be changed during a measurement.
- MS – MCU start – Begin execution of measurement or MCU mode based on the state of DV_PWR.
 - 0 = Stop
Sequences are stopped and MCU clock is turned off.
 - 1 = Start
The MCU clock is started and the MCU mode is executed.

7-3-2. Flags (D046h)

Table9. FLAGS

Address	MSB D7	D6	D5	D4	D3	D2	D1	LSB D0
D046h					OS1		HV1	SV
Write Access	None	None	None	None	Host & MCU	None	Host & MCU	Host & MCU
Default				0	0	0	0	0

- SV – Supply Voltage (VDD) Flag
 - 0 = Supply voltage is within specification.
 - 1 = Supply voltage is outside of specification.
- HV1 – Heater Voltage Flag
 - 0 = Heater voltage is within specification.
 - 1 = Heater voltage is outside of specification.
- OS1 – Open Sensor Flag
 - 0 = Sensor is connected.
 - 1 = Sensor is not connected.

- HV2 and OS2 are reserved bits. In case of write access, you should set to “0”.

* If you want to read flag register, it is recommended to read twice in order to avoid conflict with the MCU update.

7-3-3. CRC Calculation Control (D049h)

Table 10. INT_CTRL

ADDR	MSB D7	D6	D5	D4	D3	D2	D1	LSB D0
D049h							CRC_EN	
Write Access	NONE	NONE	NONE	NONE	NONE	NONE	Host & MCU	NONE
Default	0	0	0	0	0	0	1	0

- CRC_EN – CRC check calculation enable (See below for more information about the CRC)
 - 0 = CRC check calculation disable
 - 1 = CRC check calculation enable

Description of the CRC calculation

- CRC Overview

The CRC is used as an error detection method in a data communication. Our flow sensor use the CRC8 polynomial $x^8 + x^5 + x^4 + 1$. The following is an example of I2C access 2 byte read using CRC function.

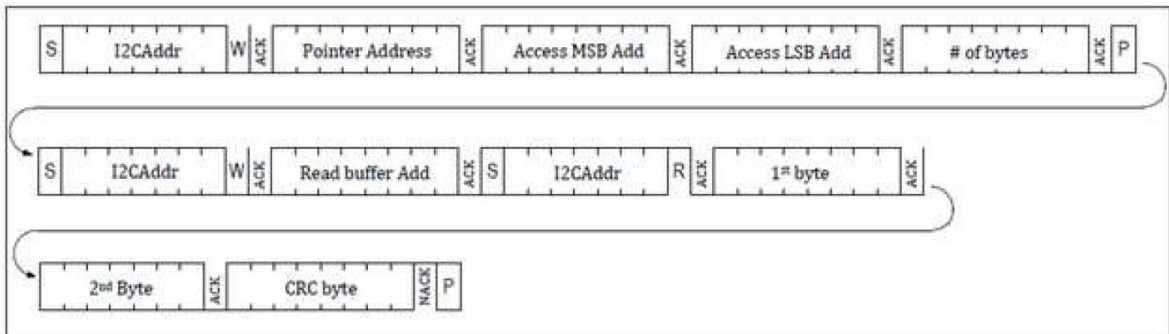


Fig.6 Example of 2byte read with CRC

- Bit unit CRC-8 calculation method
 1. The data bit sequence will be aligned in a line.
 2. The polynomial bit string will be aligned under the line of the data bit sequence.
 3. If the data bit above the leftmost the polynomial bit sequence is 0, the polynomial bit sequence is shifted one bit to the right. If the data bit above the leftmost polynomial bit sequence is 1, the data bit and the polynomial bit are calculated by XOR. Then the polynomial bit sequence are shifted one bit to the right.
 4. 1-3steps are repeated until the polynomial bit sequence reaches the right end of the data bit sequence.

