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).

![Flow Sensor chip and Substrate in Fig.1](image1)

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

3. Dimensions

![Outline dimensions of D6F-PH in Fig.2](image2)

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.

### Table 1. Specifications of D6F-PH

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

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

*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.
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.

![Diagram of tube connection method](image)

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.

![Diagram of electrical connection method](image)

Fig. 5 Electrical connection method of D6F-PH
7 Specification of Communication

7-1. Outline of I2C Interface

<table>
<thead>
<tr>
<th>Item</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication method</td>
<td>I2C</td>
</tr>
<tr>
<td>SCL Frequency</td>
<td>Max 400kHz (Fast Mode)</td>
</tr>
<tr>
<td>Output format</td>
<td>Binary data (Upper byte, Lower byte)</td>
</tr>
<tr>
<td>Slave Address</td>
<td>1101100b or 0x6C</td>
</tr>
</tbody>
</table>

* 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).

<table>
<thead>
<tr>
<th>Configuration Address</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h</td>
<td>Access Address 1</td>
</tr>
<tr>
<td>01h</td>
<td>Access Address 2</td>
</tr>
<tr>
<td>02h</td>
<td>Serial Control</td>
</tr>
<tr>
<td>03h</td>
<td>Write Buffer 0</td>
</tr>
<tr>
<td>04h</td>
<td>Write Buffer 1</td>
</tr>
<tr>
<td>05h</td>
<td>Write Buffer 2</td>
</tr>
<tr>
<td>06h</td>
<td>Write Buffer 3</td>
</tr>
<tr>
<td>07h</td>
<td>Read Buffer 0</td>
</tr>
<tr>
<td>08h</td>
<td>Read Buffer 1</td>
</tr>
<tr>
<td>09h</td>
<td>Read Buffer 2</td>
</tr>
<tr>
<td>0Ah</td>
<td>Read Buffer 3</td>
</tr>
<tr>
<td>0Bh</td>
<td>Initialize</td>
</tr>
</tbody>
</table>

**Table4. Internal Register Map**

<table>
<thead>
<tr>
<th>Address</th>
<th>Register name</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>D040h</td>
<td>SENS_CTRL</td>
<td>Sensor Control Register</td>
</tr>
<tr>
<td>D046h</td>
<td>FLAGS</td>
<td>Flag Register</td>
</tr>
<tr>
<td>D049h</td>
<td>INT_CTRL</td>
<td>CRC Calculation Control</td>
</tr>
<tr>
<td>D051h</td>
<td>COMP_DATA1_H</td>
<td>Compensated Flow rate Register</td>
</tr>
<tr>
<td>D052h</td>
<td>COMP_DATA1_L</td>
<td></td>
</tr>
<tr>
<td>D061h</td>
<td>TMP_H</td>
<td>Internal Temperature Register</td>
</tr>
<tr>
<td>D062h</td>
<td>TMP_L</td>
<td></td>
</tr>
<tr>
<td>D065h</td>
<td>REF_FLOW1_H</td>
<td>Sensor Reference Flow Register</td>
</tr>
<tr>
<td>D066h</td>
<td>REF_FLOW1_L</td>
<td></td>
</tr>
<tr>
<td>D067h</td>
<td>THRESH_FLOW1_H</td>
<td>Sensor Threshold Flow Register</td>
</tr>
<tr>
<td>D068h</td>
<td>THRESH_FLOW1_L</td>
<td></td>
</tr>
</tbody>
</table>
7-2. Interface Configuration Registers

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

Table 5. Interface Configuration Register Map

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


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.

Table 6. Access Address Register

<table>
<thead>
<tr>
<th>Address</th>
<th>MSB D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>LSB D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h</td>
<td>A15</td>
<td>A14</td>
<td>A13</td>
<td>A12</td>
<td>A11</td>
<td>A10</td>
<td>A9</td>
<td>A8</td>
</tr>
<tr>
<td>01h</td>
<td>A7</td>
<td>A6</td>
<td>A5</td>
<td>A4</td>
<td>A3</td>
<td>A2</td>
<td>A1</td>
<td>A0</td>
</tr>
</tbody>
</table>

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

Table 7. Serial Control Register (02h)

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

<table>
<thead>
<tr>
<th>Address</th>
<th>MSB D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>LSB D0</th>
</tr>
</thead>
</table>

- 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

<table>
<thead>
<tr>
<th>START</th>
<th>Slave Address</th>
<th>ACK</th>
<th>Access Address</th>
<th>ACK</th>
<th>Reg Address H</th>
<th>ACK</th>
<th>Reg Address L</th>
<th>ACK</th>
<th>STOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>D8h (6Ch (7b)+ 0)</td>
<td>A</td>
<td>00h</td>
<td>A</td>
<td>D0h</td>
<td>A</td>
<td>40h</td>
<td>A</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>START</th>
<th>Slave Address</th>
<th>ACK</th>
<th>Access Address</th>
<th>ACK</th>
<th>Read Data H</th>
<th>ACK</th>
<th>Read Data L</th>
<th>ACK</th>
<th>STOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>D8h (6Ch (7b)+ 0)</td>
<td>A</td>
<td>07h</td>
<td>A</td>
<td>xxh</td>
<td>A</td>
<td>xxh</td>
<td>NA</td>
<td>P</td>
</tr>
</tbody>
</table>

