HOLTEK

Temperature and Humidity Digital Sensor

BM25S2021-1

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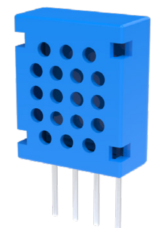
Features



- Accurate relative humidity sensor
  - ♦ Resolution: 0.1% RH
  - ♦ Accuracy: ± 3% RH
- Accurate temperature sensor
  - ♦ Resolution: 0.1°C
  - ♦ Accuracy: ± 0.5°C
- Temperature and humidity sensing range
  - ♦ Temperature: -40°C ~ 80°C
  - ♦ 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
  - ♦ I^2C
  - ♦ 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 I^2C 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.

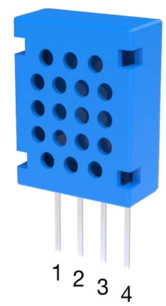
Applications

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

Selection Table

Part No.	Performance		Interface
	Humidity	Temperature	
BM25S2021-1	10%RH~95%RH, ±3%RH	-40°C~80°C, ±0.5°C	I²C/One-Wire

Pin Assignment

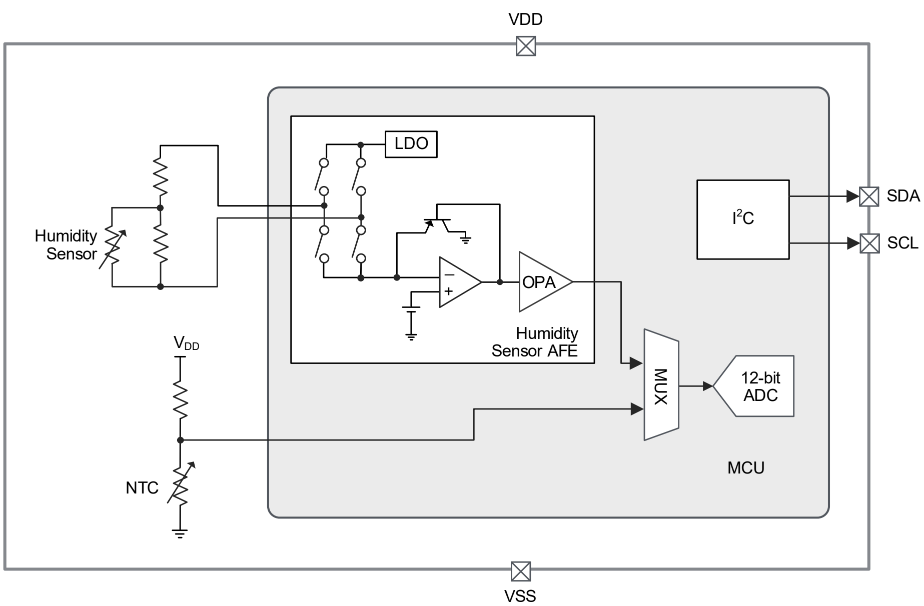


Pin Description

Pin Number	Function	Type	Description
1	VDD	PWR	Positive power supply
2	SDA	I/O	I²C data line
	DATA	I/O	One-wire communication data line
3	GND	PWR	Negative power supply, GND
4	SCL	I	I²C clock line
	CS	I	One-wire communication mode selection

Legend: PWR: Power; I: Digital Input; I/O: Digital Input/Output

Block Diagram



Absolute Maximum Ratings

Supply Voltage .... V_{SS}-0.3V to V_{SS}+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

Ta=25°C, V_{DD}=5V

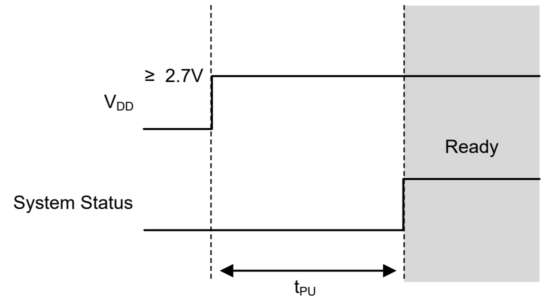
Parameter	Test Conditions	Min.	Typ.	Max.	Unit
Supply Voltage (V_{DD})	—	2.7	5.0	5.5	V
Power Consumption	Normal Mode Operation	—	2.5	—	mA
	Sleep Mode Operation	—	—	3	μA
Input Low Voltage	—	0	—	0.2V_{DD}	V
Input High Voltage	—	0.8V_{DD}	—	V_{DD}	V