The following example shows how to calculate the CRC byte based on XOR calculation.

	hex	bin
1st Byte of data	04h	00000100
2nd Byte of data	02h	00000010
Polynomial ($x^8 + x^5 + x^4 + 1$)	131h	100110001
CRC-byte checksum	225h	11100001

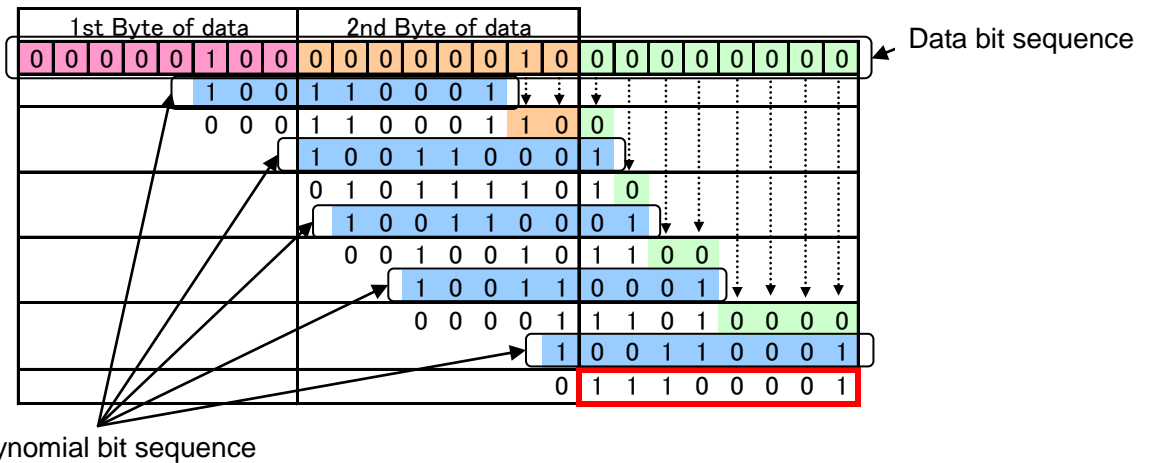


Fig.7 XOR operation example of CRC-8

7-3-4. Data Registers (D051h-D068h)

Table11. 16bit Data Register Map

Address	Registers Name	MSB								LSB	Description
		D7	D6	D5	D4	D3	D2	D1	D0		
D051h	COMP_DATA1_H	DATA<15:8>									Compensated Flow rate Register
D052h	COMP_DATA1_L	DATA<7:0>									
D061h	TMP_H	DATA<15:8>									Internal Temperature Register
D062h	TMP_L	DATA<7:0>									

For additional information, please refer to Section 8: Explanation of output data.

8. Explanation of output data

The measured data is sent to the dedicated registers. These registers contain, respectively, upper byte and lower byte of the sensing signals of the sensor.

For example, the compensated flow data is given by the concatenation COMP_DATA1_H & COMP_DATA1_L in unsigned 16bit number. And the raw flow data is given by the concatenation UCFM1_H & UCFM1_L and it is expressed as a 2's complement of signed 16bit number.

8-1. Data alignment

Sensing data is represented as 16bit numbers. The data is split and sent in two consecutive bytes to Flow Registers in "Big Endian" format.

"Big Endian" means that the upper byte of the number is stored in a register at the lowest address, and the lower byte at the highest address.

8-2. Register content

- COMP_DATA1_H & COMP_DATA1_L [D051h – D052h] : Compensated Data (unsigned)
These registers contain compensated flow rate data.

- If pressure range is ± 50 [Pa] or ± 500 [Pa]

$$Dp[\text{Pa}] = (Pv - 1024) / 60000 * \text{RANGE} - \text{RANGE} / 2 \quad (\text{RANGE} = 100 \text{ or } 1000)$$

Where, Pv is Register content stored in the Compensated Flow Data registers [D051h – D052h].

- If pressure range is 0-250[Pa]

$$Dp[\text{Pa}] = (Pv - 1024) / 60000 * \text{RANGE} \quad (\text{RANGE} = 250)$$

Where, Pv is Register content stored in the Compensated Flow Data registers [D051h – D052h].

- TMP_H & TMP_L [D061h – D062h] : Temperature data (signed)

The values stored in these registers represent the temperature data measured by the internal temperature of the ASIC.

