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I²C HUMIDITY AND TWO-ZONE TEMPERATURE SENSOR

Features

- Precision Relative Humidity Sensor
 - ± 3% RH (max), 0–80% RH
- High Accuracy Temperature Sensor
 - ±0.4 °C (max), –10 to 85 °C
- 0 to 100% RH operating range
- Up to –40 to +125 °C operating range
- Low Voltage Operation (1.9 to 3.6 V)
- Low Power Consumption
 - 150 µA active current
 - 60 nA standby current
- Factory-calibrated
- I²C Interface
- Integrated on-chip heater
- Auxiliary Sensor input
 - Direct readout of remote thermistor temperature in °C
- Package: 3x3 mm DFN
- Excellent long term stability
- Optional factory-installed cover
 - Low-profile
 - Protection during reflow
 - Excludes liquids and particulates

Applications

- HVAC/R
- Thermostats/humidistats
- Instrumentation
- White goods
- Micro-environments/data centers
- Industrial Controls
- Indoor weather stations

Description

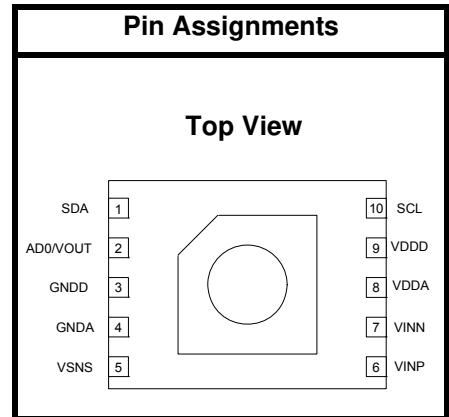
The Si7013 I²C Humidity and 2-Zone Temperature Sensor is a monolithic CMOS IC integrating humidity and temperature sensor elements, an analog-to-digital converter, signal processing, calibration data, and an I²C Interface. The patented use of industry-standard, low-K polymeric dielectrics for sensing humidity enables the construction of low-power, monolithic CMOS Sensor ICs with low drift and hysteresis, and excellent long term stability.

The humidity and temperature sensors are factory-calibrated and the calibration data is stored in the on-chip non-volatile memory. This ensures that the sensors are fully interchangeable, with no recalibration or software changes required.

An auxiliary sensor input with power management can be tied directly to an external thermistor network or other voltage-output sensor. On-board logic performs calibration/linearization of the external input using user-programmable coefficients. The least-significant bit of the Si7013's I²C address is programmable, allowing two devices to share the same bus.

The Si7013 is available in a 3x3 mm DFN package and is reflow solderable. The optional factory-installed cover offers a low profile, convenient means of protecting the sensor during assembly (e.g., reflow soldering) and throughout the life of the product, excluding liquids (hydrophobic/oleophobic) and particulates.

The Si7013 offers an accurate, low-power, factory-calibrated digital solution ideal for measuring humidity, dew-point, and temperature, in applications ranging from HVAC/R and asset tracking to industrial and consumer platforms.



Patent Protected. Patents pending

Si7013-A20

Functional Block Diagram

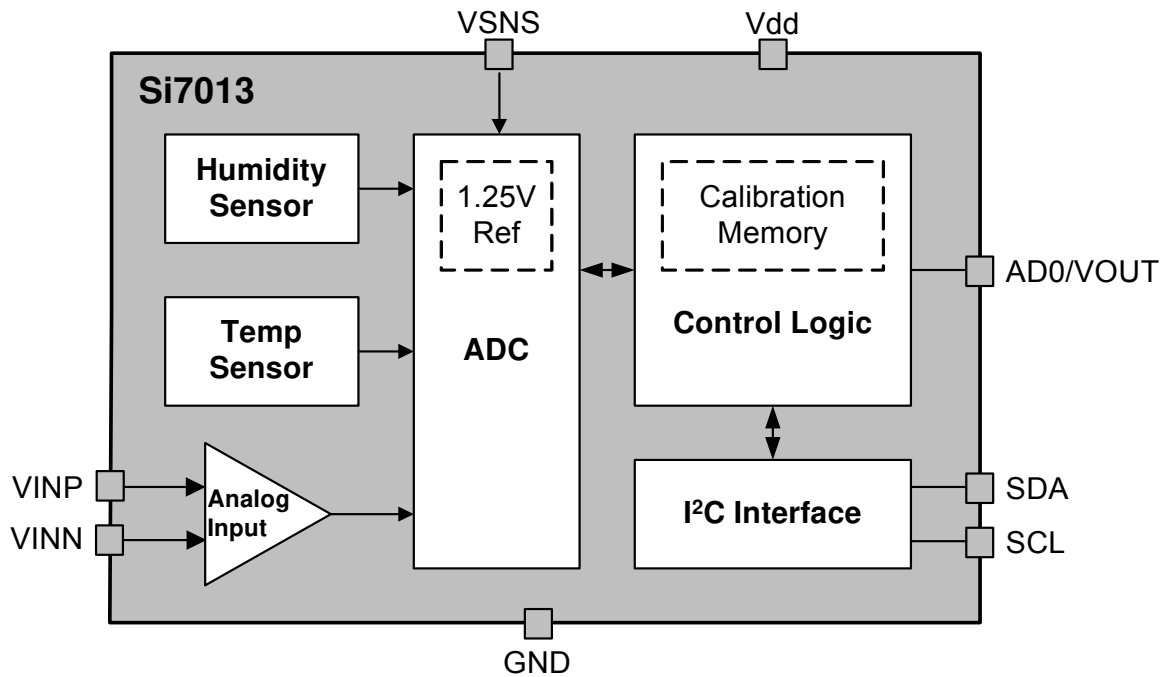


TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1. Electrical Specifications	4
2. Typical Application Circuits	12
3. Bill of Materials	14
4. Functional Description	15
4.1. Relative Humidity Sensor Accuracy	16
4.2. Hysteresis	17
4.3. Prolonged Exposure to High Humidity	17
4.4. PCB Assembly	17
4.5. Protecting the Sensor	19
4.6. Bake/Hydrate Procedure	20
4.7. Long Term Drift/Aging	20
5. I2C Interface	21
5.1. Issuing a Measurement Command	22
5.2. Reading and Writing User Registers	25
5.3. Measuring Analog Voltage	25
5.4. Nonlinear Correction of Voltage Inputs:	26
5.5. Firmware Revision	31
5.6. Heater	31
5.7. Electronic Serial Number	32
6. Control Registers	33
6.1. Register Descriptions	34
7. Pin Descriptions: Si7013 (Top View)	37
8. Ordering Guide	38
9. Package Outline	39
9.1. Package Outline: 3x3 10-pin DFN	39
9.2. Package Outline: 3x3 10-pin DFN with Protective Cover	40
10. PCB Land Pattern and Solder Mask Design	41
11. Top Marking	42
11.1. Si7013 Top Marking	42
11.2. Top Marking Explanation	42
12. Additional Reference Resources	43
Document Change List	44

Si7013-A20

1. Electrical Specifications

Unless otherwise specified, all min/max specifications apply over the recommended operating conditions.

Table 1. Recommended Operating Conditions

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Power Supply	V _{DD}		1.9	—	3.6	V
Operating Temperature	T _A	I and Y grade	-40	—	+125	°C
Operating Temperature	T _A	G grade	-40	—	+85	°C

Table 2. General Specifications

1.9 ≤ V_{DD} ≤ 3.6 V; T_A = -40 to 85 °C (G grade) or -40 to 125 °C (I/Y grade); default conversion time unless otherwise noted.

