

## I<sup>2</sup>C HUMIDITY AND TWO-ZONE TEMPERATURE SENSOR

### Features

- Precision Relative Humidity Sensor
  - $\pm 3\%$  RH (max), 0–80% RH
- High Accuracy Temperature Sensor
  - $\pm 0.4\text{ }^{\circ}\text{C}$  (max),  $-10$  to  $85\text{ }^{\circ}\text{C}$
- 0 to 100% RH operating range
- Up to  $-40$  to  $+125\text{ }^{\circ}\text{C}$  operating range
- Low Voltage Operation (1.9 to 3.6 V)
- Low Power Consumption
  - 150  $\mu\text{A}$  active current
  - 60 nA standby current
- Factory-calibrated
- I<sup>2</sup>C Interface
- Integrated on-chip heater
- Auxiliary Sensor input
  - Direct readout of remote thermistor temperature in  $^{\circ}\text{C}$
- 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

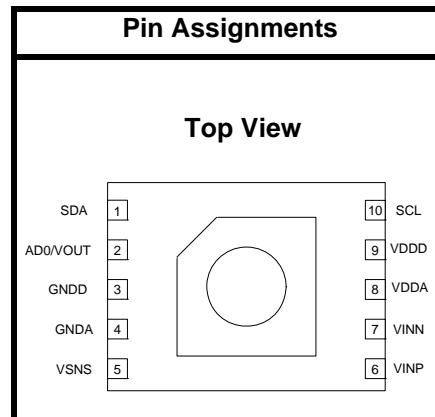
The Si7013 I<sup>2</sup>C Humidity and 2-Zone Temperature Sensor is a monolithic CMOS IC integrating humidity and temperature sensor elements, an analog-to-digital converter, signal processing, calibration data, and an I<sup>2</sup>C Interface. The patented use of industry-standard, low-K polymeric dielectrics 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 I<sup>2</sup>C 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.

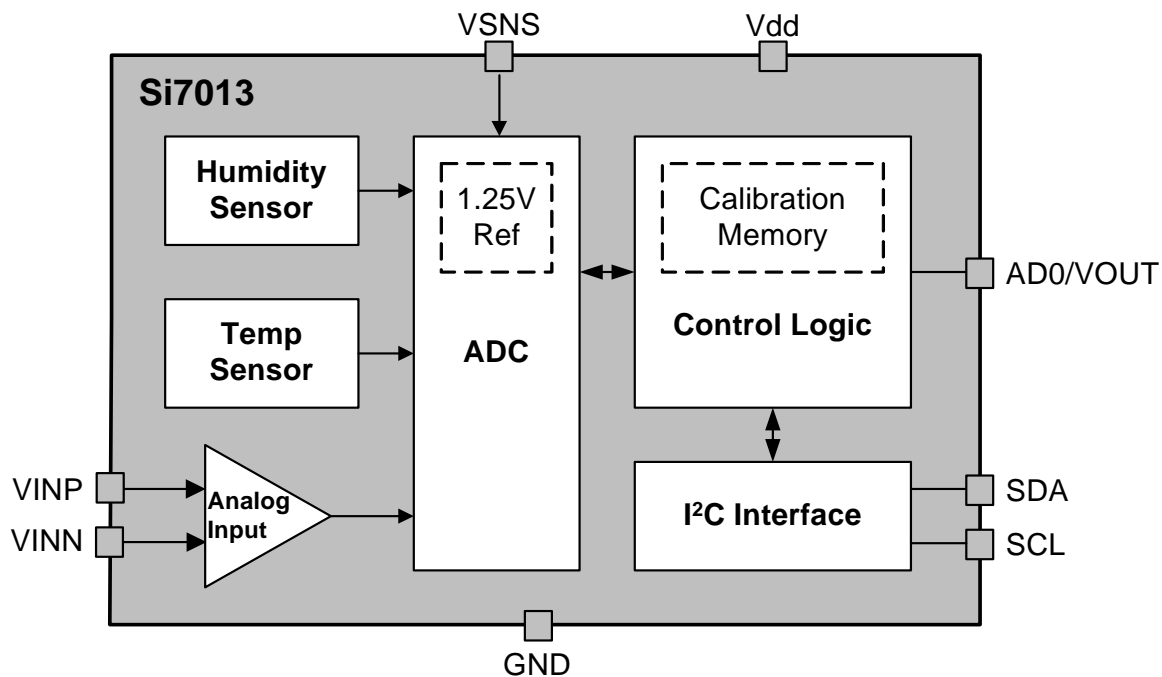
The Si7013 offers an accurate, low-power, factory-calibrated digital solution ideal for measuring humidity, dew-point, and temperature, in applications ranging from HVAC/R and asset tracking to industrial and consumer platforms.



Patent Protected. Patents pending

# Si7013-A20

## Functional Block Diagram



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## 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 <sub>DD</sub>		1.9	—	3.6	V
Operating Temperature	T <sub>A</sub>	I and Y grade	−40	—	+125	°C
Operating Temperature	T <sub>A</sub>	G grade	−40	—	+85	°C

**Table 2. General Specifications**

1.9 ≤ V<sub>DD</sub> ≤ 3.6 V; T<sub>A</sub> = −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 <sub>IH</sub>	AD0, SCL, SDA, VSNS pins	0.7xV <sub>DD</sub>	—	—	V
Input Voltage Low	V <sub>IL</sub>	AD0, SCL, SDA, VSNS pins	—	—	0.3xV <sub>DD</sub>	V
Input Voltage Range	V <sub>IN</sub>	SCL, SDA, VSNS pins with respect to GND	0.0	—	V <sub>DD</sub>	V
Input Leakage	I <sub>IL</sub>	SCL, SDA pins; V <sub>IN</sub> = GND	—	—	1	μA
		VSNS pin (200K nominal pull up); V <sub>in</sub> = GND	5xV <sub>DD</sub>			μA
Output Voltage Low	V <sub>OL</sub>	SDA pin; I <sub>OL</sub> = 2.5 mA; V <sub>DD</sub> = 3.3 V	—	—	0.6	V
		SDA pin; I <sub>OL</sub> = 1.2 mA; V <sub>DD</sub> = 1.9 V	—	—	0.4	V
Output Voltage High	V <sub>OH</sub>	V <sub>OUT</sub> pin, I <sub>OH</sub> = −0.5 mA, V <sub>DD</sub> = 2.0 V	V <sub>DD</sub> − 0.2	—	—	V
		V <sub>OUT</sub> pin, I <sub>OH</sub> = −10 μA	V <sub>DD</sub> − 0.1	—	—	V
		V <sub>OUT</sub> pin, I <sub>OH</sub> = −1.7 mA, V <sub>DD</sub> = 3.0 V	V <sub>DD</sub> − 0.4	—	—	V
Current Consumption	I <sub>DD</sub>	RH conversion in progress	—	150	180	μA
		Temperature conversion in progress	—	90	120	μA
		Standby, −40 to +85 °C <sup>2</sup>	—	0.06	0.62	μA
		Standby, −40 to +125 °C <sup>2</sup>	—	0.06	3.8	μA
		Peak I <sub>DD</sub> during powerup <sup>3</sup>	—	3.5	4.0	mA
		Peak I <sub>DD</sub> during I <sup>2</sup> C operations <sup>4</sup>	—	3.5	4.0	mA
Heater Current <sup>5</sup>	I <sub>HEAT</sub>		—	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<sub>CONV(RH)</sub> + t<sub>CONV(T)</sub>.
2. No conversion or I<sup>2</sup>C transaction in progress. Typical values measured at 25 °C.
3. Occurs once during powerup. Duration is <5 msec.
4. Occurs during I<sup>2</sup>C 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 <sup>1</sup>	$t_{CONV}$	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 I<sup>2</sup>C transaction in progress. Typical values measured at  $25$  °C.
3. Occurs once during powerup. Duration is  $<5$  msec.
4. Occurs during I<sup>2</sup>C 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  $<50$   $\mu$ s for all commands except Measure Analog Voltage or Thermistor Temperature, which has  $<150$   $\mu$ 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. I<sup>2</sup>C Interface Specifications<sup>1</sup>**

$1.9 \leq V_{DD} \leq 3.6$  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 <sup>2</sup>	$f_{SCL}$		—	—	400	kHz
SCL High Time	$t_{SKH}$		0.6	—	—	$\mu$ 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 I<sup>2</sup>C speed of 400 kHz the stretching will be  $<50$   $\mu$ s.
3. Pulses up to and including 50 ns will be suppressed.

