Temperature and Humidity Digital Sensor

BM25S2021-1
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Features

- Accurate relative humidity sensor
  - Resolution: 0.1% RH
  - Accuracy: ± 3% RH
- Accurate temperature sensor
  - Resolution: 0.1℃
  - Accuracy: ± 0.5℃
- Temperature and humidity sensing range
  - Temperature: -40℃ ~ 80℃
  - Humidity: 10% RH ~ 95% RH
- Low current consumption
  - Operating Current: < 2.5mA@5V
  - Standby Current: < 3μA
- Wide operating voltage: 2.7V ~ 5.5V
- Optional communication interfaces
  - I2C
  - One-wire
- Factory-calibrated

General Description

The BM25S2021-1 is a digital output resistive type temperature and humidity sensor that integrates a temperature sensor, a humidity sensor, a high-performance Analog Front End circuit and an A/D Converter. These hardware functions when combined with appropriate algorithms give the module the characteristics of high performance, low power consumption as well as a high level of functional integration and small size. All modules are factory calibrated with the calibrated data stored in the memory to ensure that the module can be used directly or replaced without requiring software calibration.

The BM25S2021-1 has two communication interfaces, an I2C bus and a one-wire bus. The module is suitable for use in small home appliances, HVAC/R products, environmental sensing products and IoT terminal devices.

Applications

- White goods
- HVAC/R such as for heating, ventilation and air conditioning/refrigeration
- Environmental sensing products
- IoT devices
- Industrial equipment
### Selection Table

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Performance</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM25S2021-1</td>
<td>10%RH~95%RH, ±3%RH</td>
<td>I²C/One-Wire</td>
</tr>
<tr>
<td></td>
<td>-40ºC~80ºC, ±0.5ºC</td>
<td></td>
</tr>
</tbody>
</table>

### Pin Assignment

![Pin Assignment Diagram]

### Pin Description

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Function</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VDD</td>
<td>PWR</td>
<td>Positive power supply</td>
</tr>
<tr>
<td>2</td>
<td>SDA</td>
<td>I/O</td>
<td>I²C data line</td>
</tr>
<tr>
<td>3</td>
<td>GND</td>
<td>PWR</td>
<td>Negative power supply, GND</td>
</tr>
<tr>
<td>4</td>
<td>SCL</td>
<td>I</td>
<td>I²C clock line</td>
</tr>
<tr>
<td></td>
<td>CS</td>
<td>I</td>
<td>One-wire communication mode selection</td>
</tr>
</tbody>
</table>


### Block Diagram

![Block Diagram]

Legend:
- LDO: Linear Voltage Regulator
- OPA: Operational Amplifier
- 12-bit ADC: 12-bit Analog-to-Digital Converter
- MCU: Microcontroller Unit
- NTC: Negative Temperature Coefficient
- VDD: Positive Power Supply
- VSS: Negative Power Supply
Absolute Maximum Ratings

Supply Voltage .................................................. $V_{SS}$-0.3V to $V_{DD}$+6.0V
Input Voltage .................................................. $V_{SS}$-0.3V to $V_{DD}$+0.3V
Storage Temperature .................................................. 10°C to 40°C
Storage Relative Humidity .................................................. 20%~60% RH
Operating (Ambient) Temperature .................................. -40°C~80°C
Operating (Ambient) Humidity ........................................ 10%~95% RH
Total Power Dissipation ............................................ 18mW

Note: These are stress ratings only. Stresses exceeding the range specified under “Absolute Maximum Ratings” may cause substantial damage to the device. Functional operation of the device at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