A.C. Electrical Characteristics

System Timing

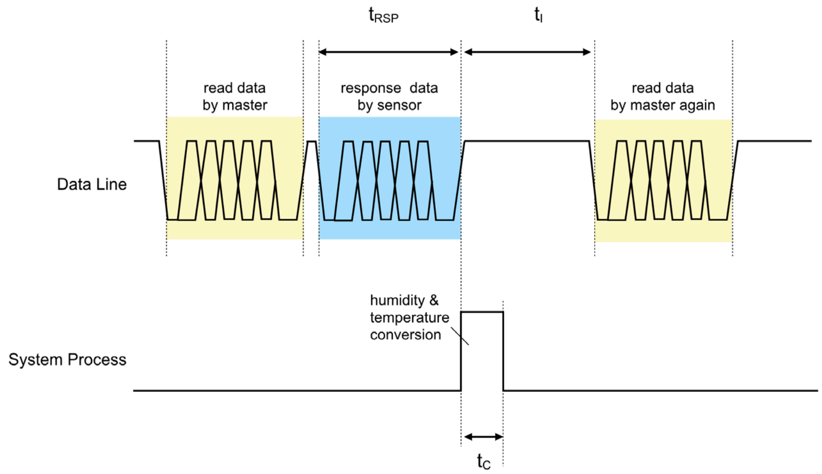
Ta=25°C, V_{DD}=5V

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
t_{PU}	Power-up Time	When V_{DD} ≥ 2.7V module is ready for conversion and communication	—	100	—	ms
t_C	Conversion Time	Humidity & temperature conversion	—	35	—	ms
t_I	Interval Time	—	300	—	—	ms
t_{RSP}	Response Data Time	I^2C mode, read temperature value only	—	5	—	ms
		I^2C mode, read humidity value only	—	5	—	ms
		I^2C mode, read humidity & temperature value	—	7	—	ms
		One-wire mode, read humidity & temperature value	—	4.5	—	ms



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.



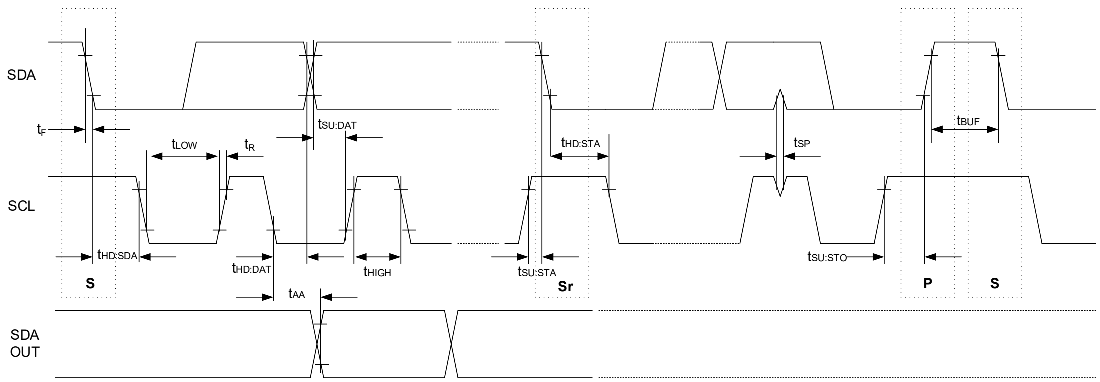
Communication Process & Data Conversion Timing Chart

I²C Interface

Ta=25°C, V_{DD}=5V

Symbol	Parameter	Test Conditions	Min	Typ.	Max.	Unit
f_{SCL}	Clock Frequency	—	—	—	40	kHz
t_{BUF}	Bus Free Time	Time in which the bus must be free before a new transmission can start	4.7	—	—	μs
t_{HD_STA}	Start Condition Hold Time	After this period, the first clock pulse is generated	4.0	—	—	μs
t_{LOW}	SCL Low Time	—	4.7	—	—	μs
t_{HIGH}	SCL High Time	—	4.0	—	—	μs
t_{SU_STA}	Start Condition Setup Time	Time only relevant for repeated START condition	4.7	—	—	μs
t_{HD_DAT}	Data Hold Time	—	0	—	—	ns
t_{SU_DAT}	Data Setup Time	—	250	—	—	ns
t_R	SDA and SCL Rise Time(Note)	—	—	—	1	μs
t_F	SDA and SCL Fall Time(Note)	—	—	—	0.3	μs
t_{SU_STO}	Stop Condition Set-up time	—	4.0	—	—	μs
t_{AA}	Output Valid from Clock	—	—	—	3.45	μs
t_{SP}	Input Filter Time Constant (SDA and SCL Pins)	Noise suppression time	—	—	50	ns