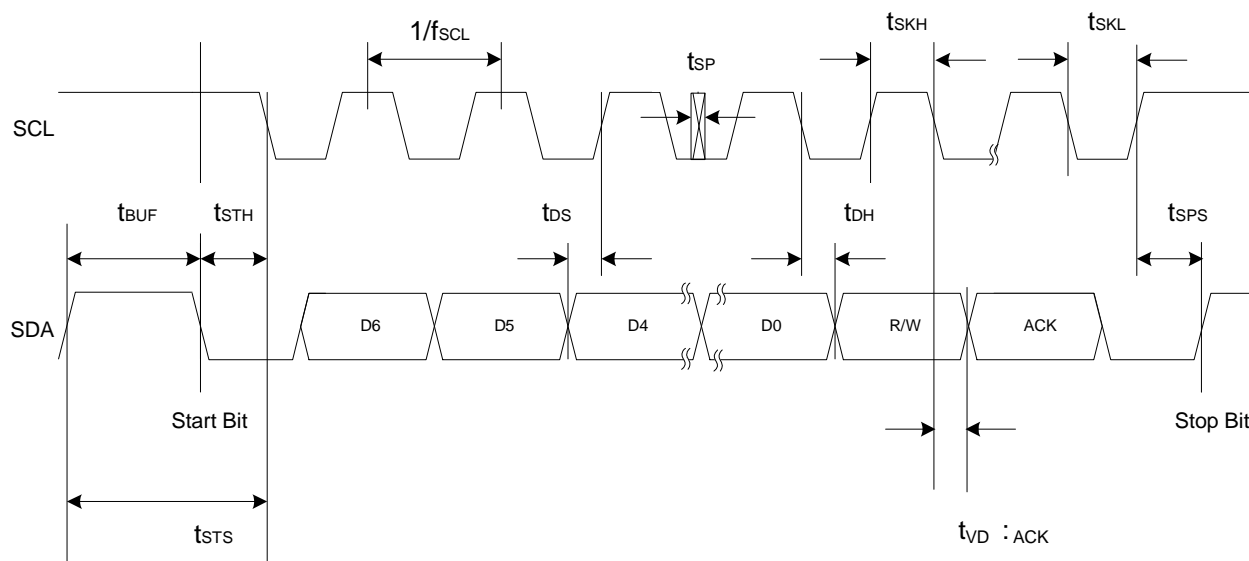
**Table 3. I<sup>2</sup>C Interface Specifications<sup>1</sup> (Continued)**

$1.9 \leq V_{DD} \leq 3.6$  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	—	—	$\mu$ s
Start Hold Time	$t_{STH}$		0.6	—	—	$\mu$ s
Start Setup Time	$t_{STS}$		0.6	—	—	$\mu$ s
Stop Setup Time	$t_{SPS}$		0.6	—	—	$\mu$ s
Bus Free Time	$t_{BUF}$	Between Stop and Start	1.3	—	—	$\mu$ 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	$\mu$ s
SDA Acknowledge Valid Time	$t_{VD;ACK}$	From SCL low to data valid	—	—	0.9	$\mu$ s
Suppressed Pulse Width <sup>3</sup>	$t_{SP}$		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 I<sup>2</sup>C speed of 400 kHz the stretching will be  $<50$   $\mu$ s.
3. Pulses up to and including 50 ns will be suppressed.



**Figure 1. I<sup>2</sup>C 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 <sup>1</sup>		Non-condensing	0	—	100	%RH
Accuracy <sup>2, 3</sup>		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 <sup>4</sup>	$T_{63\%}$	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 <sup>3</sup>			—	≤ 0.25	—	%RH/yr
<b>Notes:</b> <ol style="list-style-type: none"> <li>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.</li> <li>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.</li> <li>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”</li> <li>4. Response time to a step change in RH. Time for the RH output to change by 63% of the total RH change.</li> </ol>						