D.C. Electrical Characteristics

$$\text{Ta}=25^\circ\text{C}, \ V_{DD}=5V$$

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage ($V_{DD}$)</td>
<td>—</td>
<td>2.7</td>
<td>5.0</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>Normal Mode Operation</td>
<td>—</td>
<td>2.5</td>
<td>—</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>Sleep Mode Operation</td>
<td>—</td>
<td>—</td>
<td>3</td>
<td>μA</td>
</tr>
<tr>
<td>Input Low Voltage</td>
<td>—</td>
<td>0</td>
<td>—</td>
<td>0.2$V_{DD}$</td>
<td>V</td>
</tr>
<tr>
<td>Input High Voltage</td>
<td>—</td>
<td>0.8$V_{DD}$</td>
<td>—</td>
<td>$V_{DD}$</td>
<td>V</td>
</tr>
</tbody>
</table>

A.C. Electrical Characteristics

System Timing

$$\text{Ta}=25^\circ\text{C}, \ V_{DD}=5V$$

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{PU}$</td>
<td>Power-up Time</td>
<td>When $V_{DD} \geq 2.7V$ module is ready for conversion and communication</td>
<td>—</td>
<td>100</td>
<td>—</td>
<td>ms</td>
</tr>
<tr>
<td>$t_{C}$</td>
<td>Conversion Time</td>
<td>Humidity &amp; temperature conversion</td>
<td>—</td>
<td>35</td>
<td>—</td>
<td>ms</td>
</tr>
<tr>
<td>$t_{I}$</td>
<td>Interval Time</td>
<td>—</td>
<td>300</td>
<td>—</td>
<td>—</td>
<td>ms</td>
</tr>
<tr>
<td>$t_{RSP}$</td>
<td>Response Data Time</td>
<td>$^\circ$C mode, read temperature value only</td>
<td>—</td>
<td>5</td>
<td>—</td>
<td>ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^\circ$C mode, read humidity value only</td>
<td>—</td>
<td>5</td>
<td>—</td>
<td>ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^\circ$C mode, read humidity &amp; temperature value</td>
<td>—</td>
<td>7</td>
<td>—</td>
<td>ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>One-wire mode, read humidity &amp; temperature value</td>
<td>—</td>
<td>4.5</td>
<td>—</td>
<td>ms</td>
</tr>
</tbody>
</table>
System Power-up Timing Chart

Note: The System Ready signal indicates that the system initialisation has completed and the sensor is ready to receive commands sent by the master device.

Communication Process & Data Conversion Timing Chart

I2C Interface

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{SCL}$</td>
<td>Clock Frequency</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>kHz</td>
</tr>
<tr>
<td>$t_{BUF}$</td>
<td>Bus Free Time</td>
<td>Time in which the bus must be free before a new transmission can start</td>
<td>4.7</td>
<td>—</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>$t_{HD_STA}$</td>
<td>Start Condition Hold Time</td>
<td>After this period, the first clock pulse is generated</td>
<td>4.0</td>
<td>—</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>$t_{LOW}$</td>
<td>SCL Low Time</td>
<td>—</td>
<td>4.7</td>
<td>—</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>$t_{HIGH}$</td>
<td>SCL High Time</td>
<td>—</td>
<td>4.0</td>
<td>—</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>$t_{SU_STA}$</td>
<td>Start Condition Setup Time</td>
<td>Time only relevant for repeated START condition</td>
<td>4.7</td>
<td>—</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>$t_{HD_DAT}$</td>
<td>Data Hold Time</td>
<td>—</td>
<td>0</td>
<td>—</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{SU_DAT}$</td>
<td>Data Setup Time</td>
<td>—</td>
<td>250</td>
<td>—</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td>$t_r$</td>
<td>SDA and SCL Rise Time</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>µs</td>
</tr>
<tr>
<td>$t_{r}$</td>
<td>SDA and SCL Fall Time</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.3</td>
<td>µs</td>
</tr>
<tr>
<td>$t_{SU_STO}$</td>
<td>Stop Condition Set-up time</td>
<td>—</td>
<td>4.0</td>
<td>—</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>$t_{OA}$</td>
<td>Output Valid from Clock</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>3.45</td>
<td>µs</td>
</tr>
<tr>
<td>$t_{FP}$</td>
<td>Input Filter Time Constant</td>
<td>Noise suppression time</td>
<td>—</td>
<td>—</td>
<td>50</td>
<td>ns</td>
</tr>
</tbody>
</table>