The following formula can be applied to convert register data into temperature value.

$$Tv [^{\circ}\text{C}] = (Rv - 10214) / 37.39$$

Where, Tv is Converted temperature value in the degC format, and Rv is Register content stored in the Temperature Data register.

Note: Temperature data is for reference ONLY. Its accuracy is not specified in the device specifications.

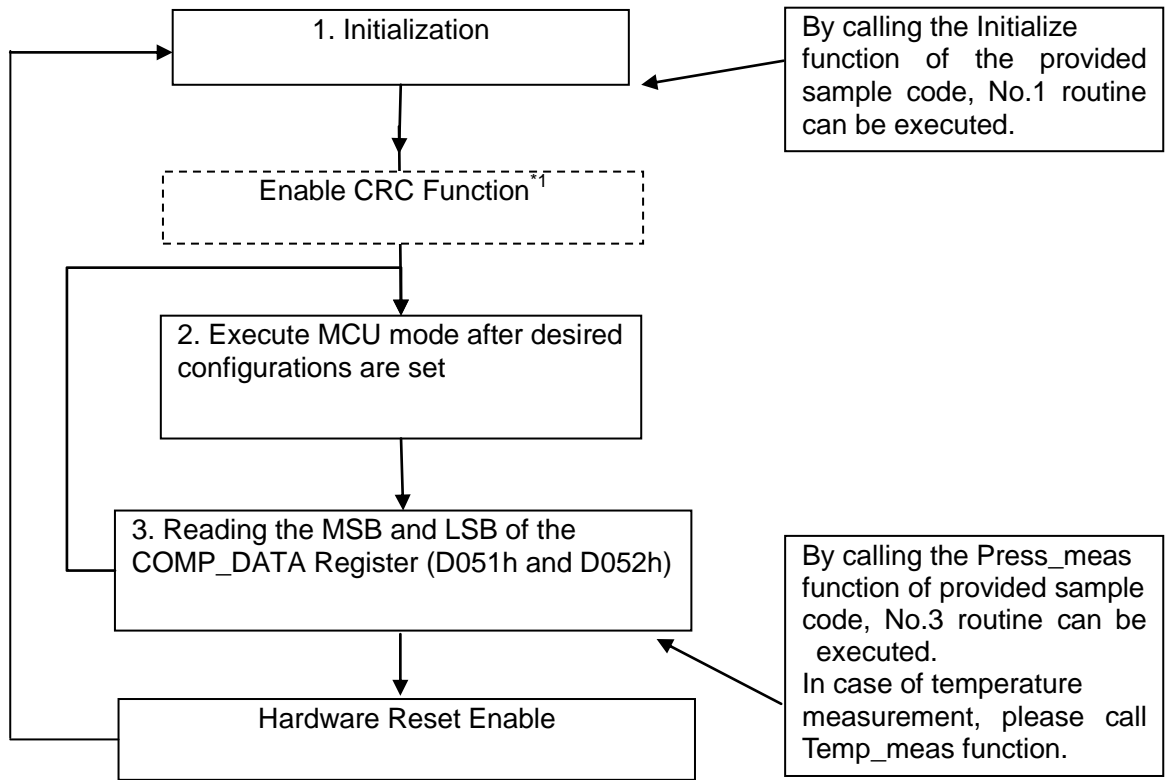
8-3. Example of Sensing data

The below tables provide a few basic examples of the data that is read in Flow Sensor Registers when the device is subject to given flow and temperature. The values listed in the tables are given under the hypothesis of perfect device calibration (i.e. no offset, no gain error, etc).

Table12. Temperature Data registers content vs. Temperature value

Address of Registers		Value of Registers		Converted Temperature values
TMP_H	TMP_L	HEX	DEC	
D061h	D062h	2B8Dh	11149	25.0 degC
2Bh	8Dh	2EFFh	12031	48.6 degC
2Eh	FFh	26BBh	9915	-8.0 degC
26h	BBh			

9. Sensor Operation flow chart



*1 If you use CRC function, please send some command refer to Page.17.