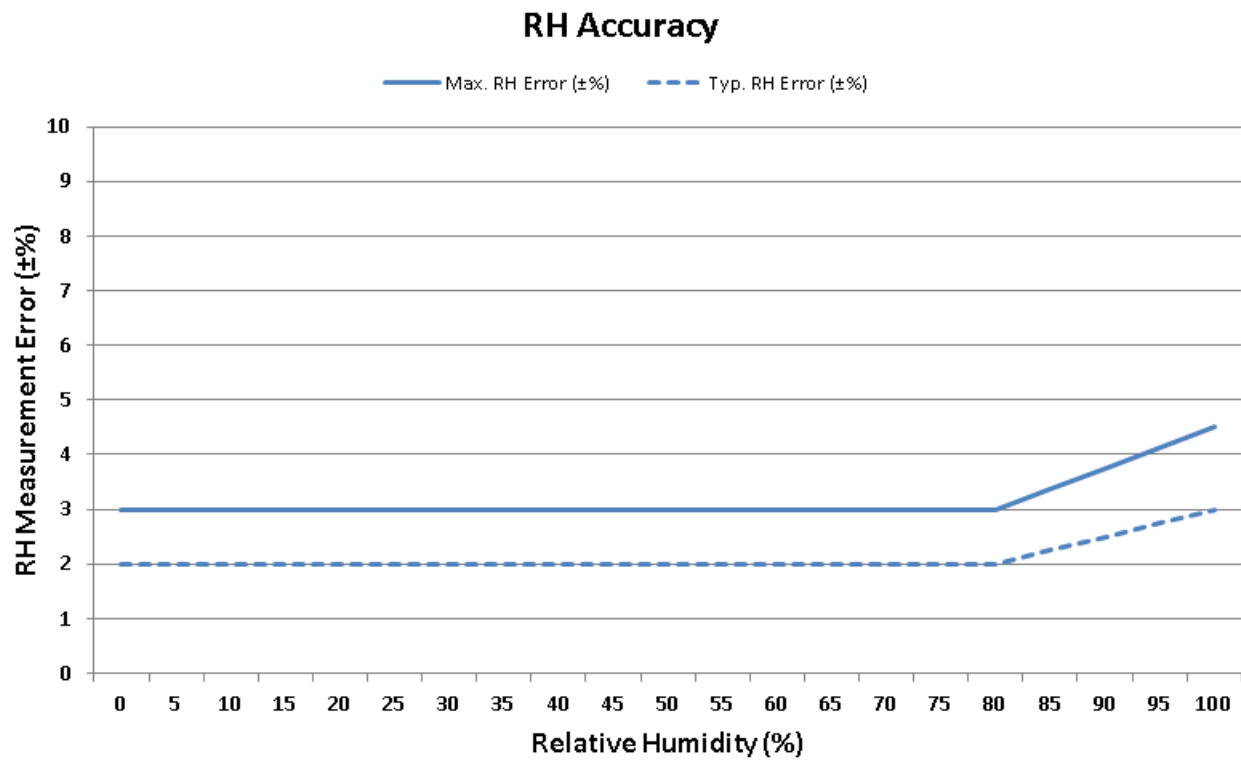


Figure 2. RH Accuracy at 30 °C

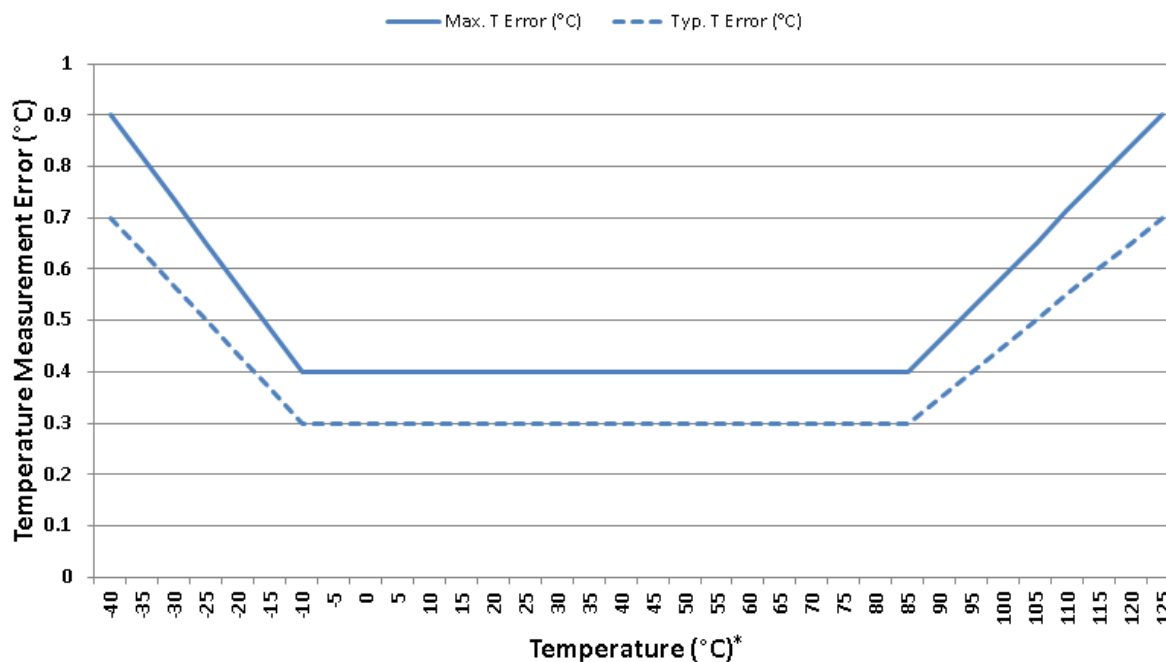
**Table 5. Temperature Sensor**

$1.9 \leq V_{DD} \leq 3.6 \text{ V}$ ;  $T_A = -40 \text{ to } +85 \text{ }^\circ\text{C}$  (G grade) or  $-40 \text{ to } +125 \text{ }^\circ\text{C}$  (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	$^\circ\text{C}$
		G Grade	-40	—	+85	$^\circ\text{C}$
Accuracy <sup>1</sup>		$-10 \text{ }^\circ\text{C} \leq t_A \leq 85 \text{ }^\circ\text{C}$	—	$\pm 0.3$	$\pm 0.4$	$^\circ\text{C}$
		$-40 \text{ }^\circ\text{C} \leq t_A \leq 125 \text{ }^\circ\text{C}$	Figure 3.			$^\circ\text{C}$
Repeatability-Noise		14-bit resolution	—	0.01	—	$^\circ\text{C RMS}$
		13-bit resolution	—	0.02	—	$^\circ\text{C RMS}$
		12-bit resolution	—	0.04	—	$^\circ\text{C RMS}$
		11-bit resolution	—	0.08	—	$^\circ\text{C RMS}$
Response Time <sup>2</sup>	$T_{63\%}$	Unmounted device	—	0.7	—	s
		Si7013-EB board	—	5.1	—	s
Long Term Stability			—	$\leq 0.01$	—	$^\circ\text{C/Yr}$

**Notes:**

1. 14b measurement resolution (default).
2. 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.

**Temperature Accuracy****Figure 3. Temperature Accuracy\***

\*Note: Applies only to I and Y devices beyond  $+85 \text{ }^\circ\text{C}$ .

**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 <sub>REF</sub> /32768	—	V
Integral Non-linearity	INL	VINP-VINN  < V <sub>REF</sub> /2	—	1	—	LSB
Differential Non-linearity	DNL	VINP-VINN  < V <sub>REF</sub> /2	—	1	—	LSB
Noise	N	VINP-VINN  < V <sub>REF</sub> /2, V <sub>REF</sub> = 1.25 V, Normal Mode	—	25	—	μV <sub>RMS</sub>
		VINP-VINN  < V <sub>REF</sub> /2, V <sub>REF</sub> = 1.25 V, Fast Mode	—	50	—	
Input Offset (Buffered Mode)	V <sub>OS</sub>	VINP-VINN  = 0	—	—	10	mV
Input Offset (Unbuffered Mode) <sup>1,2</sup>	V <sub>OS</sub>	VINP-VINN  = 0	—	—	1	mV
Gain Accuracy	ΔG	V <sub>REF</sub> = 1.25 V; gain is absolute	—	±1	±2	%
		V <sub>REF</sub> = V <sub>DD</sub> ; gain is relative to V <sub>DD</sub>	—	±0.25	±0.5	%
<b>Notes:</b> 1. Guaranteed by design. 2. In unbuffered mode, R <sub>IN</sub> *C <sub>IN</sub> should be < 0.5usec. C <sub>IN</sub> minimum is around 10 pF.						

Table 7. Thermal Characteristics

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

Table 8. Absolute Maximum Ratings<sup>1,2</sup>

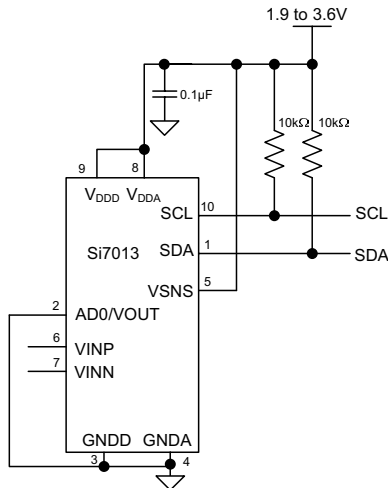
Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Ambient temperature under bias			-55	—	125	°C
Storage Temperature			-65	—	150	°C
Voltage on I/O pins			-0.3	—	VDD+0.3 V	V
Voltage on VDD with respect to GND			-0.3	—	4.2	V
ESD Tolerance		HBM	—	—	2	kV
		CDM	—	—	1.25	kV
		MM	—	—	250	V