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



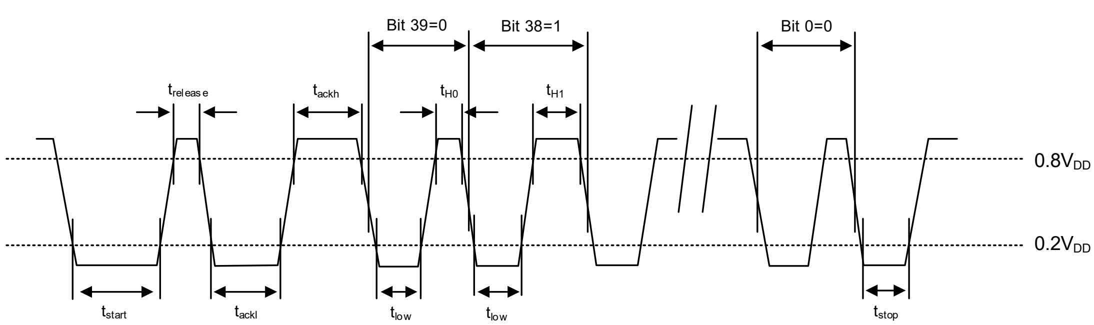
I²C Timing Chart

One-wire Communication

Ta=25°C, V_{DD}=5V

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

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



One-wire Communication Timing Chart

Sensor Characteristics

Humidity Sensor

Ta=25°C, V_{DD}=5V

Parameter	Test Conditions	Min.	Typ.	Max.	Unit
Resolution	—	—	0.1	—	%RH
Sensing Range	—	10	—	95	%RH
Accuracy	RH = 10%RH to 95%RH, excluding hysteresis	—	±3	±4	%RH
Repeatability(1)	Consecutive measurement of 3σ	—	± 0.1	—	%RH
Responses Time(2)	$T_{63\%}$	2	6	8	S
Long Term Drift	—	±0.5	±1	±1.5	%RH/yr
Hysteresis	—	±0.5	±1	±2	%RH

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

Ta=25°C, V_{DD}=5V

Parameter	Test Conditions	Min.	Typ.	Max.	Unit
Resolution	—	—	0.1	—	°C
Sensing Range	—	-40	—	80	°C
Accuracy	Ta=-40°C~60°C	±0.2	±0.5	±1	°C
Repeatability(1)	Consecutive measurement of 3σ	—	±0.3	—	°C
Responses Time(2)	$T_{63\%}$	—	2	—	S
Long Term Drift	—	—	0.3	—	°C/yr

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 pratical application response time will depend on the sensor design.