Fig.8 Flowchart of Sensor operation

•Communication time

Item	Sign	Remarks
Response time	α	$\alpha \geq 33 \text{ ms}$
Sampling interval	β	$\beta > \alpha$

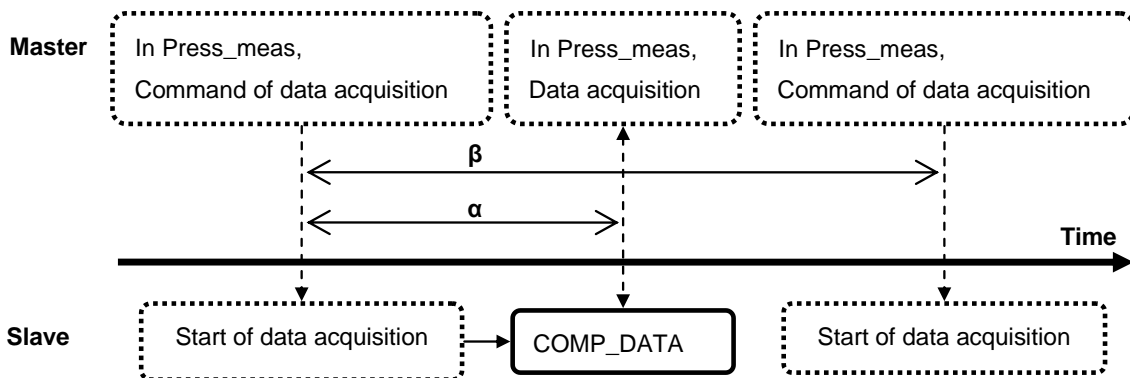


Fig.9 Time axis image view of the differential pressure measurement

10. I2C Instruction for Sensor Operation

1. Initialization after power up [Must be done]

I2C command: The device must be unlocked then write 0x00 to the EEPROM Control Register(0xB) to load NVM trim values, but keep the MCU in non-reset state.

START	Slave Address	ACK	Access Address	ACK	Write Data	ACK	STOP
S	D8h (6Ch (7b)+ 0)	A	0Bh	A	00h	A	P

2. Execute MCU mode after desired configuration registers

Writing 06h to the Sensor Control Register (D040h) will execute the MCU mode outlined in Section 6 with the configured setting for the ADC Resolution and Gain, Compensation. Reading the Sensor control register after writing a 06h will show the MUX selection chosen by the MCU. After running the process, MS bit will be set to "0".

[Caution]: Do not read or write to the Device while the MCU is executing. It would be safe to read/write only after 33ms.

I2C command: Write 06h to the Sensor Control Register (D040h) (MS=1&MCU on)

START	Slave Address	ACK	Access Address	ACK	Reg Address H	ACK	Reg Address L	ACK
S	D8h (6Ch (7b)+ 0)	A	00h	A	D0h	A	40h	A

Serial Ctrl	ACK	Write Data	ACK	STOP
18h	A	06h	A	P

3. Reading the Upper and Lower byte of Compensated Flow Data Registers(D051h & D052h)

I2C command: To read Compensated flow data register, it needs to set 2Ch (it means 2byte read) to interface configuration register (address:2h).

START	Slave Address	ACK	Access Address	ACK	Reg Address H	ACK	Reg Address L	ACK
S	D8h (6Ch (7b)+ 0)	A	00h	A	D0h	A	51h	A

Serial Ctrl	ACK	STOP
2Ch	A	P

I2C command: Through Read Buffer 0(address:07h) and Read Buffer 1(address:08h), you can read the 2byte of Compensated flow data.