**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.

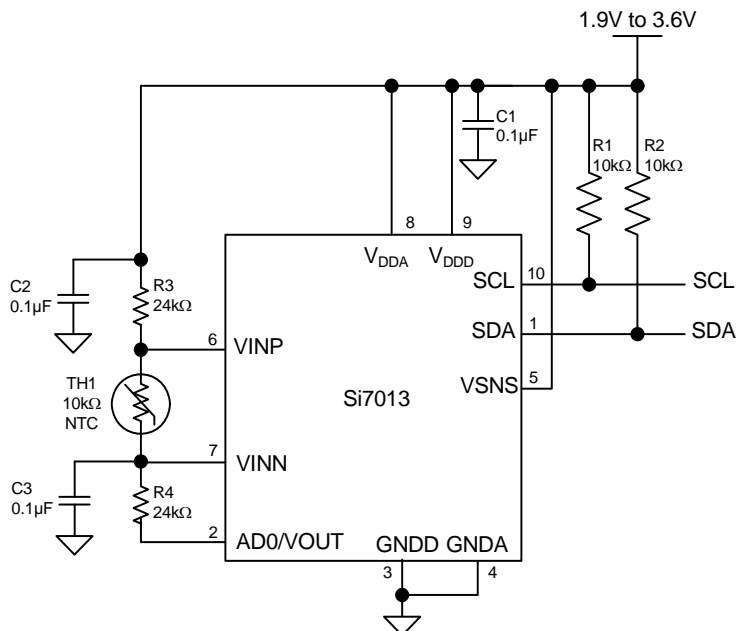
## 2. Typical Application Circuits

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**

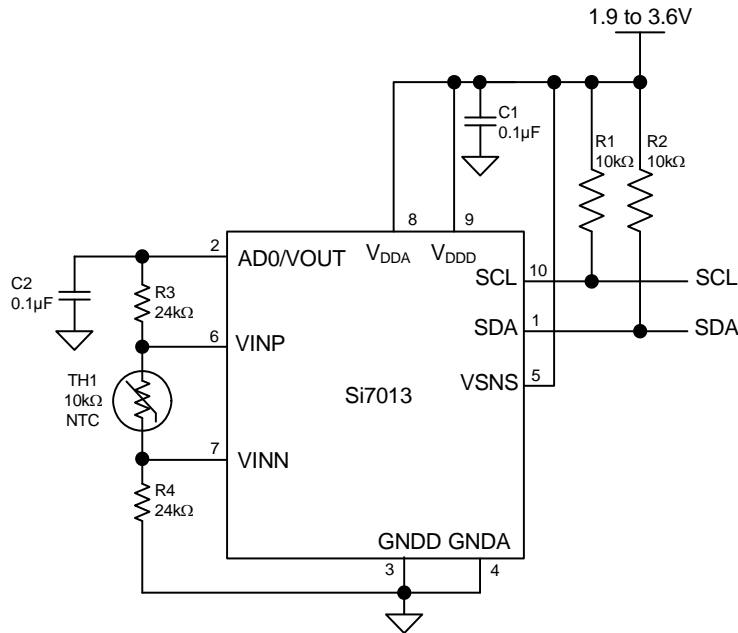
The application circuit shown in Figure 5 uses the auxiliary analog pins for measuring a remote temperature using a thermistor.



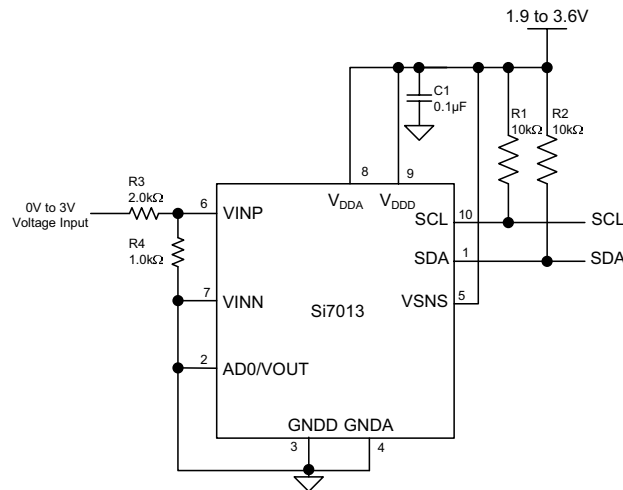
**Figure 5. Typical Application Circuit for Thermistor Interface with AD0 = 1**

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  $> 100\text{ k}\Omega$ .

The AD0/VOUT pin is a dual function pin. At powerup, it functions as an address select pin and selects the least significant I<sup>2</sup>C 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.

## 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 $\Omega$ , $\pm$ 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
R2	Resistor, 10 k $\Omega$ , $\pm$ 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
C1	Capacitor, 0.1 $\mu$ F, 16 V, X7R, 0603	C0603X7R160-104M	Venkel
U1	IC, Digital Temperature/humidity Sensor	Si7013-A20	Silicon Labs

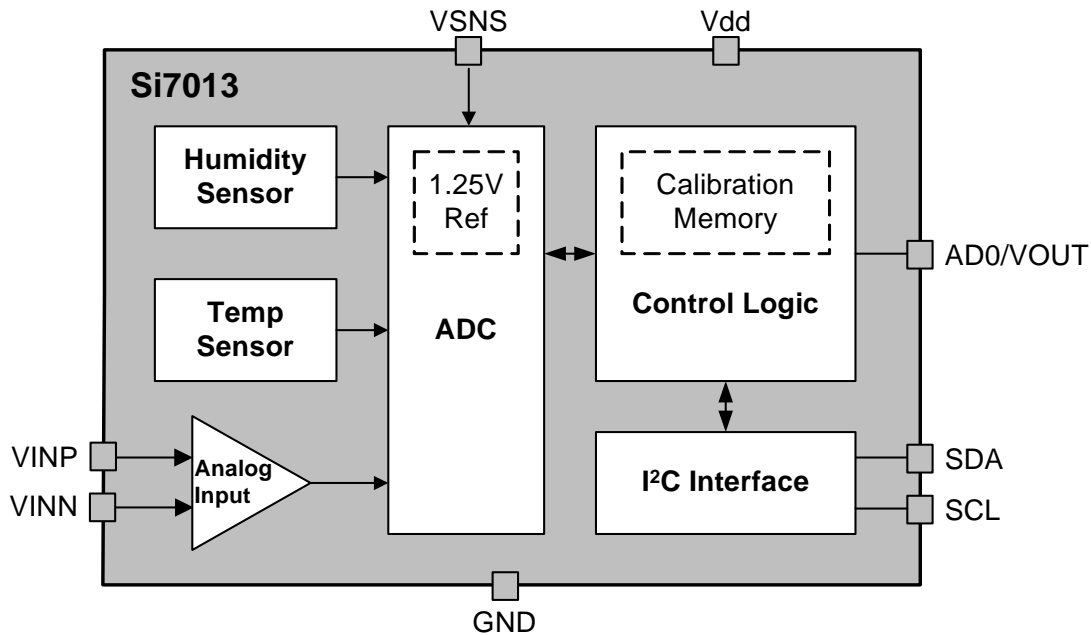
**Table 10. Typical Application Circuit BOM for Thermistor Interface**

Reference	Description	Mfr Part Number	Manufacturer
R1	Resistor, 10 k $\Omega$ , $\pm$ 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
R2	Resistor, 10 k $\Omega$ , $\pm$ 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
R3	Resistor, 24 k $\Omega$ , $\pm$ 1%, 1/16W, 0603	CR0603-16W-2402F	Venkel
R4	Resistor, 24 k $\Omega$ , $\pm$ 1%, 1/16W, 0603	CR0603-16W-2402F	Venkel
C1	Capacitor, 0.1 $\mu$ F, 16 V, X7R, 0603	C0603X7R160-104M	Venkel
C2	Capacitor, 0.1 $\mu$ F, 16 V, X7R, 0603	C0603X7R160-104M	Venkel
TH1	Thermistor, 10 k $\Omega$	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 $\Omega$ , $\pm$ 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
R2	Resistor, 10 k $\Omega$ , $\pm$ 5%, 1/16W, 0603	CR0603-16W-103JT	Venkel
R3	Resistor, 2 k $\Omega$ , $\pm$ 1%, 1/16W, 0603	CR0603-16W-2001F	Venkel
R4	Resistor, 1 k $\Omega$ , $\pm$ 1%, 1/16W, 0603	CR0603-16W-1001F	Venkel
C1	Capacitor, 0.1 $\mu$ 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 I<sup>2</sup>C 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.