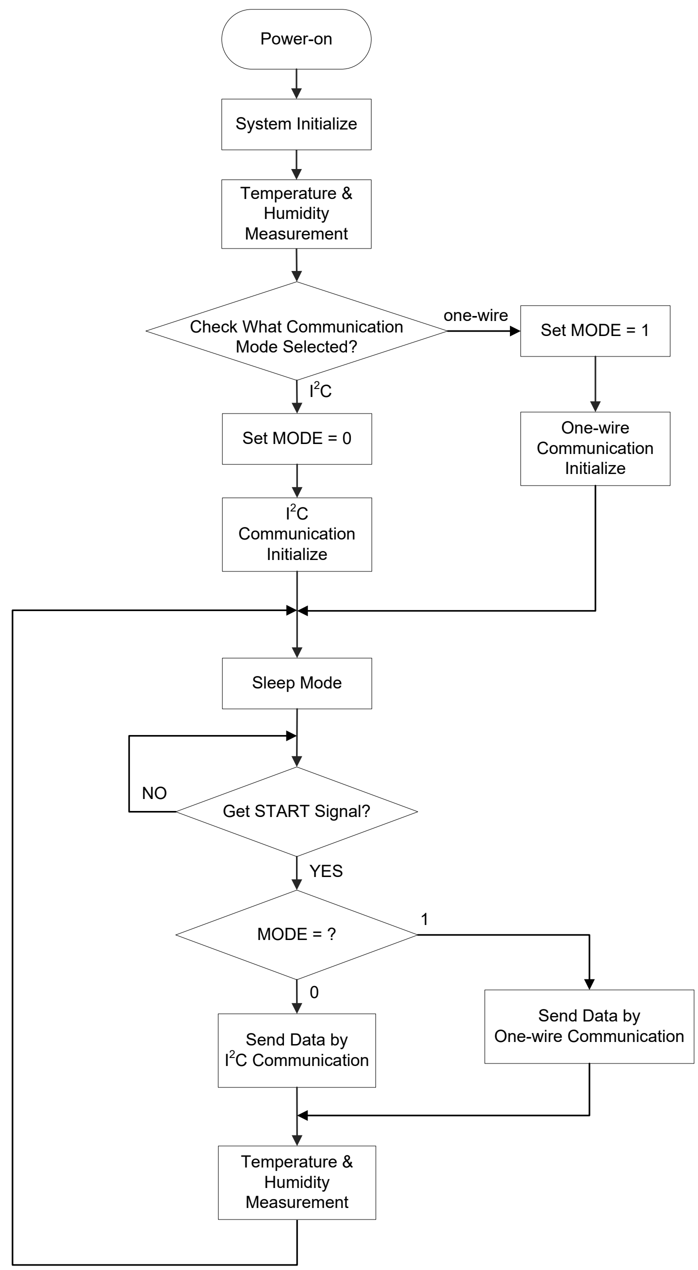
Functional Description

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.

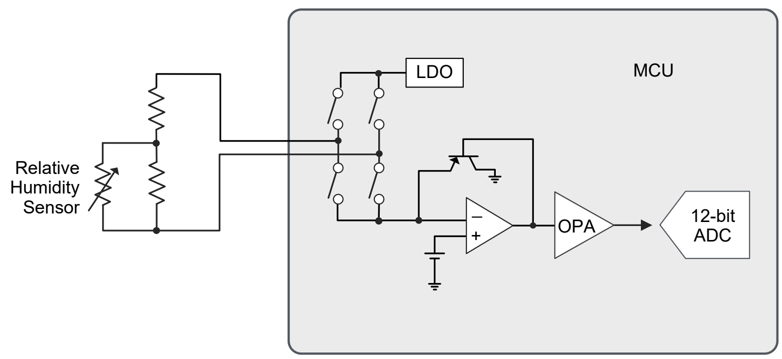
Communication Mode	Min. Continuous Read Time	Unit
I²C	2	S
One-wire	2	S

Sleep Mode

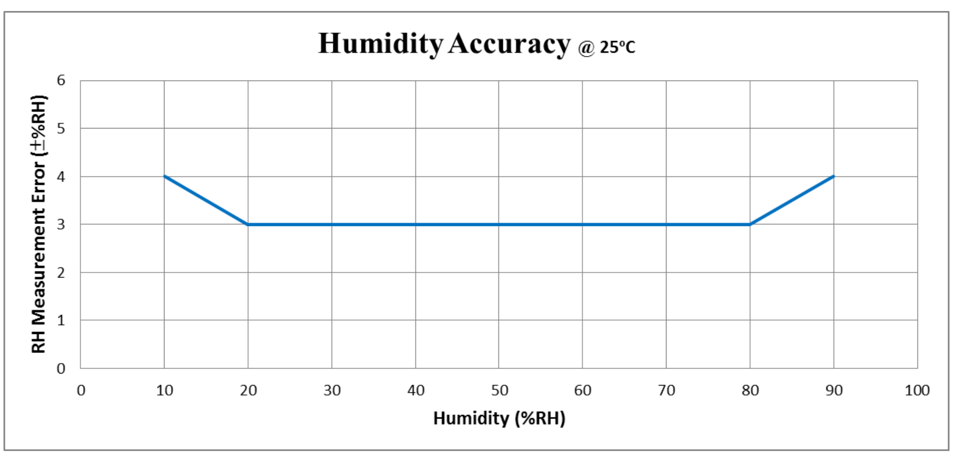
For system power saving, after completing the power-up initialisation and after the first measurement and communication mode judgement are completed, the sensor will enter the Sleep Mode. Here the measurement function is disabled until the next wake-up occurs.

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.