Note: These parameters are periodically sampled but not 100% tested.
### One-wire Communication

Ta=25°C, V_{DD}=5V

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>t_{start}</td>
<td>Master Device Start Signal Pull Down Time</td>
<td>—</td>
<td>0.8</td>
<td>1.0</td>
<td>20.0</td>
<td>ms</td>
</tr>
<tr>
<td>t_{release}</td>
<td>Master Device Release Bus Time</td>
<td>—</td>
<td>5</td>
<td>30</td>
<td>200</td>
<td>μs</td>
</tr>
<tr>
<td>t_{ackl}</td>
<td>Sensor Acknowledge Low Level Time</td>
<td>—</td>
<td>75</td>
<td>80</td>
<td>85</td>
<td>μs</td>
</tr>
<tr>
<td>t_{ackh}</td>
<td>Sensor Acknowledge High Level Time</td>
<td>—</td>
<td>75</td>
<td>80</td>
<td>85</td>
<td>μs</td>
</tr>
<tr>
<td>t_{low}</td>
<td>Data “0” and Data “1” Low Level Time</td>
<td>—</td>
<td>48</td>
<td>50</td>
<td>55</td>
<td>μs</td>
</tr>
<tr>
<td>t_{H0}</td>
<td>Data “0” High Level Time</td>
<td>—</td>
<td>22</td>
<td>26</td>
<td>30</td>
<td>μs</td>
</tr>
<tr>
<td>t_{H1}</td>
<td>Data “1” High Level Time</td>
<td>—</td>
<td>68</td>
<td>70</td>
<td>75</td>
<td>μs</td>
</tr>
<tr>
<td>t_{stop}</td>
<td>Sensor Release Bus Time</td>
<td>—</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>μs</td>
</tr>
</tbody>
</table>

Note: These parameters are periodically sampled but not 100% tested.
Sensor Characteristics

Humidity Sensor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>—</td>
<td>—</td>
<td>0.1</td>
<td>—</td>
<td>%RH</td>
</tr>
<tr>
<td>Sensing Range</td>
<td>—</td>
<td>10</td>
<td>95</td>
<td>—</td>
<td>%RH</td>
</tr>
<tr>
<td>Accuracy</td>
<td>RH = 10%RH to 95%RH, excluding hysteresis</td>
<td>—</td>
<td>±3</td>
<td>±4</td>
<td>%RH</td>
</tr>
<tr>
<td>Repeatability(1)</td>
<td>Consecutive measurement of 3σ</td>
<td>—</td>
<td>±0.1</td>
<td>—</td>
<td>%RH</td>
</tr>
<tr>
<td>Responses Time(2)</td>
<td>T_e50%</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td>S</td>
</tr>
<tr>
<td>Long Term Drift</td>
<td>—</td>
<td>±0.5</td>
<td>±1</td>
<td>±1.5</td>
<td>%RH/yr</td>
</tr>
<tr>
<td>Hysteresis</td>
<td>—</td>
<td>±0.5</td>
<td>±1</td>
<td>±2</td>
<td>%RH</td>
</tr>
</tbody>
</table>

Note: 1. Repeatability is the maximum error that the sensor consecutively measures on the same object 3 times.
2. Response Time is the time required for the sensor to change to the target object amount of 63%. This performance is for the device only. The application response time will depend on the sensor design.