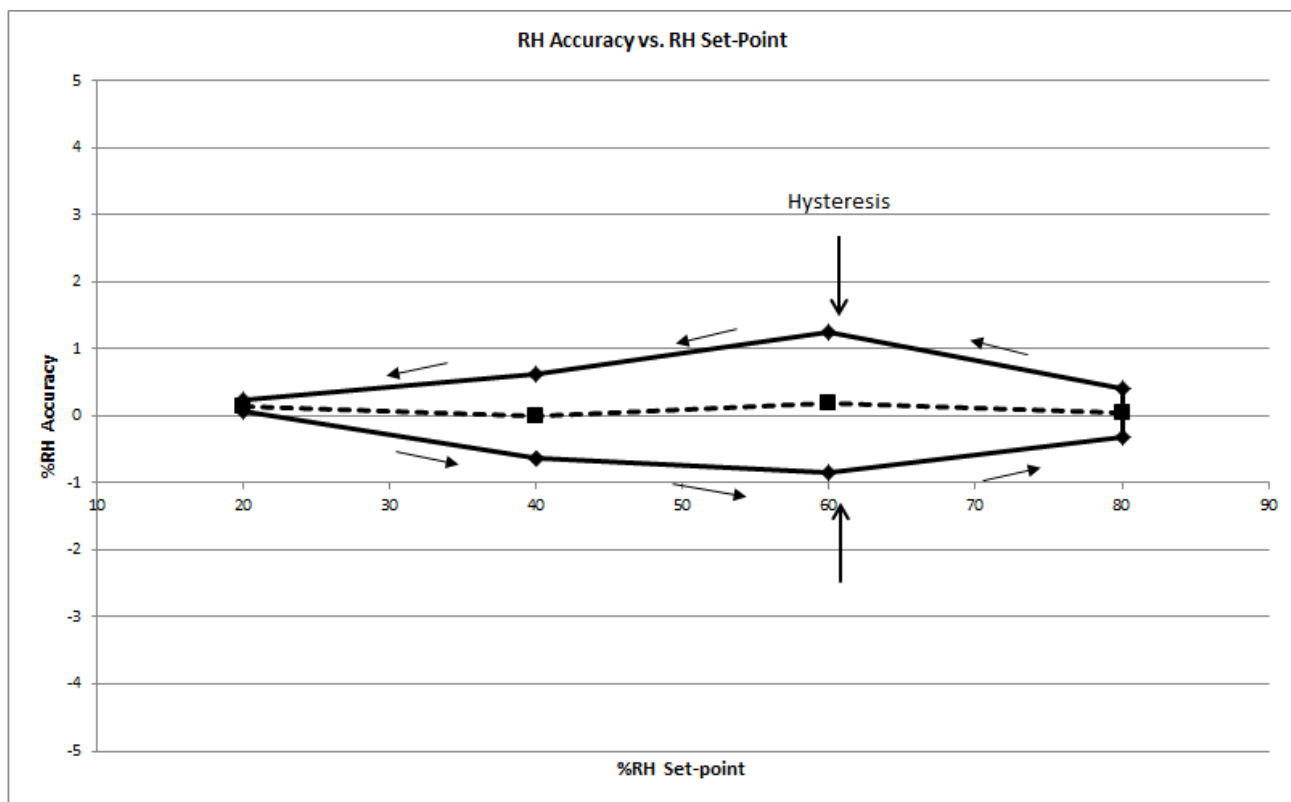
While the Si7013 is largely a conventional mixed-signal CMOS integrated circuit, relative humidity sensors in general and those based on capacitive sensing using polymeric dielectrics have unique application and use requirements that are not common to conventional (non-sensor) ICs. Chief among those 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  $\pm 1.0\%RH$ .

## **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**

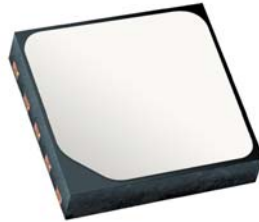
The measured humidity value will generally shift slightly after solder reflow. A portion of this shift is permanent and is accounted for in the accuracy specifications in Table 4. After soldering, an Si7013 should be allowed to equilibrate under controlled RH conditions (room temperature, 45–55%RH) for 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  $\geq 12$  hours
- Hydration at 30 °C in 75% RH for  $\geq 10$  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. I<sup>2</sup>C Interface

The Si7013 communicates with the host controller over a digital I<sup>2</sup>C interface. The 7-bit base slave address is 0x40 or 0x41; the least significant bit is pin programmable.

**Table 13. I<sup>2</sup>C Slave Address Byte**

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

Master I<sup>2</sup>C devices communicate with the Si7013 using a command structure. The commands are listed in the I<sup>2</sup>C command table. Commands other than those documented below are undefined and should not be sent to the device.

**Table 14. I<sup>2</sup>C 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.

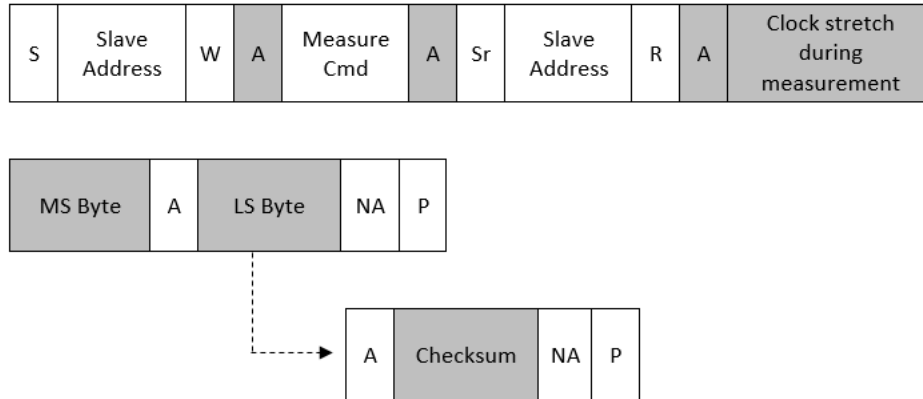
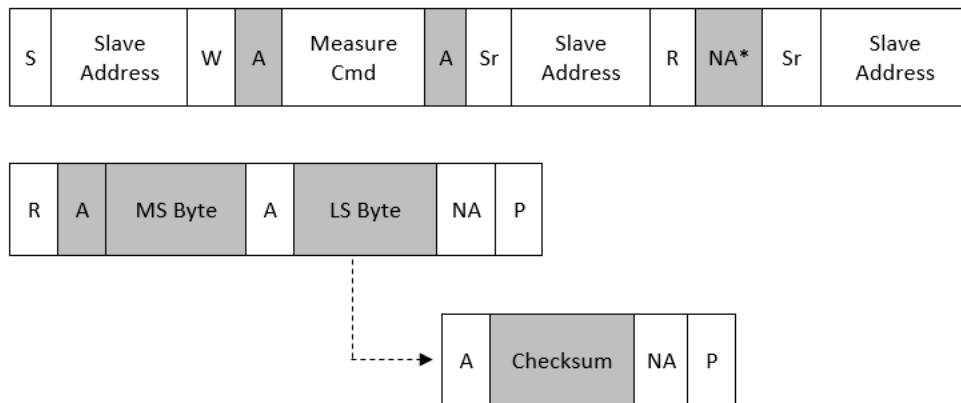
Optionally, a checksum byte can be returned from the slave for use in checking for transmission errors for Relative Humidity and Temperature measurements. The checksum byte is optional after initiating an RH or temperature measurement with commands 0xE5, 0xF5, 0xE3 and 0xF3. The checksum byte is required 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. I<sup>2</sup>C 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 I<sup>2</sup>C 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.