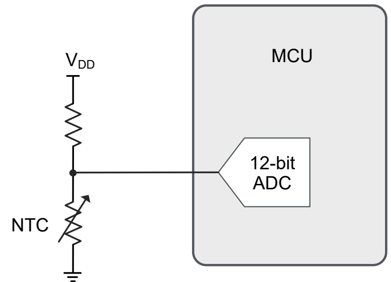
Relative Humidity Sensor Circuit



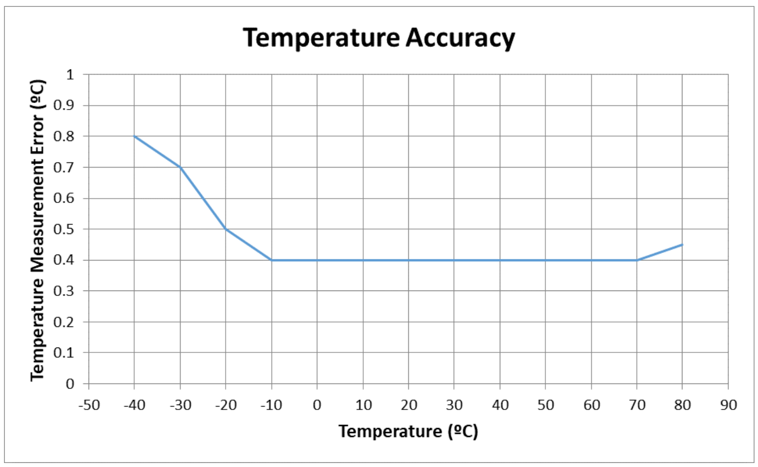
Humidity Sensor Relative Humidity Measurement Error Curve

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 25ºC, is used together with the NTC to form a voltage divider circuit for system measurements.



Temperature Sensor Circuit



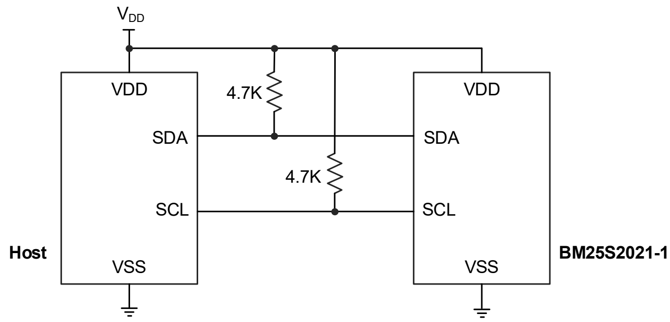
NTC Temperature Measurement Error Curve

Recommended Operating Conditions

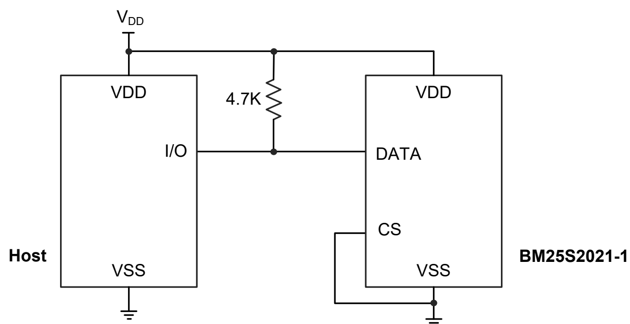
To achieve sensor optimum performance, it is recommended that the sensor operates within a temperature range of 5°C to 60°C and the humidity within a range of 20% to 80%. If the sensor is exposed to an environment exceeding the recommended values for a long time, especially a high humidity (>80%RH) and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

Application Circuits

I²C Mode



One-wire Mode



Interface

The BM25S2021-1 supports both I²C and one-wire communication methods. In the I²C 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 I²C 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.

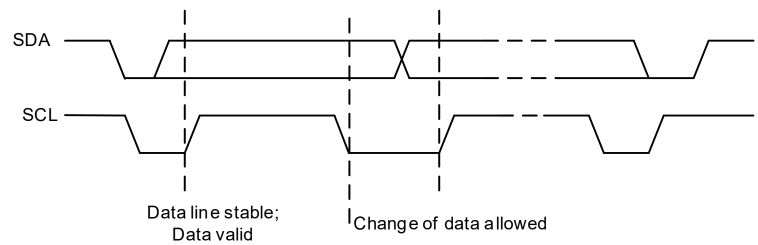
I²C Interface

I²C Operation

The BM25S2021-1 supports an I²C serial interface. The I²C 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.

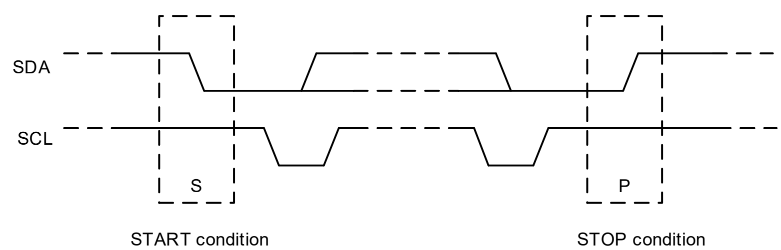
Data Validity

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.