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Input Voltage High	V _{IH}	AD0, SCL, SDA, VSNS pins	0.7xV _{DD}	—	—	V
Input Voltage Low	V _{IL}	AD0, SCL, SDA, VSNS pins	—	—	0.3xV _{DD}	V
Input Voltage Range	V _{IN}	SCL, SDA, VSNS pins with respect to GND	0.0	—	V _{DD}	V
Input Leakage	I _{IL}	SCL, SDA pins; V _{IN} = GND	—	—	1	μA
		VSNS pin (200K nominal pull up); V _{in} = GND	5xV _{DD}			μA
Output Voltage Low	V _{OL}	SDA pin; I _{OL} = 2.5 mA; V _{DD} = 3.3 V	—	—	0.6	V
		SDA pin; I _{OL} = 1.2 mA; V _{DD} = 1.9 V	—	—	0.4	V
Output Voltage High	V _{OH}	V _{OUT} pin, I _{OH} = -0.5 mA, V _{DD} = 2.0 V	V _{DD} - 0.2	—	—	V
		V _{OUT} pin, I _{OH} = -10 μA	V _{DD} - 0.1	—	—	V
		V _{OUT} pin, I _{OH} = -1.7 mA, V _{DD} = 3.0 V	V _{DD} - 0.4	—	—	V
Current Consumption	I _{DD}	RH conversion in progress	—	150	180	μA
		Temperature conversion in progress	—	90	120	μA
		Standby, -40 to +85 °C ²	—	0.06	0.62	μA
		Standby, -40 to +125 °C ²	—	0.06	3.8	μA
		Peak I _{DD} during powerup ³	—	3.5	4.0	mA
		Peak I _{DD} during I ² C operations ⁴	—	3.5	4.0	mA
Heater Current ⁵	I _{HEAT}		—	3.1 to 94.2	—	mA

Notes:

1. Initiating a RH measurement will also automatically initiate a temperature measurement. The total conversion time will be t_{CONV(RH)} + t_{CONV(T)}.
2. No conversion or I²C transaction in progress. Typical values measured at 25 °C.
3. Occurs once during powerup. Duration is <5 msec.
4. Occurs during I²C commands for Reset, Read/Write User Registers, Read EID, Read Firmware Version, Read/Write Thermistor Coefficients and Measure Analog Voltage or Thermistor Temperature. Duration is <50 μs for all commands except Measure Analog Voltage or Thermistor Temperature, which has <150 μs duration when Thermistor Correction is enabled.
5. Additional current consumption when HTRE bit enabled. See Section “5.6. Heater” for more information.

Table 2. General Specifications (Continued)

$1.9 \leq V_{DD} \leq 3.6$ V; $T_A = -40$ to 85 °C (G grade) or -40 to 125 °C (I/Y grade); default conversion time unless otherwise noted.

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Conversion Time ¹	t_{CONV}	12-bit RH	—	10	12	ms
		11-bit RH	—	5.8	7	
		10-bit RH	—	3.7	4.5	
		8-bit RH	—	2.6	3.1	
		14-bit temperature	—	7	10.8	
		13-bit temperature	—	4	6.2	
		12-bit temperature	—	2.4	3.8	
		11-bit temperature	—	1.5	2.4	
		Voltage Normal	—	—	7	
		Voltage Fast	—	—	3.1	
Powerup Time	t_{PU}	From $V_{DD} \geq 1.9$ V to ready for a conversion, 25 °C	—	18	25	ms
		From $V_{DD} \geq 1.9$ V to ready for a conversion, full temperature range	—	—	80	ms
		After issuing a software reset command	—	5	15	ms

Notes:

1. Initiating a RH measurement will also automatically initiate a temperature measurement. The total conversion time will be $t_{CONV(RH)} + t_{CONV(T)}$.
2. No conversion or I²C transaction in progress. Typical values measured at 25 °C.
3. Occurs once during powerup. Duration is <5 msec.
4. Occurs during I²C commands for Reset, Read/Write User Registers, Read EID, Read Firmware Version, Read/Write Thermistor Coefficients and Measure Analog Voltage or Thermistor Temperature. Duration is <50 μ s for all commands except Measure Analog Voltage or Thermistor Temperature, which has <150 μ s duration when Thermistor Correction is enabled.
5. Additional current consumption when HTRE bit enabled. See Section "5.6. Heater" for more information.

Table 3. I²C Interface Specifications¹

$1.9 \leq V_{DD} \leq 3.6$ V; $T_A = -40$ to $+85$ °C (G grade) or -40 to $+125$ °C (I/Y grade) unless otherwise noted.

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Hysteresis	V_{HYS}	High-to-low versus low-to-high transition	$0.05 \times V_{DD}$	—	—	V
SCLK Frequency ²	f_{SCL}		—	—	400	kHz
SCL High Time	t_{SKH}		0.6	—	—	μ s

Notes:

1. All values are referenced to V_{IL} and/or V_{IH} .
2. Depending on the conversion command, the Si7013 may hold the master during the conversion (clock stretch). At above 300 kHz SCL, the Si7013 may hold the master briefly for user register and device ID transactions. At the highest I²C speed of 400 kHz the stretching will be <50 μ s.
3. Pulses up to and including 50 ns will be suppressed.

Si7013-A20

Table 3. I²C Interface Specifications¹ (Continued)

$1.9 \leq V_{DD} \leq 3.6$ V; $T_A = -40$ to $+85$ °C (G grade) or -40 to $+125$ °C (I/Y grade) unless otherwise noted.

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
SCL Low Time	t_{SKL}		1.3	—	—	μ s
Start Hold Time	t_{STH}		0.6	—	—	μ s
Start Setup Time	t_{STS}		0.6	—	—	μ s
Stop Setup Time	t_{SPS}		0.6	—	—	μ s
Bus Free Time	t_{BUF}	Between Stop and Start	1.3	—	—	μ s
SDA Setup Time	t_{DS}		100	—	—	ns
SDA Hold Time	t_{DH}		100	—	—	ns
SDA Valid Time	$t_{VD;DAT}$	From SCL low to data valid	—	—	0.9	μ s
SDA Acknowledge Valid Time	$t_{VD;ACK}$	From SCL low to data valid	—	—	0.9	μ s
Suppressed Pulse Width ³	t_{SP}		50	—	—	ns

Notes:

1. All values are referenced to V_{IL} and/or V_{IH} .
2. Depending on the conversion command, the Si7013 may hold the master during the conversion (clock stretch). At above 300 kHz SCL, the Si7013 may hold the master briefly for user register and device ID transactions. At the highest I²C speed of 400 kHz the stretching will be <50 μ s.
3. Pulses up to and including 50 ns will be suppressed.