## 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

S	Slave Address	W	A	0xE0	A	Sr	Slave Address	R	A	MS Byte
---	---------------	---	---	------	---	----	---------------	---	---	---------

A	LS Byte	NA	P
---	---------	----	---

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

$$\text{Temperature (}^{\circ}\text{C)} = \frac{175.72 * \text{Temp\_Code}}{65536} - 46.85$$

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.

## 5.4. Nonlinear Correction of Voltage Inputs:

The Si7013 contains a look-up table for applying non-linear correction to external voltage measurements. The look-up table is contained in an internal, user-programmable OTP memory. The OTP memory is non-volatile, meaning the values are retained even when the device is powered off.

Once the lookup table values have been programmed, this correction is invoked by writing a “1” to bit 5 of user register 2. Note that humidity measurements should not be performed when this bit is set and the Si7013 must also be power cycled after writing the coefficients before they can take effect.

### 5.4.1. Calculating Lookup Table Values

The non-linear correction is based on 10 points. Each point consists of the ideal output for a given expected A/D measurement result.

Values between the ideal output points are interpolated based on the slope between the two output points.

The lookup table is stored in the Si7013 memory. Values must be programmed for each pair of input values and ideal output points. In addition, the slope between each ideal output point must also be programmed (the Si7013 will not automatically calculate the slope). Only 9 of the input/output pairs need to be in the table because the 10<sup>th</sup> output value is determined by the slope equation.

The table contains 3 sets of 9 values:

- In(1-9): 16-bit signed values for each input point read from the ADC. See Section “5.3. Measuring Analog Voltage” for more information on setting up the ADC measurement.
- Out(1-9): 16-bit unsigned values for each ideal output point that should be used for each input point.
- Slope(1-9): 16-bit signed values for the slope between each ideal output point.

**Note:** The table must be arranged in order of decreasing input values.

The slope values must be calculated as follows:

$$\text{slope}_N = 256 * (\text{output}_{N+1} - \text{output}_N) / (\text{input}_{N+1} - \text{input}_N)$$

The actual output value is determined by extrapolation:

If  $\text{in} > \text{in}_2$ ,  $\text{out} = \text{out}_1 + \text{slope}_1 * (\text{in} - \text{in}_1) / 256$

Else if  $\text{in} > \text{in}_3$ ,  $\text{out} = \text{out}_2 + \text{slope}_2 * (\text{in} - \text{in}_2) / 256$

Else if  $\text{in} > \text{in}_4$ ,  $\text{out} = \text{out}_3 + \text{slope}_3 * (\text{in} - \text{in}_3) / 256$

Else if  $\text{in} > \text{in}_5$ ,  $\text{out} = \text{out}_4 + \text{slope}_4 * (\text{in} - \text{in}_4) / 256$

Else if  $\text{in} > \text{in}_6$ ,  $\text{out} = \text{out}_5 + \text{slope}_5 * (\text{in} - \text{in}_5) / 256$

Else if  $\text{in} > \text{in}_7$ ,  $\text{out} = \text{out}_6 + \text{slope}_6 * (\text{in} - \text{in}_6) / 256$

Else if  $\text{in} > \text{in}_8$ ,  $\text{out} = \text{out}_7 + \text{slope}_7 * (\text{in} - \text{in}_7) / 256$

Else if  $\text{in} > \text{in}_9$ ,  $\text{out} = \text{out}_8 + \text{slope}_8 * (\text{in} - \text{in}_8) / 256$

Else  $\text{out} = \text{out}_9 + \text{slope}_9 * (\text{in} - \text{in}_9)$

#### 5.4.2. Entering Lookup Table Values into OTP Memory:

The table is entered into memory addresses 0x82 – 0xB7 one byte at a time. Until the OTP has been programmed, all memory addresses default to a value of 0xFF. The table below indicates where the values are written:

**Table 17. Lookup Table Memory Map**

Name	Memory Location	Name	Memory Location	Name	Memory Location
Input1 (MSB)	0x82	Output1 (MSB)	0x94	Slope1 (MSB)	0xA6
Input1 (LSB)	0x83	Output1 (LSB)	0x95	Slope1 (LSB)	0xA7
Input2 (MSB)	0x84	Output2 (MSB)	0x96	Slope2 (MSB)	0xA8
Input2 (LSB)	0x85	Output2 (LSB)	0x97	Slope2 (LSB)	0xA9
Input3 (MSB)	0x86	Output3 (MSB)	0x98	Slope3 (MSB)	0xAA
Input3 (LSB)	0x87	Output3 (LSB)	0x99	Slope3 (LSB)	0xAB
Input4 (MSB)	0x88	Output4 (MSB)	0x9A	Slope4 (MSB)	0xAC
Input4 (LSB)	0x89	Output4 (LSB)	0x9B	Slope4 (LSB)	0xAD
Input5 (MSB)	0x8A	Output5 (MSB)	0x9C	Slope5 (MSB)	0xAE
Input5 (LSB)	0x8B	Output5 (LSB)	0x9D	Slope5 (LSB)	0xAF
Input6 (MSB)	0x8C	Output6 (MSB)	0x9E	Slope6 (MSB)	0xB0
Input6 (LSB)	0x8D	Output6 (LSB)	0x9F	Slope6 (LSB)	0xB1
Input7 (MSB)	0x8E	Output7 (MSB)	0xA0	Slope7 (MSB)	0xB2
Input7 (LSB)	0x8F	Output7 (LSB)	0xA1	Slope7 (LSB)	0xB3
Input8 (MSB)	0x90	Output8 (MSB)	0xA2	Slope8 (MSB)	0xB4
Input8 (LSB)	0x91	Output8 (LSB)	0xA3	Slope8 (LSB)	0xB5
Input9 (MSB)	0x92	Output9 (MSB)	0xA4	Slope9 (MSB)	0xB6
Input9 (LSB)	0x93	Output9 (LSB)	0xA5	Slope9 (LSB)	0xB7

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The sequences for reading and writing thermistor coefficients are given below:

## Sequence to write thermistor correction coefficients

S	Slave Address	W	A	0xC5	A	Memory Location	A	Write Data	A	P
---	---------------	---	---	------	---	-----------------	---	------------	---	---

## Sequence to read thermistor correction coefficients

S	Slave Address	W	A	0x84	A	Memory Location	A	Sr	Slave Address	R	A	Read Data	NA	P
---	---------------	---	---	------	---	-----------------	---	----	---------------	---	---	-----------	----	---

For example, to program a Si7013 at slave address 0x40 with the 16-bit value 0x4C2F, starting at memory location 0x82, you would write:

<Start Condition> 0x40 W ACK 0xC5 ACK 0x82 ACK 0x4C ACK <Stop Condition>

<Start Condition> 0x40 W ACK 0xC5 ACK 0x83 ACK 0x2F ACK <Stop Condition>

The internal memory is one-time-programmable, so it is not possible to change the values once written. However, to verify the values were written properly use command 0x84. For example, to verify that 0x4C was written to location 0x82 use:

<Start Condition> 0x40 W ACK 0x84 ACK 0x82 ACK <Start Condition> 0x40 R ACK 0x4C NACK <Stop Condition> where 0x4C is the expected return value of the read transaction.