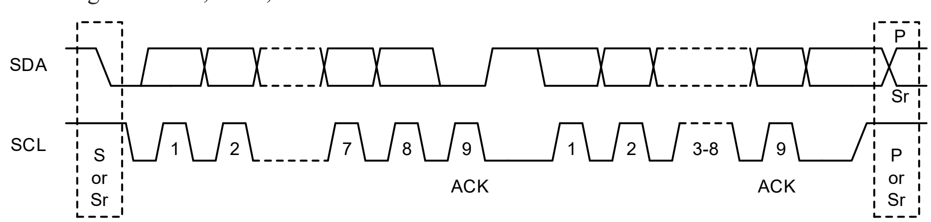
START and STOP Conditions

- 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

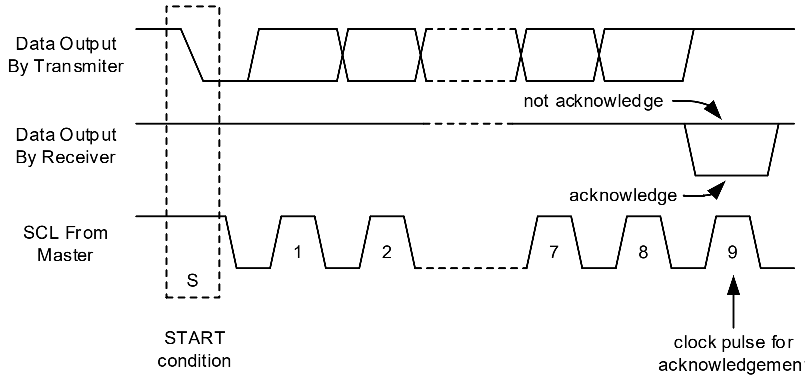
Every byte put on the SDA line must be 8-bits long. The number of bytes that can be transmitted per transfer is unrestricted. Each byte has to be followed by an acknowledge bit. Data is transferred with the most significant bit, MSB, first.



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.



Slave Addressing - 1011100

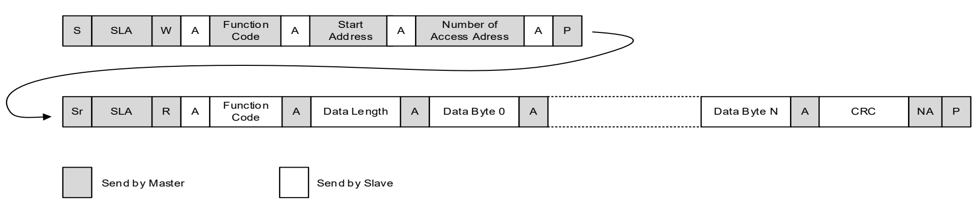
- The slave address byte is the first byte received following the START condition from the master device. The first seven bits of the first byte make up the slave address. The eighth bit defines whether a read or write operation is to be performed. When the R/W bit is "1", a read operation is selected. 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				→
MSB							LSB
1	0	1	1	1	0	0	R/W

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.



S : START bit (1 bit).
Sr : repeated START bit (1 bit).
SLA : slave address = 1011100b (7 bits, fixed).
R/W : Read/Write bit (1 bit); R/W = R → Read; R/W = W → Write.
A : acknowledge (1 bit).
NA : not acknowledge (1 bit).
P : STOP bit (1 bit).
Function Code : 00000011b = 03h (8 bits, fixed).
Start Address : from 00h ~ 0Eh (except 04h~07h), refer to address summary (8 bits).
Number of Access Address : number of addresses accessing from the start address (8 bits).
Data Length : number of byte returned (8 bits).
Data Byte : return data, N depends on data length.

Read Measurement Result Sequence

Data Address	Data	Category
00H	Relative Humidity Data High Byte (RHH)	Measurement Data
01H	Relative Humidity Data Low Byte (RHL)	
02H	Temperature Data High Byte (TMPH)	
03H	Temperature Data Low Byte (TMPL)	
04H	—	Reserved
05H	—	
06H	—	
07H	—	
08H	Device Number High Byte	Device Information
09H	Device Number Low Byte	
0AH	Version Number	
0BH	Serial Number Byte 3	
0CH	Serial Number Byte 2	
0DH	Serial Number Byte 1	
0EH	Serial Number Byte 0	
0FH	—	Reserved

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.

Numeral Calculations

Humidity calculation:

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

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

RHH = 01h = 1

RHL = F4h = 244

⇒Relative Humidity = (1 × 256 + 244) / 10 = 50%RH

Temperature calculation:

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

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

TMPH = 00h = 0

TMPL = FAh = 250

⇒Temperature = (0 × 256 + 250) / 10 = 25ºC

CRC Operation

The I²C 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.