Temperature Sensor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>—</td>
<td>—</td>
<td>0.1</td>
<td>—</td>
<td>°C</td>
</tr>
<tr>
<td>Sensing Range</td>
<td>—</td>
<td>-40</td>
<td>80</td>
<td>—</td>
<td>°C</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Ta=-40°C~60°C</td>
<td>±0.2</td>
<td>±0.5</td>
<td>±1</td>
<td>°C</td>
</tr>
<tr>
<td>Repeatability(1)</td>
<td>Consecutive measurement of 3σ</td>
<td>—</td>
<td>±0.3</td>
<td>—</td>
<td>°C</td>
</tr>
<tr>
<td>Responses Time(2)</td>
<td>T_e50%</td>
<td>2</td>
<td>—</td>
<td>—</td>
<td>S</td>
</tr>
<tr>
<td>Long Term Drift</td>
<td>—</td>
<td>0.3</td>
<td>—</td>
<td>—</td>
<td>°C/yr</td>
</tr>
</tbody>
</table>

Note: 1. Repeatability is the maximum error that the sensor consecutively measures on the same object 3 times.
2. Response Time is the time required for the sensor to change to the target object amount of 63%. This performance is for the device only. The practical application response time will depend on the sensor design.

Functional Description

System Description

The BM25S2021-1 is a module which includes integrated temperature and humidity measurement sensors. The main sensor is composed of a resistive type humidity component with an accuracy of ±3%RH and a high accuracy NTC. The resistance value of the humidity component will vary with the ambient humidity. When used together with the internal signal processing circuit, the measurement data stability and accuracy can be improved. The humidity component when used together with the NTC can provide accurate environmental temperature and humidity information for a wide variety of applications.

Operating Principle

When the sensor initialisation is completed after the system is powered up, the BM25S2021-1 will execute the first temperature and humidity conversion and then determine whether the sensor communication mode is I^2C or one-wire via the SCL line connection. If the SCL line is not connected to VSS, I^2C communication mode will be selected. In this case, the module will execute I^2C command processing and I^2C time-out detection after which it will enter the Sleep Mode to
wait for an I²C interrupt wake-up. If the SCL line is connected to VSS, one-wire communication mode will be selected. In this case, the module will execute one-wire bus command processing, after which it will enter the Sleep Mode to wait for the next wake-up. Communication details can be obtained by referring to the interface section.

** BM25S2021-1 System Flow Chart **

**Minimum Continuous Read Time**

After each of the temperature and humidity values is read, the sensor will trigger a temperature and humidity measurement conversion ready for the next reading. For this reason, if the measurement value is not read for a long time, it is recommended to read twice to ensure that a correct temperature and humidity value is obtained.
Sleep Mode

For system power saving, after completing the power-up initialisation and after the first measurement and communication mode judgement are completed, the sensor will enter the Sleep Mode. Here the measurement function is disabled until the next wake-up occurs.

Relative Humidity Sensor

The construction of a resistive-type humidity component is a polymer film coated on a ceramic substrate which is equipped with a conductive electrode. For the humidity component, where the ambient relative humidity changes in a logarithmic manner, the component that is used by the BM25S2021-1 has a relationship where the higher the humidity is, the lower the resistance will be. Due to the characteristics of this component, it needs to be used together with an AC method. Therefore, the MCU mounted on the sensor contains an analog front end logarithmic amplifier. The amplified signal is captured, conditioned and converted to a corresponding relative humidity by the A/D Converter.

### Communication Mode

<table>
<thead>
<tr>
<th>Communication Mode</th>
<th>Min. Continuous Read Time</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>I²C</td>
<td>2</td>
<td>S</td>
</tr>
<tr>
<td>One-wire</td>
<td>2</td>
<td>S</td>
</tr>
</tbody>
</table>

![Relative Humidity Sensor Circuit](image)

**Humidity Accuracy @ 25°C**

![Humidity Sensor Relative Humidity Measurement Error Curve](image)
**Temperature Sensor**

The BM25S2021-1 uses a negative temperature coefficient NTC. This means that the higher the temperature, the lower the resistance. A resistor, the resistance of which is consistent with the NTC at a temperature of 25°C, is used together with the NTC to form a voltage divider circuit for system measurements.