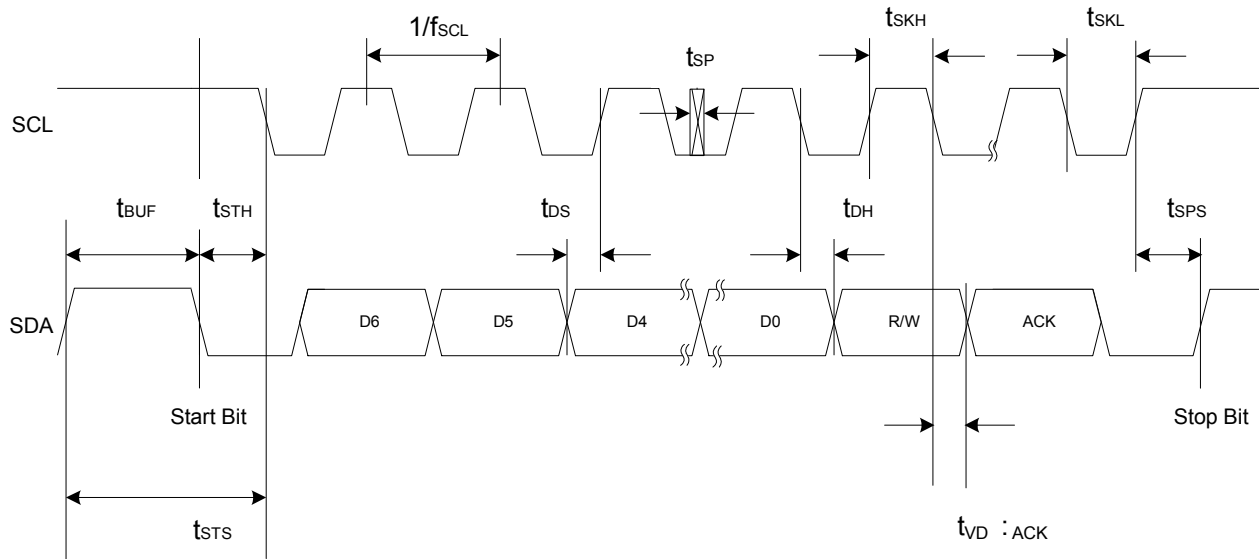


Figure 1. I²C Interface Timing Diagram

Table 4. Humidity Sensor

$1.9 \leq V_{DD} \leq 3.6$ V; $T_A = 30$ °C; default conversion time unless otherwise noted.

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Operating Range ¹		Non-condensing	0	—	100	%RH
Accuracy ^{2, 3}		0 – 80% RH	—	±2	±3	%RH
		80 – 100% RH	See Figure 2.			%RH
Repeatability-Noise		12-bit resolution	—	0.025	—	%RH RMS
		11-bit resolution	—	0.05	—	%RH RMS
		10-bit resolution	—	0.1	—	%RH RMS
		8-bit resolution	—	0.2	—	%RH RMS
Response Time ⁴	$T_{63\%}$	1 m/s airflow, with cover	—	18	—	S
		1 m/s airflow, without cover	—	17	—	
Drift vs. Temperature			—	0.05	—	%RH/°C
Hysteresis			—	±1	—	%RH
Long Term Stability ³			—	≤ 0.25	—	%RH/yr

Notes:

1. Recommended humidity operating range is 20% to 80% RH (non-condensing) over –10 °C to 60 °C. Prolonged operation beyond these ranges may result in a shift of sensor reading with slow recovery time.
2. Excludes hysteresis, long term drift, and certain other factors and is applicable to non-condensing environments only. See Section “4.1. Relative Humidity Sensor Accuracy” for more details.
3. Drift due to aging effects at typical room conditions of 30°C and 30% to 50% RH. May be impacted by dust, vaporized solvents or other contaminants, e.g., out-gassing tapes, adhesives, packaging materials, etc. See Section “4.7. Long Term Drift/Aging”
4. Response time to a step change in RH. Time for the RH output to change by 63% of the total RH change.