Remember to power cycle the Si7013 after writing the coefficient data.

### 5.4.3. Example Thermistor Calculations

For the Si7013 evaluation board with a 10 K ohm thermistor and two 24.3 K $\Omega$  bias resistors and assuming the A/D conversion is done using  $V_{DD}$  as a reference with buffered inputs, the ideal input voltage versus temperature is:

$$V_{in} = V_{DD} * R_{thermistor} / (R_{thermistor} + 48.6 \text{ K})$$

Since  $V_{DD}$  is also the reference then the expected A/D conversion result is:

$$\text{A/D counts} = 32768 * R_{thermistor} / (R_{thermistor} + 48.6 \text{ K})$$

If it is desired to linearize this result for the same temperature representation as the on board temperature sensor:

$$\text{Temperature } ^\circ\text{C} = (\text{Output\_Code} * 175.72 / 65536 - 46.85), \text{ then the desired output code is:}$$

$$\text{Output\_Code} = 65536 * (\text{Temperature} + 46.85) / 175.72$$

Using thermistor data sheet values of resistance versus temperature and choosing to linearize at the points  $-15^\circ\text{C}$ ,  $-5^\circ\text{C}$ ,  $5^\circ\text{C}$ ,  $15^\circ\text{C}$ ,  $25^\circ\text{C}$ ,  $35^\circ\text{C}$ ,  $45^\circ\text{C}$ ,  $55^\circ\text{C}$ ,  $65^\circ\text{C}$  and  $75^\circ\text{C}$  results in the following. The values in gray are the table entries for Si7013:

**Table 18. Example Non-Linear Correction to Thermistor Voltage Measurements**

Temperature (Degrees C)	Thermistor Resistance	Vin/VDD	A/D Codes	Desired Code	Slope	Table Entry
-15	71746	0.596164	19535	11879	-218	1
-5	41813	0.462467	15154	15608	-241	2
5	25194	0.34141	11187	19338	-298	3
15	15651	0.243592	7982	23067	-400	4
25	10000	0.170648	5592	26797	-563	5
35	6556	0.118863	3895	30527	-813	6
45	4401	0.83036	2721	34256	-1186	7
55	3019	0.058486	1916	37986	-1739	8
65	2115	0.041704	1367	41715	-2513	9
75	1509	0.030114	75	45445		

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Once the table entry values are calculated, they should be programmed to the Si7013 memory locations as shown below:

**Table 19. Example Non-Linear Thermistor Correction Entries into Si7013 Memory**

Memory Location	A/D Codes	Value	Memory Location	Desired Codes	Value	Memory Location	Slope	Value
82	19535	4C	94	11879	2E	A6	–218	FF
83		4F	95		67	A7		26
84	15154	3B	96	15608	3C	A8	–241	FF
85		32	97		F8	A9		0F
86	11187	2B	98	19338	4B	AA	–298	FE
87		B3	99		8A	AB		D6
88	7982	1F	9A	23067	5A	AC	–400	FE
89		2E	9B		1B	AD		70
8A	5592	15	9C	26797	68	AE	–563	FD
8B		D8	9D		Ad	AF		CD
8C	3895	F	9E	30527	77	B0	–813	FC
8D		37	9F		3F	B1		D3
8E	2721	A	A0	34256	85	B2	–1186	FB
8F		A1	A1		D0	B3		5E
90	1916	7	A2	37986	94	B4	–1739	F9
91		7C	A3		62	B5		35
92	1367	5	A4	41715	A2	B6	–2513	F6
93		57	A5		F3	B7		2F

## 5.5. Firmware Revision

The internal firmware revision can be read with the following I2C transaction:

S	Slave Address	W	A	0x84	A	0xB8	A	S	Slave Address
---	---------------	---	---	------	---	------	---	---	---------------

R	A	FWREV	A	NA	P
---	---	-------	---	----	---

The values in this field are encoded as follows:

0xFF = Firmware revision 1.0

0x20 = Firmware revision 2.0

## 5.6. Heater

The Si7013 contains an integrated resistive heating element that may be used to raise the temperature of the sensor. This element can be used to test the sensor, to drive off condensation, or to implement dew-point measurement when the Si7013 is used in conjunction with a separate temperature sensor such as another Si7013 (the heater will raise the temperature of the internal temperature sensor).

The heater can be activated using HTRE, bit 2 in User Register 1. Turning on the heater will reduce the tendency of the humidity sensor to accumulate an offset due to "memory" of sustained high humidity conditions. Several different power levels are available. The various settings are adjusted using User Register 3 and are described in Table 20.

**Table 20. Heater Control Settings**

HEATER[3:0]	Typical Current Draw* (mA)
0000	3.09
0001	9.18
0010	15.24
...	...
0100	27.39
...	...
1000	51.69
...	...
1111	94.20
*Note: Assumes $V_{DD} = 3.3\text{ V}$ .	

## 5.7. Electronic Serial Number

The Si7013 provides a serial number individualized for each device that can be read via the I<sup>2</sup>C serial interface.

Two I<sup>2</sup>C commands are required to access the device memory and retrieve the complete serial number. The command sequence, and format of the serial number response is described in the figure below:

First access:

S	Slave Address	W	ACK	0xFA	ACK	0X0F	ACK		
S	Slave Address	R	ACK						
	SNA_3	ACK	CRC	ACK	SNA_2	ACK	CRC	ACK	
	SNA_1	ACK	CRC	ACK	SNA_0	ACK	CRC	NACK	P

2nd access:

S	Slave Address	W	ACK	0xFC	ACK	0xC9	ACK
S	Slave Address	R	ACK				
	SNB_3	ACK	SNB_2	ACK	CRC	ACK	
	SNB_1	ACK	SNB_0	ACK	CRC	NACK	P

The format of the complete serial number is 64-bits in length, divided into 8 data bytes. The complete serial number sequence is shown below:

SNA_3	SNA_2	SNA_1	SNA_0	SNB_3	SNB_2	SNB_1	SNB_0
-------	-------	-------	-------	-------	-------	-------	-------

The SNB3 field contains the device identification to distinguish between the different Silicon Labs relative humidity and temperature devices. The value of this field maps to the following devices according to this table:

0x00 or 0xFF engineering samples

0x0D=13=Si7013

0x14=20=Si7020

0x15=21=Si7021

## 6. Control Registers

**Table 21. Register Summary**

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
User Register 1	RES1	VDDS	RSVD			HTRE	RSVD	RES0
User Register 2		NO_HOLD	THERM_CORR	CONV_TIME	RSVD	VIN_BUF	VREFP	VOUT
User Register 3	RSVD				HEATER[3:0]			

**Notes:**

1. Any register not listed here is reserved and must not be written. The result of a read operation on these registers is undefined.
2. Except where noted, reserved register bits always read back as "1", and are not affected by write operations. For future compatibility, it is recommended that prior to a write operation, registers should be read. Then the values read from the RSVD bits should be written back unchanged during the write operation.