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**Recommended Operating Conditions**

To achieve sensor optimum performance, it is recommended that the sensor operates within a temperature range of 5°C to 60°C and the humidity within a range of 20% to 80%. If the sensor is exposed to an environment exceeding the recommended values for a long time, especially a high humidity (>80%RH) and high temperatures (>80°C) environment, this will create abnormal conditions for the sensor which will accelerate sensor ageing.
Application Circuits

**I^2C Mode**

![I^2C Circuit Diagram](attachment:diagram.png)

**One-wire Mode**

![One-wire Circuit Diagram](attachment:diagram.png)

**Interface**

The BM25S2021-1 supports both I^2C and one-wire communication methods. In the I^2C communication mode, the BM25S2021-1 is used as a slave device. Here a master device can read the temperature and humidity measurement values and device information from the BM25S2021-1. Communication details can be obtained by referring to the I^2C interface section. The second communication method is the one-wire interface, which has only a single line. In the one-wire mode, the master device can read the temperature and humidity measurement values from the BM25S2021-1 using a fixed format. Communication details can be obtained by referring to the one-wire communication section.

**I^2C Interface**

**I^2C Operation**

The BM25S2021-1 supports an I^2C serial interface. The I^2C bus is used for bidirectional, two-line communication between different ICs or modules. The two lines used are a serial data line, SDA, and a serial clock line, SCL. Both lines are connected to the positive supply via pull-up resistors with a typical value of 4.7kΩ. When the bus is free, both lines are high. Devices connected to the bus must have open-drain or open-collector outputs to implement a wired-and function. Data transfer is initiated only when the bus is not busy.
Data Validity
The data on the SDA line must be stable during the high period of the serial clock. The high or low state of the data line can only change when the clock signal on the SCL line is Low as shown in the diagram.

START and STOP Conditions
- A high to low transition on the SDA line while SCL is high defines a START condition.
- A low to high transition on the SDA line while SCL is high defines a STOP condition.
- START and STOP conditions are always generated by the master. The bus is considered to be busy after the START condition. The bus is considered to be free again a certain time after the STOP condition.
- The bus stays busy if a repeated START (Sr) is generated instead of a STOP condition. In some respects, the START(S) and repeated START (Sr) conditions are functionally identical.

Byte Format
Every byte put on the SDA 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. Data is transferred with the most significant bit, MSB, first.

Acknowledge
- Each byte of eight bits is followed by one acknowledge bit. This Acknowledge bit is a low level placed on the bus by the receiver. The master generates an extra acknowledge related clock pulse.
- A slave receiver which is addressed must generate an Acknowledge, ACK, after the reception of each byte.
- The device that acknowledges must pull down the SDA line during the acknowledge clock pulse so that it remains stable low during the high period of this clock pulse.
- A master receiver must signal an end of data to the slave by generating a not-acknowledge, NACK, bit on the last byte that has been clocked out of the slave. In this case, the master receiver
must leave the data line high during the 9th pulse to not acknowledge. The master will generate a
STOP or repeated START condition.

![Timing Diagram]

**Slave Addressing - 1011100**

- The slave address byte is the first byte received following the START condition from the master
device. The first seven bits of the first byte make up the slave address. The eighth bit defines
whether a read or write operation is to be performed. When the R/W bit is “1”, a read operation is
selected. When the R/W bit is “0”, a write operation is selected.
- The BM25S2021-1 device address bits are “1011100”. When an address byte is sent, the device
compares the first seven bits after the START condition. If they match, the device outputs an
Acknowledge on the SDA line.

![Slave Address Diagram]

**I²C Communication Protocol**

**How to Read from the BM25S2021-1**

The BM25S2021-1 contains a dedicated communication protocol based on the I²C standard
protocol. The SCL frequency is up to 40kHz and the protocol is mainly divided into two steps,
which are sending commands and reading back the values. First, the master device needs to transmit
a command to the sensor. The sensor will wake up after receiving the command and then analyse it.
When the master device confirms that the sensor is online and has been acknowledged, it will read
the sensor values. The complete communication timing is shown below.