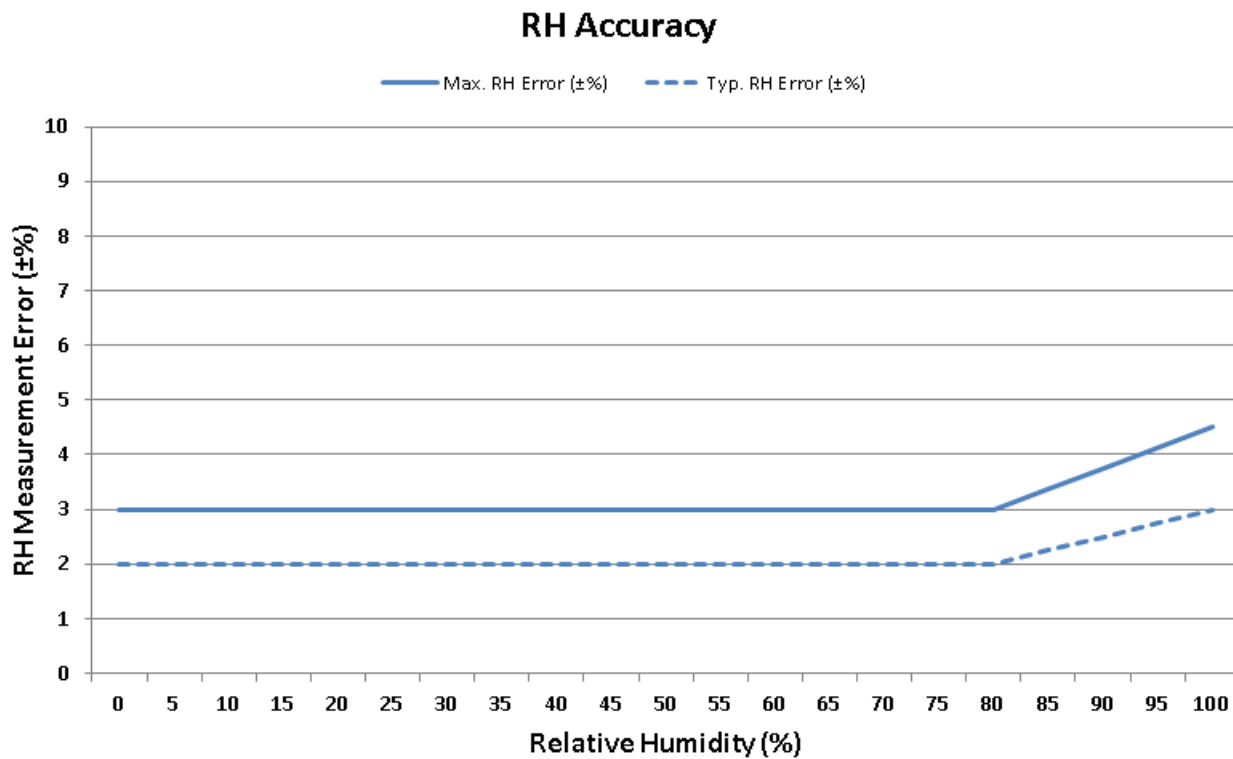


Figure 2. RH Accuracy at 30 °C

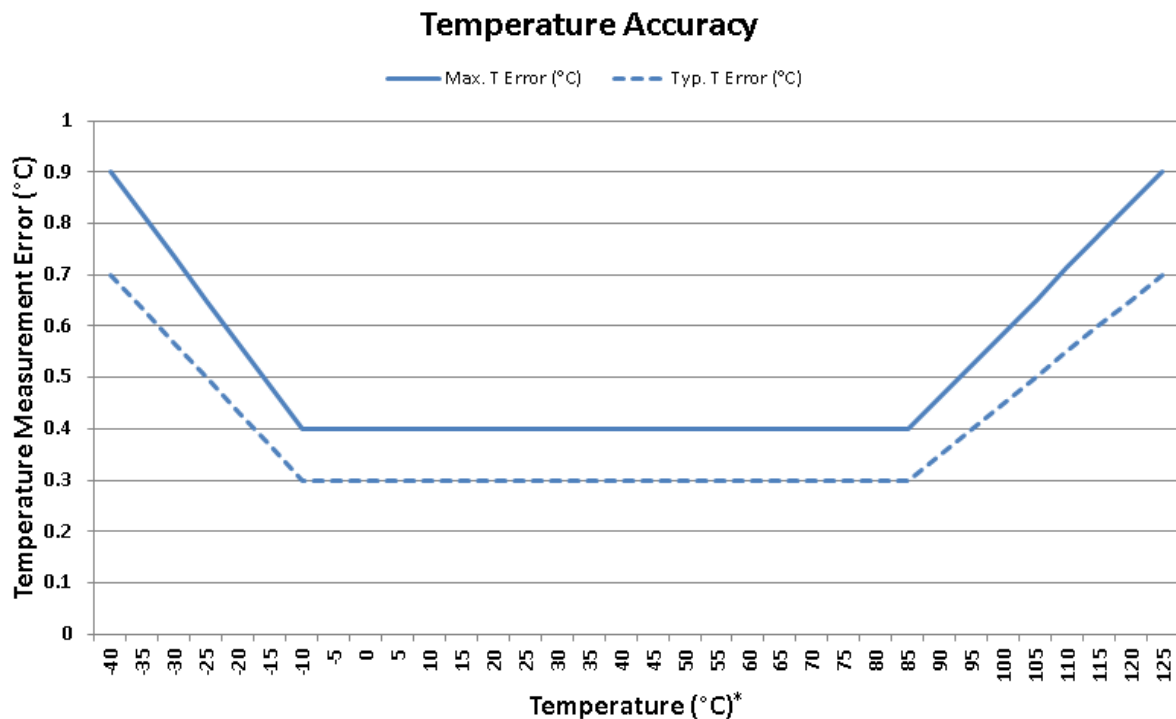
Table 5. Temperature Sensor

$1.9 \leq V_{DD} \leq 3.6$ V; $T_A = -40$ to $+85$ °C (G grade) or -40 to $+125$ °C (I/Y grade), default conversion time unless otherwise noted.

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Operating Range		I and Y Grade	-40	—	+125	°C
		G Grade	-40	—	+85	°C
Accuracy ¹		-10 °C $\leq t_A \leq 85$ °C	—	± 0.3	± 0.4	°C
		-40 °C $\leq t_A \leq 125$ °C	Figure 3.			°C
Repeatability-Noise		14-bit resolution	—	0.01	—	°C RMS
		13-bit resolution	—	0.02	—	°C RMS
		12-bit resolution	—	0.04	—	°C RMS
		11-bit resolution	—	0.08	—	°C RMS
Response Time ²	$T_{63\%}$	Unmounted device	—	0.7	—	s
		Si7013-EB board	—	5.1	—	s
Long Term Stability			—	≤ 0.01	—	°C/Yr

Notes:

- 14b measurement resolution (default).
- Time to reach 63% of final value in response to a step change in temperature. Actual response time will vary dependent on system thermal mass and airflow.

**Figure 3. Temperature Accuracy***

*Note: Applies only to I and Y devices beyond $+85$ °C.

Table 6. Voltage Converter Specifications

$1.9 \leq V_{DD} \leq 3.6$ V; $T_A = -40$ to $+85$ °C (G grade) or -40 to $+125$ °C (I/Y grade); normal mode conversion time, $V_{REF} = 1.25$ V internal or V_{DDA} , buffered and unbuffered mode, unless otherwise noted.

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Resolution			—	$V_{REF}/32768$	—	V
Integral Non-linearity	INL	$ VINP-VINN < V_{REF}/2$	—	1	—	LSB
Differential Non-linearity	DNL	$ VINP-VINN < V_{REF}/2$	—	1	—	LSB
Noise	N	$ VINP-VINN < V_{REF}/2$, $V_{REF} = 1.25$ V, Normal Mode	—	25	—	μV_{RMS}
		$ VINP-VINN < V_{REF}/2$, $V_{REF} = 1.25$ V, Fast Mode	—	50	—	
Input Offset (Buffered Mode)	V_{OS}	$ VINP-VINN = 0$	—	—	10	mV
Input Offset (Unbuffered Mode) ^{1,2}	V_{OS}	$ VINP-VINN = 0$	—	—	1	mV
Gain Accuracy	ΔG	$V_{REF} = 1.25$ V; gain is absolute	—	± 1	± 2	%
		$V_{REF} = V_{DD}$; gain is relative to V_{DD}	—	± 0.25	± 0.5	%

Notes:

- Guaranteed by design.
- In unbuffered mode, $R_{IN} \cdot C_{IN}$ should be < 0.5 usec. C_{IN} minimum is around 10 pF.

Table 7. Thermal Characteristics

Parameter	Symbol	Test Condition	DFN-6	Unit
Junction to Air Thermal Resistance	θ_{JA}	JEDEC 2-Layer board, No Airflow	236	°C/W
Junction to Air Thermal Resistance	θ_{JA}	JEDEC 2-Layer board, 1 m/s Airflow	203	°C/W
Junction to Air Thermal Resistance	θ_{JA}	JEDEC 2-Layer board, 2.5 m/s Airflow	191	°C/W
Junction to Case Thermal Resistance	θ_{JC}	JEDEC 2-Layer board	20	°C/W
Junction to Board Thermal Resistance	θ_{JB}	JEDEC 2-Layer board	112	°C/W

Table 8. Absolute Maximum Ratings^{1,2}

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Ambient temperature under bias			-55	—	125	°C
Storage Temperature			-65	—	150	°C
Voltage on I/O pins			-0.3	—	VDD+0.3 V	V
Voltage on VDD with respect to GND			-0.3	—	4.2	V
ESD Tolerance		HBM	—	—	2	kV
		CDM	—	—	1.25	kV
		MM	—	—	250	V

Notes:

1. Absolute maximum ratings are stress ratings only, operation at or beyond these conditions is not implied and may shorten the life of the device or alter its performance.
2. Special handling considerations apply; see application note, "AN607: Si70xx Humidity Sensor Designer's Guide" for details.

2. Typical Application Circuits

The primary function of the Si7013 is to measure relative humidity and temperature. Figure 4 demonstrates the typical application circuit to achieve these functions; pins 6 and 7 are not required and should be left unconnected.

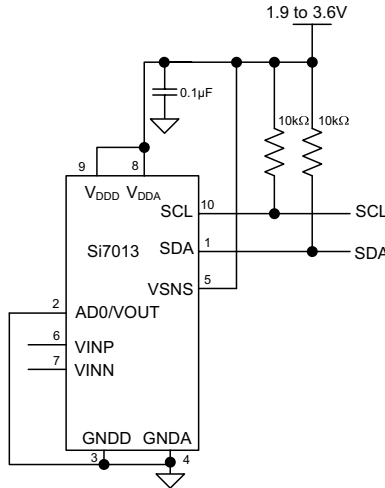


Figure 4. Typical Application Circuit for Relative Humidity and Temperature Measurement

The application circuit shown in Figure 5 uses the auxiliary analog pins for measuring a remote temperature using a thermistor.

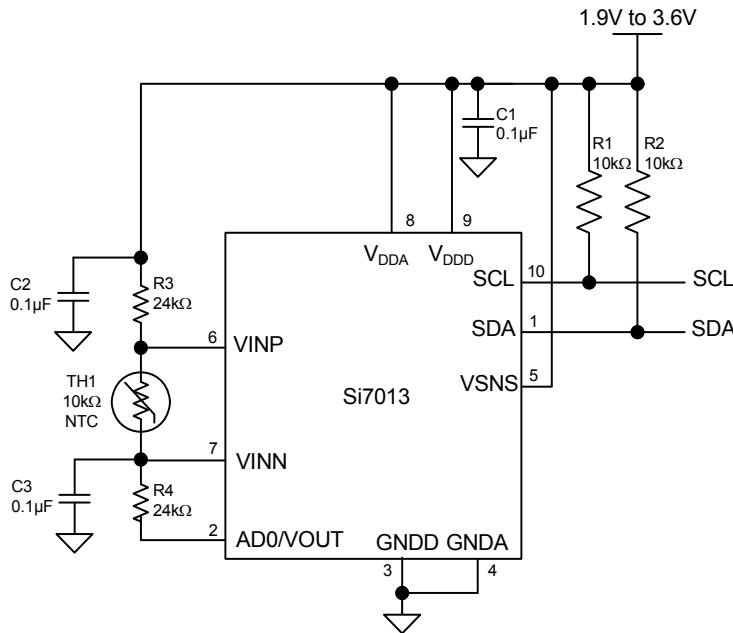


Figure 5. Typical Application Circuit for Thermistor Interface with AD0 = 1

The voltage connected at VDDA serves as the reference voltage for both the Analog-to-Digital converter and the resistor string. Therefore, the ADC must be configured to take its reference from VDDA. The top of the resistor string is connected to the VOUT pin, allowing the resistor string to be powered down, saving power between temperature conversions. In this mode of operation, the analog inputs are buffered and present an input impedance of > 100 kΩ.