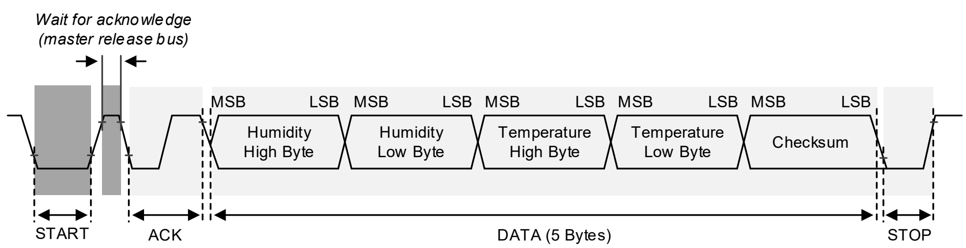
Step 7. When all of the data bytes are completely calculated, swap the CRC register high byte with the low byte.

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.



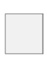
START = Communication start signal (1 bit)

ACK = Module acknowledge (1bit)

DATA = Data signal (40 bits)

STOP = Communication stop signal (1 bit)


Send by master


Send by module

One-wire Communication Protocol

Name		Length	Description
START		1 bit	The master device (host MCU) pulls down the DATA line to wake up the module.
ACK		1 bit	The module pulls down the DATA line for 80μs, then pulls the DATA line high for 80μs to respond to the master device
DATA	Relative Humidity	16 bits	The relative humidity value is 16 bits, MSB first. The sensor relative humidity output value is 10 times that of the actual humidity value.
	Temperature	16 bits	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
	Checksum	8 bits	Checksum = RHH(1) + RHL(2) + TMPH(3) + TMPL(4)

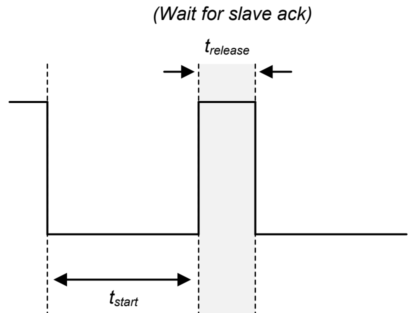
Name	Length	Description
STOP	1 bit	After the last significant bit of the checksum is transferred, the module (slave device) pulls down the DATA line for at least 45μs, then releases it.

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

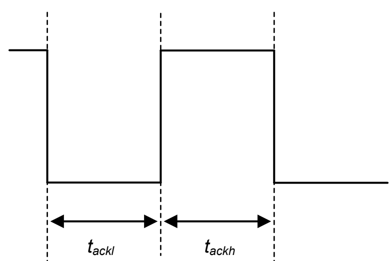
The START signal is generated by the master device (host MCU). The master device pulls down the DATA line for a time of t_{start} to wake up the slave device (module). It is suggested that t_{start} = 1ms.



Symbol	Parameter	Min.	Typ.	Max.	Unit
t_{start}	Master Start Signal Pull Down Time	0.8	1.0	20.0	ms
$t_{release}$	Master Release Bus Time	5	30	200	μs

ACK Waveform

An ACK signal is sent by the module to respond to the master device. An ACK signal waveform is composed of t_{ackl} and t_{ackh}. The recommended values are as follows.



Symbol	Parameter	Min.	Typ.	Max.	Unit
t_{ackl}	Sensor Acknowledge Low Level Time	75	80	85	μs
t_{ackh}	Sensor Acknowledge High Level Time	75	80	85	μs

Data Waveform

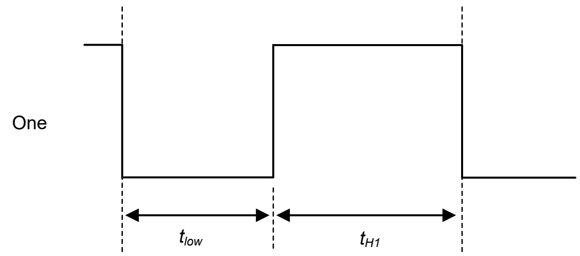
The DATA format has a fixed format of 5 bytes composed of Relative Humidity (2 bytes), Temperature (2 bytes) and Checksum (1 byte). The format details can be obtained by referring to the relevant chapter. In the one-wire communication mode, the waveform of the Data Bit conditions is as follow.