![Communication Timing Diagram]

**Read Measurement Result Sequence**
<table>
<thead>
<tr>
<th>Data Address</th>
<th>Data</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>00H</td>
<td>Relative Humidity Data High Byte (RHH)</td>
<td>Measurement Data</td>
</tr>
<tr>
<td>01H</td>
<td>Relative Humidity Data Low Byte (RHL)</td>
<td></td>
</tr>
<tr>
<td>02H</td>
<td>Temperature Data High Byte (TMPH)</td>
<td></td>
</tr>
<tr>
<td>03H</td>
<td>Temperature Data Low Byte (TMPL)</td>
<td></td>
</tr>
<tr>
<td>04H</td>
<td>—</td>
<td>Reserved</td>
</tr>
<tr>
<td>05H</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>06H</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>07H</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>08H</td>
<td>Device Number High Byte</td>
<td></td>
</tr>
<tr>
<td>09H</td>
<td>Device Number Low Byte</td>
<td></td>
</tr>
<tr>
<td>0AH</td>
<td>Version Number</td>
<td>Device Information</td>
</tr>
<tr>
<td>0BH</td>
<td>Serial Number Byte 3</td>
<td></td>
</tr>
<tr>
<td>0CH</td>
<td>Serial Number Byte 2</td>
<td></td>
</tr>
<tr>
<td>0DH</td>
<td>Serial Number Byte 1</td>
<td></td>
</tr>
<tr>
<td>0EH</td>
<td>Serial Number Byte 0</td>
<td></td>
</tr>
<tr>
<td>0FH</td>
<td>—</td>
<td>Reserved</td>
</tr>
</tbody>
</table>

**Data Address Summary**

Note: It should be noted that if the sent command is not in accordance with the specification, the sensor may receive an incorrect and random value.

**Numerical Calculations**

Humidity calculation:

Relative Humidity = \( \frac{RHH \times 256 + RHL}{10} \)

Ex. If the returned value RHH = 01h and RHL = F4h, the actual humidity calculation is as follows:

\[ \begin{align*}
RHH &= 01h = 1 \\
RHL &= F4h = 244 \\
\Rightarrow \text{Relative Humidity} &= \frac{1 \times 256 + 244}{10} = 50\%RH
\end{align*} \]

Temperature calculation:

Temperature = \( \frac{TMPH \times 256 + TMPL}{10} \)

Ex. If the returned value TMPH = 00h, TMPL = FAh, the actual temperature calculation is as follows:

\[ \begin{align*}
TMPH &= 00h = 0 \\
TMPL &= FAh = 250 \\
\Rightarrow \text{Temperature} &= \frac{0 \times 256 + 250}{10} = 25^\circ C
\end{align*} \]

**CRC Operation**

The I^2C communication uses CRC-16 as its verification mechanism. The CRC polynomial and detailed operation steps are as follows.

- CRC-16 polynomial operation: \( X^{16} + X^{15} + X^2 + 1 \) (e.g.1010 0000 0000 0001)

Step 1. Define a 16-bit register, the default value of which is FFFFh (e.g.11111111 11111111 b). The register is called the CRC register.

Step 2. Execute an “Exclusive OR” operation with data byte 0 and the CRC register low byte. The result is stored back into the CRC register.

Step 3. Shift the CRC register value right by one bit and move a “0” into the MSB and check the right shifted bit.
Step 4. If the shifted bit is “0”, repeat step 3. If the shifted bit is “1”, execute an “Exclusive OR” operation with the CRC register and polynomial. Then the operation result is stored back into the CRC register.

Step 5. Repeat step 3~ step 4 until 8 right shifts are completely calculated.

Step 6. Proceed to process the next data byte, repeat step 2~ step 5.

Step 7. When all of the data bytes are completely calculated, swap the CRC register high byte with the low byte.

Step 8. The swapped CRC register value is the final CRC code.