The AD0/VOUT pin is a dual function pin. At powerup, it functions as an address select pin and selects the least significant I²C Figure 5, the AD0/VOUT pin is pulled high, selecting AD0 = 1. In Figure 6, the AD0/VOUT pin is pulled low selecting AD0 = 0.

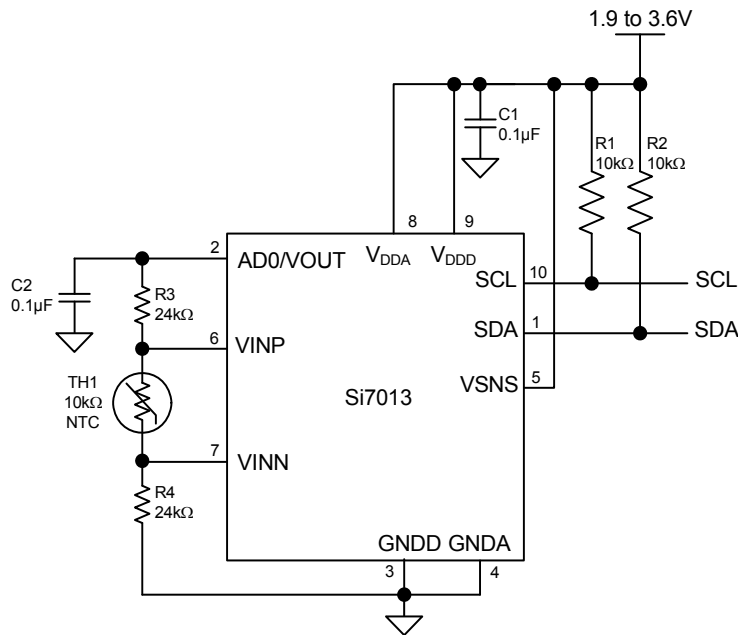


Figure 6. Typical Application Circuit for Thermistor Interface with AD0 = 0

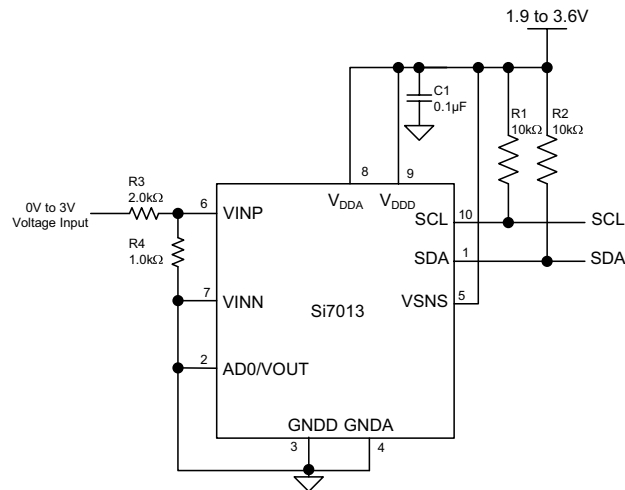


Figure 7. Typical Application Circuit for Single Ended 0 to 3 V Measurement

Figure 7 demonstrates a single ended 0 to 3 V input range configuration. The voltage reference is the internal 1.25 V reference. The 1 kΩ and 2 kΩ resistor divider keeps the voltage range to 1.0 V, which is within the recommended 80% of V_{REF} . Full scale of 32767 counts is 3.75 V.

Si7013-A20

3. Bill of Materials

Table 9. Typical Application Circuit BOM for Relative Humidity and Temperature Measurement

Reference	Description	Mfr Part Number	Manufacturer
R1	Resistor, 10 k Ω , \pm 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
R2	Resistor, 10 k Ω , \pm 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
C1	Capacitor, 0.1 μ F, 16 V, X7R, 0603	C0603X7R160-104M	Venkel
U1	IC, Digital Temperature/humidity Sensor	Si7013-A20	Silicon Labs

Table 10. Typical Application Circuit BOM for Thermistor Interface

Reference	Description	Mfr Part Number	Manufacturer
R1	Resistor, 10 k Ω , \pm 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
R2	Resistor, 10 k Ω , \pm 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
R3	Resistor, 24 k Ω , \pm 1%, 1/16W, 0603	CR0603-16W-2402F	Venkel
R4	Resistor, 24 k Ω , \pm 1%, 1/16W, 0603	CR0603-16W-2402F	Venkel
C1	Capacitor, 0.1 μ F, 16 V, X7R, 0603	C0603X7R160-104M	Venkel
C2	Capacitor, 0.1 μ F, 16 V, X7R, 0603	C0603X7R160-104M	Venkel
TH1	Thermistor, 10 k Ω	NTCLE100E3103	Vishay
U1	IC, digital temperature/humidity sensor	Si7013-A20	Silicon Labs

Table 11. Typical Application Circuit BOM for Single Ended 0 to 3 V Measurement

Reference	Description	Mfr Part Number	Manufacturer
R1	Resistor, 10 k Ω , \pm 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
R2	Resistor, 10 k Ω , \pm 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
R3	Resistor, 2 k Ω , \pm 1%, 1/16W, 0603	CR0603-16W-2001F	Venkel
R4	Resistor, 1 k Ω , \pm 1%, 1/16W, 0603	CR0603-16W-1001F	Venkel
C1	Capacitor, 0.1 μ F, 16 V, X7R, 0603	C0603X7R160-104M	Venkel
U1	IC, Digital Temperature/humidity Sensor	Si7013-A20	Silicon Labs