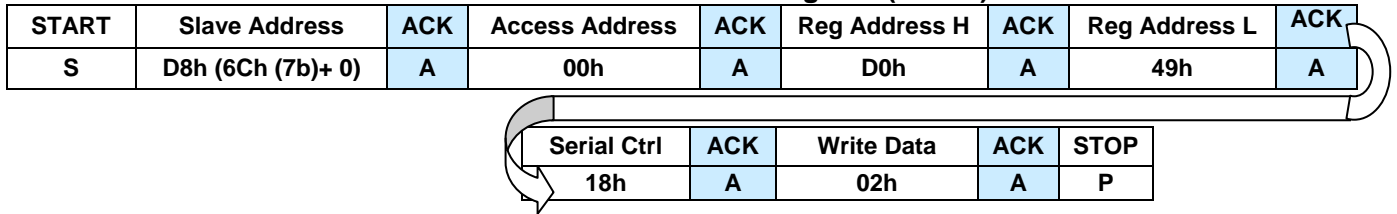
START	Slave Address	ACK	Access Address	ACK
S	D8h (6Ch (7b)+ 0)	A	07h	A

Re-Start	Slave Address	ACK	Read Data H	ACK	Read Data L	ACK	STOP
RS	D9h (6Ch (7b)+ 1)	A	xxh	A	xxh	NA	P

Enable CRC Function

1. Set to "1" to bit[1] of the CRC control register.

I2C command: Write 02h to the CRC Control Register (D049h).



Execute Hardware Reset

1. Set to "1" to bit[7] of the Power Sequence register.

I2C command: Write 80h to the Power Sequence Register (0Dh).

START	Slave Address	ACK	Access Address	ACK	Write Data	ACK	STOP
S	D8h (6Ch (7b)+ 0)	A	0Dh	A	80h	A	P

The hardware reset after the execution, bit 7 is cleared to "0" automatically.

11. Sample Source Code

The following is a sample source code of the D6F-PH control in the case of using STM32microcontroller. The I2C control unit will need to be adjusted to whatever microcontroller is used.

11-1. D6F_PH_Sample.h

```

/*=====*/
/* D6F-PH Digital Flow Sensor Header File (using STM32)
 * :Copyright: (C) OMRON Corporation, Microdevice H. Q.
 * :Auther   :
 * :Revision: $Rev$
 * :Id:      $Id$
 * :Date:    $Date$
 *
 * All Rights Reserved
 * OMRON Proprietary Right
 *=====*/
/*=====*/
/* for General      */
/*=====*/
#define SA_7        0x6C // for 7bit Slave Address
//#define RANGE_MODE 100 // Full Range +/-50[Pa]
#define RANGE_MODE 250 // Full Range 0-250[Pa]
//#define RANGE_MODE 1000 // Full Range +/-500[Pa]
/*=====*/
/* for Measure Mode */
/*=====*/
#define P      1 // Pressure mode
#define T      2 // Temperature mode
/* Function prototypes -----*/
void Initialize( void );
short Press_meas( void );
short Temp_meas( void );
/* Private Functions -----*/
int  I2C_WR(unsigned char add, char *dbuf, unsigned char n);
uint8_t I2C_RD_8(unsigned char add, char *dbuf, unsigned char n);
short I2C_RD_16(unsigned char add, char *dbuf, unsigned char n);
unsigned short I2C_RD_u16(unsigned char add, char *dbuf, unsigned char n);
void I2C1_Init(void);
void I2C1_Start(void);
void I2C1_MastrSel(uint8_t address, uint8_t rw);
void I2C1_AckEn(void);
void I2C1_AckDis(void);
void I2C1_Stop(void);
void I2C1_senddata(uint8_t data);
uint8_t I2C1_rcvdata(void);

```

Please change the RANGE_MODE define for your target Product Pressure range.

11-2. D6F_PH_Sample.c

```

/*=====*/
/* D6F-PH Digital Flow Sensor Sample Code (using STM32)
 * :Copyright: (C) OMRON Corporation, Microdevice H.Q.
 * :Auther   :
 * :Revision: $Rev$
 * :Id:      $Id$
 * :Date:    $Date$
 *
 * All Rights Reserved
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 *=====*/

#include "stm32f10x_i2c.h"
#include "D6F_PH_Sample.h"

#define I2C1_SCL_PIN          GPIO_Pin_6
#define I2C1_SDA_PIN         GPIO_Pin_7
#define I2C2_SCL_PIN         GPIO_Pin_10
#define I2C2_SDA_PIN         GPIO_Pin_11

typedef unsigned char  uint8;
typedef unsigned short uint16;
typedef unsigned long  uint32;

        short RD_FIFO; /* 16bit data width */
unsigned short uRD_FIFO; /* 16bit data width */
        uint8_t RD_REG; /* 8bit data width */
        char  setting_done_flag = 0;

// Dummy wait routine
void adc_wait(volatile unsigned long delay)
{
        while(delay) delay--;
}

/*=====*/
/* Initialize Function          */
/* Usage      : Initialize( void ) */
/* Argument   : Null           */
/* Return value : T.B.D       */
/*=====*/
void Initialize( void )
{
        /* EEPROM Control <= 00h */