One-wire Communication

One-wire Communication Protocol

In the one-wire communication mode, the BM25S2021-1 DATA pin is used to communicate with the master device. This communication method exists as a master-slave relationship. The communication START signal is sent by the master device, which occurs by pulling down the DATA line for a short time. After this it releases the DATA line and waits for an acknowledge signal from the sensor (slave device). This is followed by 40-bits of data, the order of which is Relative Humidity (2 bytes), Temperature (2 bytes) and Checksum (1 byte), with MSB first and LSB last. After the 40-bits of data has been transferred, the sensor will pull down the DATA line for a short time, which will be regarded as a communication STOP signal.

<table>
<thead>
<tr>
<th>Name</th>
<th>Length</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>START</td>
<td>1 bit</td>
<td>The master device (host MCU) pulls down the DATA line to wake up the module.</td>
</tr>
<tr>
<td>ACK</td>
<td>1 bit</td>
<td>The module pulls down the DATA line for 80μs, then pulls the DATA line high for 80μs to respond to the master device</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>16 bits</td>
<td>The relative humidity value is 16 bits, MSB first. The sensor relative humidity output value is 10 times that of the actual humidity value.</td>
</tr>
<tr>
<td>Temperature</td>
<td>16 bits</td>
<td>The temperature value is 16 bits, MSB first. The sensor temperature output value is 10 times that of the actual temperature value. The MSB (bit 15) of the temperature value represents positive or negative temperature. The temperature is negative if MSB=1 or positive if MSB=0</td>
</tr>
<tr>
<td>Checksum</td>
<td>8 bits</td>
<td>Checksum = RHH(1) + RHL(2) + TMPH(3) + TMPL(4)</td>
</tr>
</tbody>
</table>

START = Communication start signal (1 bit)
ACK = Module acknowledge (1bit)
DATA = Data signal (40 bits)
STOP = Communication stop signal (1 bit)
<table>
<thead>
<tr>
<th>Name</th>
<th>Length</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STOP</td>
<td>1 bit</td>
<td>After the last significant bit of the checksum is transferred, the module (slave device) pulls down the DATA line for at least 45μs, then releases it.</td>
</tr>
</tbody>
</table>

Note: 1. RHH = Relative Humidity High Byte  
   2. RHL = Relative Humidity Low Byte  
   3. TMPH = Temperature High Byte  
   4. TMPL = Temperature Low Byte

One-wire Communication Waveform

START Waveform

The START signal is generated by the master device (host MCU). The master device pulls down the DATA line for a time of $t_{\text{start}}$ to wake up the slave device (module). It is suggested that $t_{\text{start}} = 1 \text{ms}$.

\[
\text{(Wait for slave ack)}
\]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{\text{start}}$</td>
<td>Master Start Signal Pull Down Time</td>
<td>0.8</td>
<td>1.0</td>
<td>20.0</td>
<td>ms</td>
</tr>
<tr>
<td>$t_{\text{release}}$</td>
<td>Master Release Bus Time</td>
<td>5</td>
<td>30</td>
<td>200</td>
<td>μs</td>
</tr>
</tbody>
</table>

ACK Waveform

An ACK signal is sent by the module to respond to the master device. An ACK signal waveform is composed of $t_{\text{ackL}}$ and $t_{\text{ackH}}$. The recommended values are as follows.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{\text{ackL}}$</td>
<td>Sensor Acknowledge Low Level Time</td>
<td>75</td>
<td>80</td>
<td>85</td>
<td>μs</td>
</tr>
<tr>
<td>$t_{\text{ackH}}$</td>
<td>Sensor Acknowledge High Level Time</td>
<td>75</td>
<td>80</td>
<td>85</td>
<td>μs</td>
</tr>
</tbody>
</table>
Data Waveform

The DATA format has a fixed format of 5 bytes composed of Relative Humidity (2 bytes), Temperature (2 bytes) and Checksum (1 byte). The format details can be obtained by referring to the relevant chapter. In the one-wire communication mode, the waveform of the Data Bit conditions is as follow.