4. Functional Description

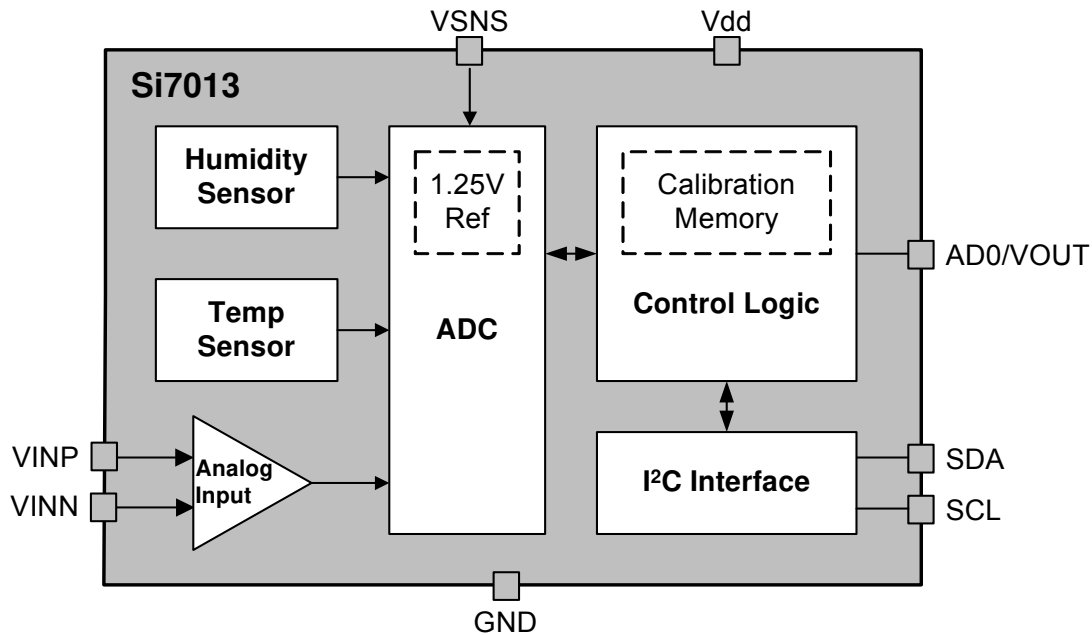


Figure 8. Si7013 Block Diagram

The Si7013 is a digital relative humidity and temperature sensor that integrates temperature and humidity sensor elements, an analog-to-digital converter, signal processing, calibration, polynomial non-linearity correction, and an I²C interface all in a single chip. The Si7013 is individually factory-calibrated for both temperature and humidity, with the calibration data stored in on-chip non-volatile memory. This ensures that the sensor is fully interchangeable, with no recalibration or changes to software required. Patented use of industry-standard CMOS and low-K dielectrics as a sensor enables the Si7013 to achieve excellent long term stability and immunity to contaminants with low drift and hysteresis. The Si7013 offers a low power, high accuracy, calibrated and stable solution ideal for a wide range of temperature, humidity, and dew-point applications including medical and instrumentation, high reliability automotive and industrial systems, and cost-sensitive consumer electronics.

The auxiliary sensor input option exists to use the ADC with external inputs and reference. Suitable buffers are included to allow the part to be connected to high impedance circuitry such as bridges or other types of sensors, without introducing errors.

While the Si7013 is largely a conventional mixed-signal CMOS integrated circuit, relative humidity sensors in general and those based on capacitive sensing using polymeric dielectrics have unique application and use requirements that are not common to conventional (non-sensor) ICs. Chief among those are:

- The need to protect the sensor during board assembly, i.e., solder reflow, and the need to subsequently rehydrate the sensor.
- The need to protect the sensor from damage or contamination during the product life-cycle.
- The impact of prolonged exposure to extremes of temperature and/or humidity and their potential effect on sensor accuracy.
- The effects of humidity sensor “memory”.

Each of these items is discussed in more detail in the following sections.

4.1. Relative Humidity Sensor Accuracy

To determine the accuracy of a relative humidity sensor, it is placed in a temperature and humidity controlled chamber. The temperature is set to a convenient fixed value (typically 25–30 °C) and the relative humidity is swept from 20 to 80% and back to 20% in the following steps: 20% – 40% – 60% – 80% – 80% – 60% – 40% – 20%. At each set-point, the chamber is allowed to settle for a period of 60 minutes before a reading is taken from the sensor. Prior to the sweep, the device is allowed to stabilize to 50%RH. The solid trace in Figure 9 shows the result of a typical sweep.

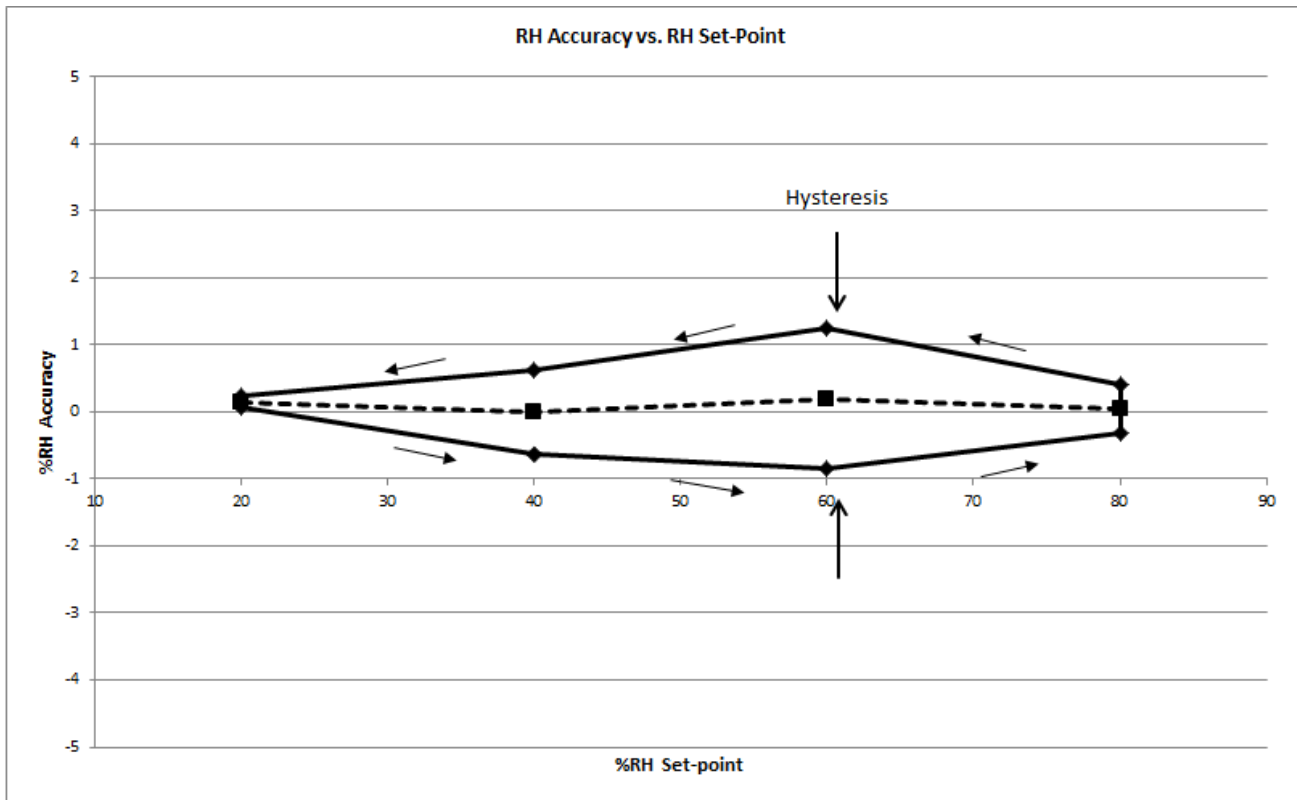


Figure 9. Measuring Sensor Accuracy Including Hysteresis

The RH accuracy is defined as the dotted line shown in Figure 9, which is the average of the two data points at each relative humidity set-point. In this case, the sensor shows an accuracy of 0.25%RH. The Si7013 accuracy specification (Table 4) includes:

- Unit-to-unit and lot-to-lot variation
- Accuracy of factory calibration
- Margin for shifts that can occur during solder reflow

The accuracy specification does not include:

- Hysteresis (typically $\pm 1\%$)
- Effects from long term exposure to very humid conditions
- Contamination of the sensor by particulates, chemicals, etc.
- Other aging related shifts ("Long-term stability")
- Variations due to temperature

4.2. Hysteresis

The moisture absorbent film (polymeric dielectric) of the humidity sensor will carry a memory of its exposure history, particularly its recent or extreme exposure history. A sensor exposed to relatively low humidity will carry a negative offset relative to the factory calibration, and a sensor exposed to relatively high humidity will carry a positive offset relative to the factory calibration. This factor causes a hysteresis effect illustrated by the solid trace in Figure 9. The hysteresis value is the difference in %RH between the maximum absolute error on the decreasing humidity ramp and the maximum absolute error on the increasing humidity ramp at a single relative humidity setpoint and is expressed as a bipolar quantity relative to the average error (dashed trace). In the example of Figure 9, the measurement uncertainty due to the hysteresis effect is +/-1.0%RH.