```

```

char send1[] = {0x0B, 0x00};
I2C_WR(SA_7, send1, 2);

}

/*=====*/
/* Pressure measure Function */
/* Usage      : Press_meas( void ) */
/* Argument   : NULL */
/* Return value : Compensated Pressure value(unsigned) */
/*=====*/
short Press_meas(void)
{
    short rd_fifo;
    short rd_flow;
    unsigned long wait_time;

    /* [D040] <= 06h */
    char send2[] = {0x00, 0xD0, 0x40, 0x18, 0x06};
    I2C_WR(SA_7, send2, 5);

    wait_time = 33; /*33msec wait */
    /* wait time depend on resolution mode */
    adc_wait(wait_time);

    /* [D051/D052] => Read Compensated Flow value */
    char send3[] = {0x00, 0xD0, 0x51, 0x2C, 0x07};
    uRD_FIFO = I2C_RD_u16(SA_7, send3, 5);

    // Press Mode : [Pa] = (xx[count] - 1024) * Full Range [Pa]/ 60000 - Full Range [Pa] at
other
    if (RANGE_MODE == 250) {
        rd_flow = ((rd_fifo - 1024) * RANGE_MODE *10/ 60000); /* convert to [Pa] */
    }
    else {
        rd_flow = ((rd_fifo - 1024) * RANGE_MODE *10/ 60000) - RANGE_MODE*10/2; /* convert
to [Pa] */
    }

    return rd_flow;
}

/*=====*/
/* Temperature measure Function */
/* Usage      : Temp_meas() */
/* Argument   : NULL */
/* Return value : x10 Temperature */
/*=====*/

```

```

short Temp_meas(void)
{
    short    rd_temp;
    unsigned long wait_time;

    /* [D040] <= 06h */
    char send2[] = {0x00, 0xD0, 0x40, 0x18, 0x06};
    I2C_WR(SA_7, send2, 5);

    /* wait time depend on resolution mode */
    wait_time = 33; /* 33msec wait */
    adc_wait(wait_time);

    /* [D061/D062] => Read TMP_H/TMP_L value */
    char send3[] = {0x00, 0xD0, 0x61, 0x2C, 0x07};
    RD_FIFO = I2C_RD_16 (SA_7, send3, 5);
    rd_temp = ((RD_FIFO - 10214)*1000 / 3739); // convert to degree-C(x10)

    return rd_temp;
}

/* Public Basic Functions -----*/
/*=====*/
/* I2C Write command */
/* Usage      : I2C1_WR() */
/* Argument   : 7bit Slave Address(char) */
/*
/* Return value : 8bit Read result */
/*=====*/
int I2C_WR(unsigned char add, char *dbuf, unsigned char n) {
    int i = 0;

    I2C1_Start();          /* Start condition */
    I2C1_MastrSel(add, 0); /* Slave Address */
    while (n--) {
        I2C1_senddata(dbuf[i]); /* Send Data */
        i++;
    }
    I2C1_Stop();          /* Stop condition */
    return 0;
}

/*=====*/
/* I2C Read command */
/* Usage      : I2C_RD() */
/* Argument   : char add (7bit Slave Address) */
/*            : char *dbuf (Write data) */
/*            : unsigned char n (Number of bytes)*/