Data Bit = 1

\[ T_{D1} = T_{\text{Low}} + T_{\text{H1}} \]  
\[ (T_{\text{Low1}} = 50\mu s, \ T_{\text{High1}} = 70\mu s) \]

Data Bit = 0

\[ T_{D0} = T_{\text{Low}} + T_{\text{H0}} \]  
\[ (T_{\text{Low1}} = 50\mu s, \ T_{\text{High1}} = 26\mu s) \]

### Symbol Table

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>t_{\text{low}}</td>
<td>Data “0” and Data “1” Low Level Time</td>
<td>48</td>
<td>50</td>
<td>55</td>
<td>( \mu s )</td>
</tr>
<tr>
<td>t_{\text{H0}}</td>
<td>Data “0” High Level Time</td>
<td>22</td>
<td>26</td>
<td>30</td>
<td>( \mu s )</td>
</tr>
<tr>
<td>t_{\text{H1}}</td>
<td>Data “1” High Level Time</td>
<td>68</td>
<td>70</td>
<td>75</td>
<td>( \mu s )</td>
</tr>
</tbody>
</table>

STOP Waveform

After the last significant bit of the checksum has been transferred, the module will pull down the DATA line for a period of time. This means that communication will be terminated.

### Symbol Table

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>t_{\text{stop}}</td>
<td>Sensor Release Bus Time</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>( \mu s )</td>
</tr>
</tbody>
</table>
Relative Humidity (2 Bytes)
The relative humidity value is 16-bits with the MSB first and LSB last. The actual relative humidity calculation is as follow:

\[
\text{Relative Humidity} = (\text{RHH} \times 256 + \text{RHL}) / 10
\]

Temperature (2 Bytes)
The temperature value is 16-bits, MSB first. The sensor temperature output value is 10 times that of the actual temperature value. The temperature MSB (bit 15) indicates a positive or negative temperature. The temperature is negative if MSB=1 and positive if MSB=0.

\[
\text{Temperature} = (\text{TMPH} \times 256 + \text{TMPL}) / 10
\]

Checksum (1 Byte)
The one-wire communication checksum calculation is as follow:

\[
\text{Checksum} = \text{RHH} + \text{RHL} + \text{TMPH} + \text{TMPL}
\]

Checksum Calculation Example:

\[
\begin{align*}
\text{RHH} &= 00000001 \text{ (01H)} \\
\text{RHL} &= 10000010 \text{ (82H)} \\
\text{TMPH} &= 00001010 \text{ (0AH)} \\
\text{TMPL} &= 00001000 \text{ (08H)} \\
\text{Checksum} &= \text{RHH} + \text{RHL} + \text{TMPH} + \text{TMPL} = 10010101 \text{ (95H)}
\end{align*}
\]

One-wire Communication DATA Calculation Example
Ex1. If the master device obtains 40-bits of data, as shown below:

\[
\begin{align*}
00000010 & \quad 10010010 & \quad 00000001 & \quad 00001101 & \quad 10100010 \\
\text{Relative Humidity} &= 000001010010010B = 0292H = 685 \rightarrow 68.5\%RH \\
\text{Temperature} &= 0000001010001101B = 010DH = 26.9^\circ \text{C} \\
\text{Checksum} &= 00000010 + 10010010 + 00000001 + 00001101 = \text{10100010} \text{ (Correct)}
\end{align*}
\]

Ex2. If the master device obtains 40-bits of data, as shown below:

\[
\begin{align*}
00000010 & \quad 10010010 & \quad 10000000 & \quad 01100101 & \quad 10100010 \\
\text{Relative Humidity} &= 0000001010001101B = 0292H = 685 \rightarrow 68.5\%RH \\
\text{Temperature} &= 1000000010100011B = 010DH = -10.1^\circ \text{C} \\
\text{Checksum} &= 00000010 + 10010010 + 10000000 + 01100101 = \text{01111011} \text{ (Error)}
\end{align*}
\]
BM25S2021-1 Temperature and Humidity Digital Sensor

Dimensions

[Image of dimensions]

BM25S2021-1
DC : 2.7 - 5.5V
H: 10-95%RH
T : -40-80°C
A: ±3%RH±0.5°C
AABCCDDD
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