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)

Table 8. SENS_CTRL

<table>
<thead>
<tr>
<th>Address</th>
<th>MSB</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>LSB</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>D040h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Write Access</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Host &amp; MCU</td>
<td>Host &amp; MCU</td>
<td>Host &amp; MCU</td>
<td></td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- **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)

Table 9. FLAGS

<table>
<thead>
<tr>
<th>Address</th>
<th>MSB</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>LSB</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>D046h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Write Access</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Host &amp; MCU</td>
<td>None</td>
<td>Host &amp; MCU</td>
<td>Host &amp; MCU</td>
<td></td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- **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

<table>
<thead>
<tr>
<th>ADDR</th>
<th>MSB</th>
<th>LSB</th>
</tr>
</thead>
<tbody>
<tr>
<td>D049h</td>
<td>D7</td>
<td>D0</td>
</tr>
<tr>
<td>Write Access</td>
<td>NONE</td>
<td>NONE</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- 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.

![CRC Calculation Diagram](image)

- 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.

<table>
<thead>
<tr>
<th>1st Byte of data</th>
<th>2nd Byte of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>hex</td>
<td>bin</td>
</tr>
<tr>
<td>1st Byte of data</td>
<td>04h</td>
</tr>
<tr>
<td>2nd Byte of data</td>
<td>02h</td>
</tr>
<tr>
<td>Polynomial (x^8+ x^5+ x^4+ 1)</td>
<td>131h</td>
</tr>
<tr>
<td>CRC-byte checksum</td>
<td>225h</td>
</tr>
</tbody>
</table>

Polynomial bit sequence:

- 1st Byte of data: 00000010
- 2nd Byte of data: 00000100
- Data bit sequence

Fig.7 XOR operation example of CRC-8

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

Table 11. 16bit Data Register Map

<table>
<thead>
<tr>
<th>Address</th>
<th>Registers Name</th>
<th>MSB D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>LSB D0</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D051h</td>
<td>COMP_DATA1_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Compensated Flow rate Register</td>
</tr>
<tr>
<td>D052h</td>
<td>COMP_DATA1_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DATA&lt;7:0&gt;</td>
</tr>
<tr>
<td>D061h</td>
<td>TMP_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DATA&lt;15:8&gt;</td>
</tr>
<tr>
<td>D062h</td>
<td>TMP_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Internal Temperature Register</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DATA&lt;7:0&gt;</td>
</tr>
</tbody>
</table>

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]
    \[ Dp[Pa] = (Pv - 1024)/60000 \times \text{RANGE} - \text{RANGE}/2 \] (RANGE = 100 or 1000)
    Where, \( P_v \) is Register content stored in the Compensated Flow Data registers [D051h – D052h].
  - If pressure range is 0-250[Pa]
    \[ Dp[Pa] = (Pv - 1024)/60000 \times \text{RANGE} \] (RANGE = 250 )
    Where, \( P_v \) 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.
  \[ T_v [\degree \text{C}] = (R_v - 10214) / 37.39 \]
  Where, \( T_v \) is Converted temperature value in the degC format, and \( R_v \) 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).

<table>
<thead>
<tr>
<th>Address of Registers</th>
<th>Value of Registers</th>
<th>Converted Temperature values</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMP_H D061h</td>
<td>TMP_L D062h</td>
<td>HEX D062h</td>
</tr>
<tr>
<td>2Bh</td>
<td>8Dh</td>
<td>2B8Dh 11149 25.0 degC</td>
</tr>
<tr>
<td>2Eh</td>
<td>FFh</td>
<td>2EFFh 12031 48.6 degC</td>
</tr>
<tr>
<td>26h</td>
<td>BBh</td>
<td>26BBh 9915 -8.0 degC</td>
</tr>
</tbody>
</table>

Table 12. Temperature Data registers content vs. Temperature value
9. Sensor Operation flow chart

1. Initialization

By calling the Initialize function of the provided sample code, No.1 routine can be executed.

Enable CRC Function

2. Execute MCU mode after desired configurations are set

By calling the Press_meas function of provided sample code, No.3 routine can be executed.

In case of temperature measurement, please call Temp_meas function.