```

```

/*          unsigned char n (Number of bytes)*/
/* Return value : 8bit Read result          */
/*=====*/
uint8_t I2C_RD_8 (unsigned char add, char *dbuf, unsigned char n) {
    int i= 0;
    char n_w;

    n_w = n - 1;
    /* I2C Pre-WR Access */
    I2C1_Start();          /* Start condition */
    I2C1_MastrSel(add, 0); /* Slave Address 7bit => 8bit */
    while (n_w--) {
        I2C1_senddata(dbuf[i]); /* Send Data          */
        i++;
    }
    I2C1_Stop();          /* Stop condition */

    /* I2C RD Access */
    I2C1_Start();          /* Start condition */
    I2C1_MastrSel(add, 0); /* Slave Address 7bit => 8bit */
    I2C1_senddata(dbuf[n-1]); /* Word Address          */
    I2C1_Start();          /* Re-Start condition */
    I2C1_MastrSel(add, 1); /* Slave 7bit => 8bit for RD */
    I2C1_AckDis();        /* ack diable for 1 byte */
    I2C1_Stop();          /* Stop condition send */
    RD_REG = I2C1_rcvdata(); /* Read Data */
    return RD_REG;
}

/*=====*/
/* I2C Read command          */
/* Usage          : I2C_RD_16()          */
/* Argument       : char add (7bit Slave Address)          */
/*               : char *dbuf (Write data)          */
/*               : unsigned char n (Number of bytes)*/
/* Return value   : 16bit Read result          */
/*=====*/
short I2C_RD_16 (unsigned char add, char *dbuf, unsigned char n) {
    int i= 0;
    char n_w;
    uint8_t rd_fifo[2] = {0, 0};

    n_w = n - 1;
    /* I2C Pre-WR Access */
    I2C1_Start();          /* Start condition */
    I2C1_MastrSel(add, 0); /* Slave Address 7bit => 8bit */
    while (n_w--) {
        I2C1_senddata(dbuf[i]); /* Send Data          */

```

```

    i++;
}
I2C1_Stop();          /* Stop condition */

adc_wait(5); /* 5msec wait */

I2C1_Start();        /* Start condition */
I2C1_MastrSel(add, 0); /* Slave Address 7bit => 8bit */
I2C1_senddata(dbuf[n-1]); /* Word Address */
I2C1_Start();        /* Re-Start condition */
I2C1_MastrSel(add, 1); /* Slave 7bit => 8bit for RD */
I2C1_AckEn();        /* ack enable send after MSB 1 byte read */
rd_fifo[0] = I2C1_rcvdata(); /* Read Data */
I2C1_AckDis();        /* ack disable send after LSB 1 byte read */
I2C1_Stop();         /* Stop condition send */
rd_fifo[1] = I2C1_rcvdata(); /* Read Data */
RD_FIFO = ((rd_fifo[0] << 8) | rd_fifo[1]);
return RD_FIFO;
}

/*-----*/
/* I2C Read command */
/* Usage      : I2C_RD_u16() */
/* Argument   : char add (7bit Slave Address) */
/*            : char *dbuf (Write data) */
/*            : unsigned char n (Number of bytes) */
/* Return value : 16bit Read result */
/*-----*/
unsigned short I2C_RD_u16 (unsigned char add, char *dbuf, unsigned char n) {
    int i= 0;
    char n_w;
    uint8_t rd_fifo[2] = {0, 0};

    n_w = n - 1;
    /* I2C Pre-WR Access */
    I2C1_Start();        /* Start condition */
    I2C1_MastrSel(add, 0); /* Slave Address 7bit => 8bit */
    while (n_w-->0) {
        I2C1_senddata(dbuf[i]); /* Send Data */
        i++;
    }
    I2C1_Stop();        /* Stop condition */

    adc_wait(5); /* 5msec wait */

    I2C1_Start();        /* Start condition */
    I2C1_MastrSel(add, 0); /* Slave Address 7bit => 8bit */
    I2C1_senddata(dbuf[n-1]); /* Word Address */