4.3. Prolonged Exposure to High Humidity

Prolonged exposure to high humidity will result in a gradual upward drift of the RH reading. The shift in sensor reading resulting from this drift will generally disappear slowly under normal ambient conditions. The amount of shift is proportional to the magnitude of relative humidity and the length of exposure. In the case of lengthy exposure to high humidity, some of the resulting shift may persist indefinitely under typical conditions. It is generally possible to substantially reverse this affect by baking the device (see Section “4.6. Bake/Hydrate Procedure”).

4.4. PCB Assembly

4.4.1. Soldering

Like most ICs, Si7013 devices are shipped from the factory vacuum-packed with an enclosed desiccant to avoid any drift during storage and to prevent any moisture-related issues during solder reflow. The following guidelines should be observed during PCB assembly:

- Si7013 devices are compatible with standard board assembly processes. Devices should be soldered using reflow per the recommended card reflow profile. See Section “10. PCB Land Pattern and Solder Mask Design” for the recommended card reflow profile.
- A “no clean” solder process is recommended to minimize the need for water or solvent rinses after soldering. Cleaning after soldering is possible, but must be done carefully to avoid impacting the performance of the sensor. See application note “AN607: Si70xx Humidity Sensor Designer’s Guide” for more information on cleaning.
- It is essential that the exposed polymer sensing film be kept clean and undamaged. This can be accomplished by careful handling and a clean, well-controlled assembly process. When in doubt or for extra protection, a heat-resistant, protective cover such as Kapton[®] KPPD-1/8 can be installed during PCB assembly.

Si7013s may be ordered with a factory-fitted, solder-resistant protective cover. This cover provides protection during PCB assembly or rework but without the time and effort required to install and remove the Kapton tape. It can be left in place for the lifetime of the product, preventing liquids, dust or other contaminants from coming into contact with the polymer sensor film. See Section “8. Ordering Guide” for a list of ordering part numbers that include the cover.

4.4.2. Rehydration

The measured humidity value will generally shift slightly after solder reflow. A portion of this shift is permanent and is accounted for in the accuracy specifications in Table 4. After soldering, an Si7013 should be allowed to equilibrate under controlled RH conditions (room temperature, 45–55%RH) for at least 48 hours to eliminate the remainder of the shift and return the device to its specified accuracy performance.

4.4.3. Rework

To maintain the specified sensor performance, care must be taken during rework to minimize the exposure of the device to excessive heat and to avoid damage/contamination or a shift in the sensor reading due to liquids, solder flux, etc. Manual touch-up using a soldering iron is permissible under the following guidelines:

- The exposed polymer sensing film must be kept clean and undamaged. A protective cover is recommended during any rework operation (Kapton® tape or the factory installed cover).
- Flux must not be allowed to contaminate the sensor; liquid flux is not recommended even with a cover in place. Conventional lead-free solder with rosin core is acceptable for touch-up as long as a cover is in place during the rework.
- If possible, avoid water or solvent rinses after touch-up. Cleaning after soldering is possible, but must be done carefully to avoid impacting the performance of the sensor. See “AN607: Si70xx Humidity Sensor Designer’s Guide” for more information on cleaning.
- Minimize the heating of the device. Soldering iron temperatures should not exceed 350 °C and the contact time per pin should not exceed five seconds.
- Hot air rework is not recommended. If a device must be replaced, remove the device by hot air and solder a new part in its place by reflow following the guidelines above.

***Note:** All trademarks are the property of their respective owners.

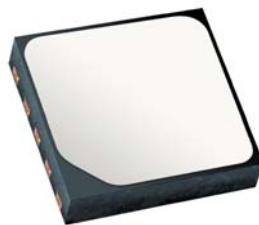


Figure 10. Si70xx with Factory-Installed Protective Cover

4.5. Protecting the Sensor

Because the sensor operates on the principal of measuring a change in capacitance, any changes to the dielectric constant of the polymer film will be detected as a change in relative humidity. Therefore, it is important to minimize the probability of contaminants coming into contact with the sensor. Dust and other particles as well as liquids can affect the RH reading. It is recommended that a cover is employed in the end system that blocks contaminants but allows water vapor to pass through. Depending on the needs of the application, this can be as simple as plastic or metallic gauze for basic protection against particulates or something more sophisticated such as a hydrophobic membrane providing up to IP67 compliant protection.

The Si7013 may be ordered with a factory-fitted, solder-resistant cover that can be left in place for the lifetime of the product. It is very low-profile, hydrophobic and oleophobic. See Section “8. Ordering Guide” for a list of ordering part numbers that include the cover. A dimensioned drawing of the IC with the cover is included in Section “9. Package Outline” . Other characteristics of the cover are listed in Table 12.

Table 12. Specifications of Protective Cover

Parameter	Value
Material	PTFE
Operating Temperature	−40 to 125 °C
Maximum Reflow Temperature	260 °C
IP Rating (per IEC 529)	IP67

4.6. Bake/Hydrate Procedure

After exposure to extremes of temperature and/or humidity for prolonged periods, the polymer sensor film can become either very dry or very wet; in each case the result is either high or low relative humidity readings. Under normal operating conditions, the induced error will diminish over time. From a very dry condition, such as after shipment and soldering, the error will diminish over a few days at typical controlled ambient conditions, e.g., 48 hours of $45 \leq \%RH \leq 55$. However, from a very wet condition, recovery may take significantly longer. To accelerate recovery from a wet condition, a bake and hydrate cycle can be implemented. This operation consists of the following steps:

- Baking the sensor at 125 °C for ≥ 12 hours
- Hydration at 30 °C in 75% RH for ≥ 10 hours

Following this cycle, the sensor will return to normal operation in typical ambient conditions after a few days.

4.7. Long Term Drift/Aging

Over long periods of time, the sensor readings may drift due to aging of the device. Standard accelerated life testing of the Si7013 has resulted in the specifications for long-term drift shown in Table 4 and Table 5. This contribution to the overall sensor accuracy accounts only for the long-term aging of the device in an otherwise benign operating environment and does not include the effects of damage, contamination, or exposure to extreme environmental conditions.

5. I²C Interface

The Si7013 communicates with the host controller over a digital I²C interface. The 7-bit base slave address is 0x40 or 0x41; the least significant bit is pin programmable.

Table 13. I²C Slave Address Byte

A6	A5	A4	A3	A2	A1	A0	R/W
1	0	0	0	0	0	AD0	1/0

Master I²C devices communicate with the Si7013 using a command structure. The commands are listed in the I²C command table. Commands other than those documented below are undefined and should not be sent to the device.

Table 14. I²C Command Table

Command Description	Command Code
Measure Relative Humidity, Hold Master Mode	0xE5
Measure Relative Humidity, No Hold Master Mode	0xF5
Measure Temperature, Hold Master Mode	0xE3
Measure Temperature, No Hold Master Mode	0xF3
Measure Analog Voltage or Thermistor Temperature	0xEE
Read Temperature Value from Previous RH Measurement	0xE0
Reset	0xFE
Write Voltage Measurement Setup (User register 2)	0x50
Read Voltage Measurement Setup (User register 2)	0x10
Write RH/T Measurement Setup (User register 1)	0xE6
Read RH/T Measurement Setup (User register 1)	0xE7
Write Heater Setup (User register 3)	0x51
Read Heater Setup (User register 3)	0x11
Write Thermistor Correction Coefficient	0xC5
Read Thermistor Correction Coefficient	0x84
Read Electronic ID 1st Word	0xFA 0x0F
Read Electronic ID 2nd Word	0xFC 0xC9
Read Firmware Revision	0x84 0xB8

5.1. Issuing a Measurement Command

The measurement commands instruct the Si7013 to perform one of four possible measurements; Relative Humidity, Temperature, Auxiliary Temperature, or Analog Voltage. While the measurement is in progress, the option of either clock stretching (Hold Master Mode) or Not Acknowledging read requests (No Hold Master Mode) is available to indicate to the master that the measurement is in progress. For Humidity and Temperature measurements, the chosen command code determines which mode is used. For Auxiliary Temperature and Analog Voltage measurements, No Hold Master mode can be enabled by writing a "1" to bit D6 in register 2. Note that internal Humidity and Temperature measurements should not be made with this bit set.