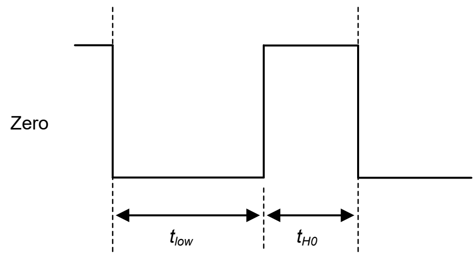
Data Bit = 1

$T_{D1} = T_{Low} + T_{H1}$ ($T_{Low1} = 50\mu s$, $T_{high1} = 70\mu s$)

Data Bit = 0

$T_{D0} = T_{Low} + T_{H0}$ ($T_{Low1} = 50\mu s$, $T_{high1} = 26\mu s$)

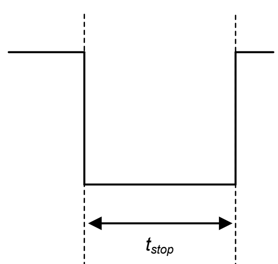




Symbol	Parameter	Min.	Typ.	Max.	Unit
t_{low}	Data “0” and Data “1” Low Level Time	48	50	55	µs
t_{H0}	Data “0” High Level Time	22	26	30	µs
t_{H1}	Data “1” High Level Time	68	70	75	µs

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	Parameter	Min.	Typ.	Max.	Unit
t_{stop}	Sensor Release Bus Time	45	50	55	µs

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:

Relative Humidity = (RHH × 256 + 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.

Temperature = (TMPH × 256 + TMPL) / 10

Checksum (1 Byte)

The one-wire communication checksum calculation is as follow:

Checksum = RHH + RHL +TMPH + TMPL

Checksum Calculation Example:

RHH = 00000001 (01H)

RHL = 10000010 (82H)

TMPH = 00001010 (0AH)

TMPL = 00001000 (08H)

Checksum = RHH + RHL + TMPH + TMPL = 10010101 (95H)

One-wire Communication DATA Calculation Example

Ex1. If the master device obtains 40-bits of data, as shown below:

00000010 10010010 00000001 00001101 10100010

Relative Humidity = 0000001010010010B = 0292H = 685 → 68.5%RH

Temperature = 0000000100001101B = 010DH = 269 → 26.9℃

Checksum = 00000010 + 10010010 + 00000001 + 00001101 = 10100010 (Correct)

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

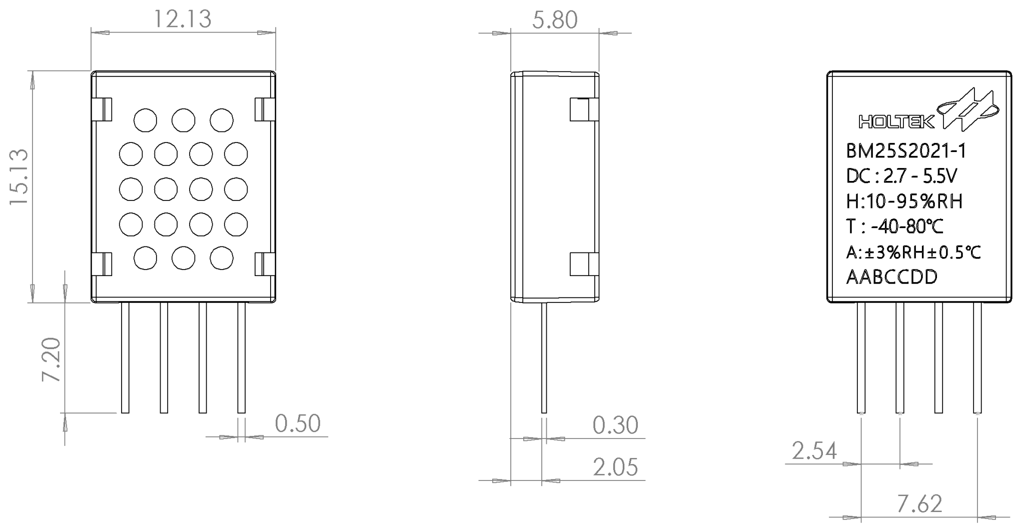
00000010 10010010 1000000 01100101 10100010

Relative Humidity = 00000010 10010010B = 0292H = 685 → 68.5%RH

Temperature = 10000000 01100101B = 010DH = 101 → -10.1℃

Checksum = 00000010 + 10010010 + 10000000 + 01100101 = 01111011 (Error)

Dimensions


12.13
15.13
7.20
0.50
5.80
0.30
2.05
HOLTEK
BM25S2021-1
DC : 2.7 - 5.5V
H:10-95%RH
T : -40-80℃
A:±3%RH±0.5℃
AABCCDD
2.54
7.62