```

```

I2C1_Start();          /* Re-Start condition */
I2C1_MastrSel(add, 1); /* Slave 7bit => 8bit for RD */
I2C1_AckEn();         /* ack enable send after MSB 1 byte read */
rd_fifo[0] = I2C1_rcvdata(); /* Read Data */
I2C1_AckDis();       /* ack diable send after LSB 1 byte read */
I2C1_Stop();         /* Stop condition send */
rd_fifo[1] = I2C1_rcvdata(); /* Read Data */
uRD_FIFO = ((rd_fifo[0] << 8) | rd_fifo[1]);
return uRD_FIFO;
}

void I2C1_Init() {
    I2C_InitTypeDef I2C1_InitStructure;

    RCC_APB1PeriphClockCmd(RCC_APB1Periph_I2C1, ENABLE); // start clock of
I2C

    I2C1_InitStructure.I2C_Mode = I2C_Mode_I2C;
    I2C1_InitStructure.I2C_DutyCycle = I2C_DutyCycle_2;
    I2C1_InitStructure.I2C_Ack = I2C_Ack_Enable;
    I2C1_InitStructure.I2C_AcknowledgedAddress = I2C_AcknowledgedAddress_7bit;
    I2C1_InitStructure.I2C_ClockSpeed = 400000;

    GPIO_InitTypeDef GPIO_InitStructure; // make instance of
InitStructure
    RCC_APB2PeriphClockCmd(RCC_APB2Periph_GPIOB, ENABLE); // start clock of GPIO
pins

    GPIO_InitStructure.GPIO_Pin =( I2C1_SCL_PIN | I2C1_SDA_PIN );
    GPIO_InitStructure.GPIO_Speed = GPIO_Speed_50MHz;
    GPIO_InitStructure.GPIO_Mode = GPIO_Mode_AF_OD;
    GPIO_Init(GPIOB, &GPIO_InitStructure);

    I2C_DeInit(I2C1);
    I2C_Init(I2C1, &I2C1_InitStructure); // Initialize with above parameters
    I2C_Cmd(I2C1, ENABLE);
}

void I2C1_Start() {
    I2C_GenerateSTART(I2C1, ENABLE); // issue start condition
    while(!I2C_CheckEvent(I2C1, I2C_EVENT_MASTER_MODE_SELECT));
}

void I2C1_MastrSel( uint8_t address, uint8_t RW) {
    uint8_t direct;
    uint32_t event;
    direct =(RW == 0)?I2C_Direction_Transmitter : I2C_Direction_Receiver;
    event   =(RW      ==      0)?I2C_EVENT_MASTER_TRANSMITTER_MODE_SELECTED :
I2C_EVENT_MASTER_RECEIVER_MODE_SELECTED;
}

```



```
I2C_Send7bitAddress(I2C1, (address << 1), direct ); //write to Slave
while(!I2C_CheckEvent(I2C1, event)); // wait ACK
}

void I2C1_senddata(uint8_t data) {
    I2C_SendData(I2C1, data); //transmit the received
command
    while(!I2C_CheckEvent(I2C1, I2C_EVENT_MASTER_BYTE_TRANSMITTED)); // wait ACK
}

uint8_t I2C1_rcvdata(void) {
    while(!I2C_CheckEvent(I2C1, I2C_EVENT_MASTER_BYTE_RECEIVED)); // wait ACK
    return I2C_ReceiveData(I2C1); // receive 4th 8bit data
}

void I2C1_Stop() {
    I2C_GenerateSTOP(I2C1, ENABLE); // put stop condition
}

void I2C1_AckEn() {
    I2C_AcknowledgeConfig(I2C1, ENABLE); // ack enable
}

void I2C1_AckDis() {
    I2C_AcknowledgeConfig(I2C1, DISABLE); // ack disable
}
```

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14. History

Revision	DATE	Note
Rev 1.0	Oct 1,2013	New Released
Rev 2.0	Mar 27, 2014	At table3 & table5 of section7, add expression of the initialize register. At I2C command example of section10, add the ACK to Initialization after power up.
Rev 3.0	Aug 07, 2015	Add CRC Calculation and Hardware reset. Section7(7.3.3),9(Fig.8),10(P17)