3. Reading the MSB and LSB of the COMP_DATA Register (D051h and D052h)

Hardware Reset Enable

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

Fig.8 Flowchart of Sensor operation

- Communication time

<table>
<thead>
<tr>
<th>Item</th>
<th>Sign</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response time</td>
<td>α</td>
<td>α ≥ 33 ms</td>
</tr>
<tr>
<td>Sampling interval</td>
<td>β</td>
<td>β &gt; α</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>START</th>
<th>Slave Address</th>
<th>ACK</th>
<th>Access Address</th>
<th>ACK</th>
<th>Write Data</th>
<th>ACK</th>
<th>STOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>D8h (6Ch (7b)+ 0)</td>
<td>A</td>
<td>0Bh</td>
<td>A</td>
<td>00h</td>
<td>A</td>
<td>P</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>START</th>
<th>Slave Address</th>
<th>ACK</th>
<th>Access Address</th>
<th>ACK</th>
<th>Reg Address H</th>
<th>ACK</th>
<th>Reg Address L</th>
<th>ACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>D8h (6Ch (7b)+ 0)</td>
<td>A</td>
<td>00h</td>
<td>A</td>
<td>D0h</td>
<td>A</td>
<td>40h</td>
<td>A</td>
</tr>
</tbody>
</table>

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).

<table>
<thead>
<tr>
<th>START</th>
<th>Slave Address</th>
<th>ACK</th>
<th>Access Address</th>
<th>ACK</th>
<th>Reg Address H</th>
<th>ACK</th>
<th>Reg Address L</th>
<th>ACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>D8h (6Ch (7b)+ 0)</td>
<td>A</td>
<td>00h</td>
<td>A</td>
<td>D0h</td>
<td>A</td>
<td>51h</td>
<td>A</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>START</th>
<th>Slave Address</th>
<th>ACK</th>
<th>Access Address</th>
<th>ACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>D8h (6Ch (7b)+ 0)</td>
<td>A</td>
<td>07h</td>
<td>A</td>
</tr>
</tbody>
</table>

   **Re-Start**

<table>
<thead>
<tr>
<th>Re-Start</th>
<th>Slave Address</th>
<th>ACK</th>
<th>Read Data H</th>
<th>ACK</th>
<th>Read Data L</th>
<th>ACK</th>
<th>STOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS</td>
<td>D9h (6Ch (7b)+ 1)</td>
<td>A</td>
<td>xxh</td>
<td>A</td>
<td>xxh</td>
<td>NA</td>
<td>P</td>
</tr>
</tbody>
</table>
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).

<table>
<thead>
<tr>
<th>START</th>
<th>Slave Address</th>
<th>ACK</th>
<th>Access Address</th>
<th>ACK</th>
<th>Reg Address H</th>
<th>ACK</th>
<th>Reg Address L</th>
<th>ACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>D8h (6Ch (7b)+ 0)</td>
<td>A</td>
<td>00h</td>
<td>A</td>
<td>D0h</td>
<td>A</td>
<td>49h</td>
<td>A</td>
</tr>
</tbody>
</table>

Execute Hardware Reset

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

<table>
<thead>
<tr>
<th>START</th>
<th>Slave Address</th>
<th>ACK</th>
<th>Access Address</th>
<th>ACK</th>
<th>Write Data</th>
<th>ACK</th>
<th>STOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>D8h (6Ch (7b)+ 0)</td>
<td>A</td>
<td>0Dh</td>
<td>A</td>
<td>80h</td>
<td>A</td>
<td>P</td>
</tr>
</tbody>
</table>

The hardware reset after the execution, bit 7 is cleared to "0" automatically.
The following is a sample source code of the D6F-PH control in the case of using
STM32 microcontroller. The I2C control unit will need to be adjusted to whatever microcontroller is
used.

11-1. D6F_PH_Sample.h

```c
/*=================================================*/
/* D6F-PH Digital Flow Sensor Header File (using STM32)
 * :Copyright: (C) OMRON Corporation, Microdevice H.Q.
 * :Auther : $Id$
 * :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.
# D6F PH Sample Code (using STM32)

* :Copyright: (C) OMRON Corporation, Microdevice H.Q.
* :Author :
* :Revision: $Rev$
* :Id: $Id$
* :Date: $Date$
* All Rights Reserved
* OMRON Proprietary Right

#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--;
}

void Initialize( void )
{
    // EEPROM Control <= 00h
    char send1[] = {0x0B, 0x00};
    I2C_WR(BUZZER_7, send1, 2);
    // [D042] <= 0C35h 50msec wait@4MHz
    char send2[] = {0x00, 0xD0, 0x42, 0x28, 0x0C, 0x35};
    I2C_WR(BUZZER_7, send2, 6);
    // [D041] <= 88h Heater supply voltage is 1.3V
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);

    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, 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 : I2C_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)
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;
/*   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 diable 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]); /* Read Data */
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--)
        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 */

/*=================================================*/
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
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
}
12. WARRANTY AND LIMITED LIABILITY

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14. History

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