Optionally, a checksum byte can be returned from the slave for use in checking for transmission errors for Relative Humidity and Temperature measurements. The checksum byte is optional after initiating an RH or temperature measurement with commands 0xE5, 0xF5, 0xE3 and 0xF3. The checksum byte is required for reading the electronic ID with commands 0xFA 0x0F and 0xFC 0xC9. For all other commands, the checksum byte is not supported. The checksum byte will follow the least significant measurement byte if it is acknowledged by the master. The checksum byte is not returned if the master "not acknowledges" the least significant measurement byte. The checksum byte is calculated using a CRC generator polynomial of $x^8 + x^5 + x^4 + 1$ with an initialization of 0x00.

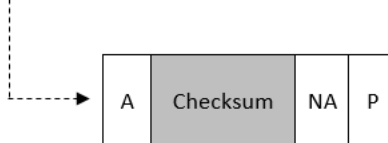
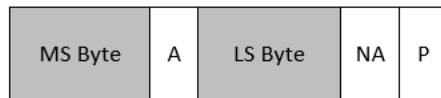
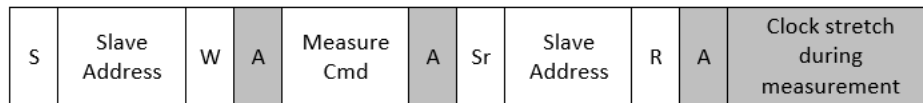
Table 15. I²C Bit Descriptions

Name	Symbol	Description
START	S	SDA goes low while SCL high.
STOP	P	SDA goes high while SCL high.
Repeated START	Sr	SDA goes low while SCL high. It is allowable to generate a STOP before the repeated start. SDA can transition to high before or after SCL goes high in preparation for generating the START.
READ	R	Read bit = 1
WRITE	W	Write bit = 0
All other bits	—	SDA value must remain high or low during the entire time SCL is high (this is the set up and hold time in Figure 1).

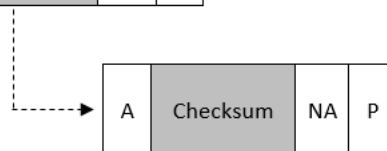
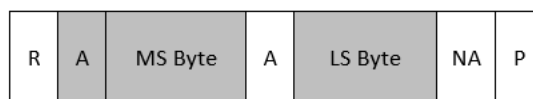
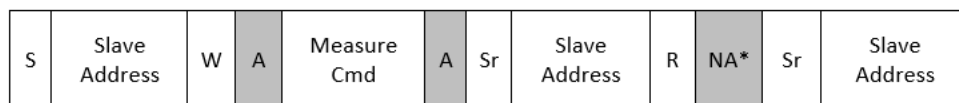
In the I²C sequence diagrams in the following sections, bits produced by the master and slave are color coded as shown:



Sequence to perform a measurement and read back result (Hold Master Mode)



Sequence to perform a measurement and read back result (No Hold Master Mode)



***Note:** Device will NACK the slave address byte until conversion is complete.

Si7013-A20

5.1.1. Measuring Relative Humidity

Once a relative humidity measurement has been made, the results of the measurement may be converted to percent relative humidity by using the following expression:

$$\%RH = \frac{125 * RH_Code}{65536} - 6$$

Where:

%RH is the measured relative humidity value in %RH

RH Code is the 16-bit word returned by the Si7013

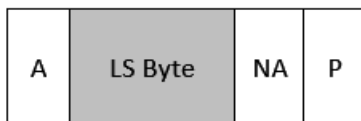
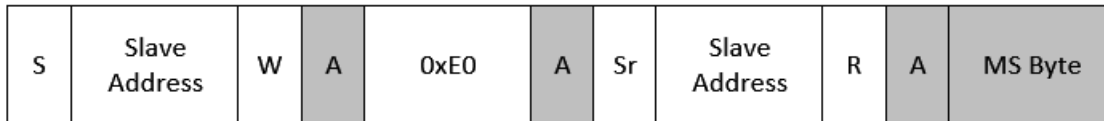
A humidity measurement will always return XXXXXX10 in the LSB field.

Note: Due to normal variations in RH accuracy of the device as described in Table 4, it is possible for the measured value of %RH to be slightly less than 0 when the actual RH level is close to or equal to 0. Similarly, the measured value of %RH may be slightly greater than 100 when the actual RH level is close to or equal to 100. This is expected behavior, and it is acceptable to limit the range of RH results to 0 to 100%RH in the host software by truncating values that are slightly outside of this range.

5.1.2. Measuring Temperature

Each time a relative humidity measurement is made a temperature measurement is also made for the purposes of temperature compensation of the relative humidity measurement. If the temperature value is required, it can be read using command 0xE0; this avoids having to perform a second temperature measurement. The measure temperature commands 0xE3 and 0xF3 will perform a temperature measurement and return the measurement value, command 0xE0 does not perform a measurement but returns the temperature value measured during the relative humidity measurement. The checksum output is not available with the 0xE0 command.

Sequence to read temperature value from previous RH measurement



The results of the temperature measurement may be converted to temperature in degrees Celsius (°C) using the following expression:

$$\text{Temperature (°C)} = \frac{175.72 * \text{Temp_Code}}{65536} - 46.85$$

Where:

Temperature (°C) is the measured temperature value in °C

Temp_Code is the 16-bit word returned by the Si7013

A temperature measurement will always return XXXXXX00 in the LSB field.

5.2. Reading and Writing User Registers

There are three user registers on the Si7013 that allow the user to set the configuration of the Si7013, the procedure for accessing these registers is set out below. The checksum byte is not supported after reading a user register.

Sequence to read a register

S	Slave Address	W	A	Read Reg Cmd	A	Sr	Slave Address	R	A	Read Data	NA	P
---	---------------	---	---	--------------	---	----	---------------	---	---	-----------	----	---

Sequence to write a register

S	Slave Address	W	A	Write Reg Cmd	A	Write Data	A	P
---	---------------	---	---	---------------	---	------------	---	---

5.3. Measuring Analog Voltage

The analog voltage input pins can accept voltage inputs within the ranges shown in Table 16. V_{REFP} is internally connected to V_{DDA} or to an internal 1.25 V reference voltage.

Table 16. Analog Input Ranges

	V_{INP} Input Range		V_{INN} Input Range	
	Min	Max	Min	Max
Buffered Input	0.35 V	$V_{DD}-0.35$ V	0.35 V	$V_{DD}-0.35$ V
Unbuffered Input	0 V	V_{DD}	0 V	V_{DD}

The voltage conversion output is a signed 16-bit integer that will vary from -32768 to 32767 as the input ($V_{INP}-V_{INN}$) goes from $-V$ to $+V$. For best performance, it is recommended that $|V_{INP}-V_{INN}|$ be limited to $V_{ref}/2$. With minor degradation in performance, this can be extended to $0.8 \cdot V_{ref}$. The checksum option for voltage mode conversions is not supported.