# Si7013-A20

## 6.1. Register Descriptions

### Register 1. User Register 1

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Name	RES1	VDDS	RSVD			HTRE	RSVD	RES0
Type	R/W	R	R/W			R/W	R/W	R/W

Reset Settings = 0011\_1010

Bit	Name	Function
D7; D0	RES[1:0]	Measurement Resolution: RH      Temp 00:      12 bit      14 bit 01:      8 bit      12 bit 10:      10 bit      13 bit 11:      11 bit      11 bit
D6	VDDS	$V_{DD}$ Status: 0: $V_{DD}$ OK 1: $V_{DD}$ Low  The minimum recommended operating voltage is 1.9 V. A transition of the $V_{DD}$ status bit from 0 to 1 indicates that $V_{DD}$ is between 1.8 V and 1.9 V. If the $V_{DD}$ drops below 1.8 V, the device will no longer operate correctly.
D5, D4, D3	RSVD	Reserved
D2	HTRE	1 = On-chip Heater Enable 0 = On-chip Heater Disable
D1	RSVD	Reserved

**Register 2. User Register 2**

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Name	RSVD	NO_HOLD	THERM_CORR	CONV_TIME	RSVD	VIN_BUF	VREFP	VOUT
Type	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Reset Settings = 0000\_100x

Bit	Name	Function
D7	RSVD	Reserved
D6	NO_HOLD	1: Auxiliary voltage and thermistor measurements made in No Hold Master Mode. Note that this bit must be set to "0" before initiating an internal temperature or humidity measurement. 0: Auxiliary voltage and thermistor measurements made in Hold Master Mode.
D5	THERM_CORR	1: Thermistor correction enabled for auxiliary voltage and thermistor measurements. Note that this bit must be set to "0" before initiating an internal temperature or humidity measurement. 0: Thermistor correction disabled.
D4	CONV_TIME	Conversion Time. Selects conversion time and noise floor of the voltage ADC. 0: Normal mode 1: Fast mode
D3	RSVD	Reserved
D2	VIN_BUF	0: VINN and VINP inputs are unbuffered 1: VINN and VINP inputs are buffered
D1	VREFP	0: A/D reference source is internal 1.25V 1: A/D reference source is VDDA
D0	VOUT*	0: VOUT pin is set to GNDD 1: VOUT pin is set to VDDD <b>Note:</b> Default is powerup state of VOUT pin
<b>*Note:</b> VOUT is generally used for driving an external thermistor interface. Default setting is the same as the power up setting.		

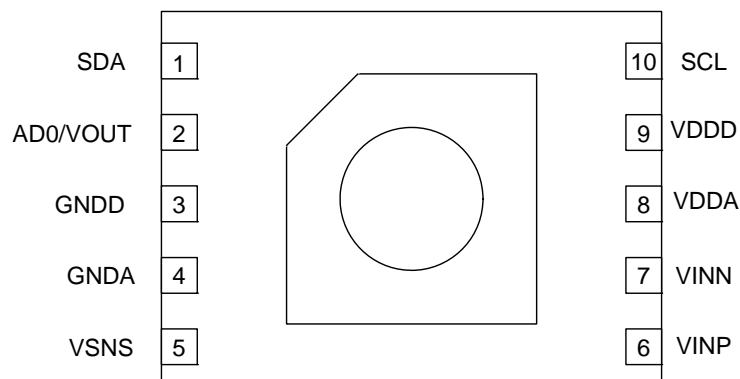
## Register 3. User Register 3

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Name	RSVD				Heater [3:0]			
Type	R/W				R/W			

Reset Settings = 0000\_0000

Bit	Name	Function				
D3:D0	HEATER[3:0]	D3	D2	D1	D0	Heater Current
		0	0	0	0	3.09 mA
		0	0	0	1	9.18 mA
		0	0	1	0	15.24 mA
				...		
		0	1	0	0	27.39 mA
				...		
		1	0	0	0	51.69 mA
				...		
		1	1	1	1	94.20 mA
D7,D6, D5,D4	RSVD	Reserved				

## 7. Pin Descriptions: Si7013 (Top View)



Pin Name	Pin #	Pin Description
SDA	1	I <sup>2</sup> C data.
AD0/VOUT	2	Dual function pin. This pin can be switched high or low and is generally used to drive an external thermistor interface. On powerup, this pin acts as a device address select pin. Tie high or low to set device address LSB. See Figure 5 and Figure 6.
GNDD	3	Digital ground. This pin is connected to ground on the circuit board.
GNDA	4	Analog ground. This pin is connected to ground on the circuit board.
VSNS	5	Voltage Sense Input. Tie to V <sub>DD</sub> .*
VINP	6	Analog to digital converter positive input.
VINN	7	Analog to digital converter negative input.
VDDA	8	Analog power. This pin is connected to power on the circuit board.
VDDD	9	Digital power. This pin is connected to power on the circuit board.
SCL	10	I <sup>2</sup> C clock
T <sub>GND</sub>	Paddle	This pad is connected to GND internally. This pad is the main thermal input to the on-chip temperature sensor. The paddle should be soldered to a floating pad.
*Note: VSNS must be high at power up or device will be held in reset.		

## 8. Ordering Guide

Table 22. Device Ordering Guide

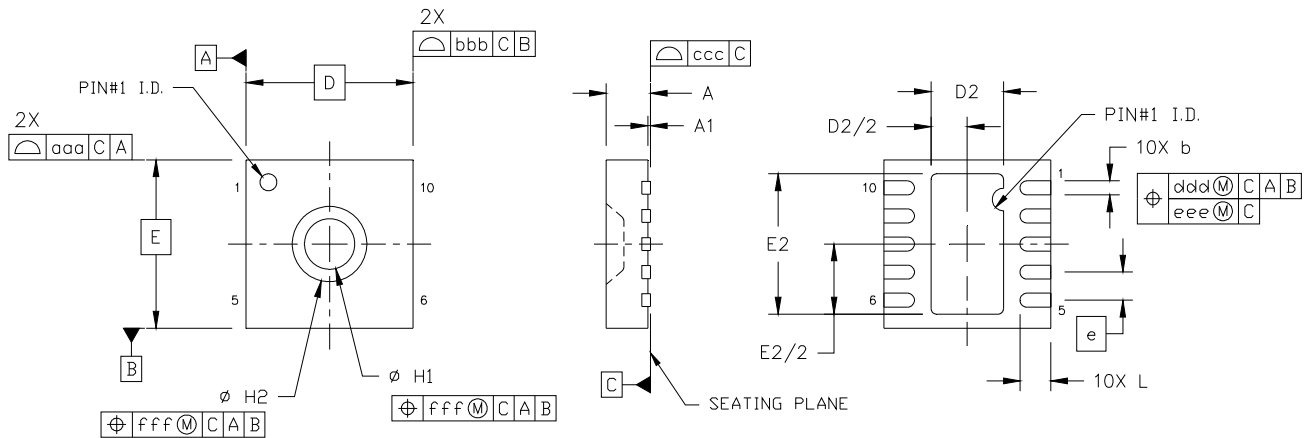
P/N	Description	Max. Accuracy		Pkg	Operating Range (°C)	Protective Cover	Packing Format
		Temp	RH				
Si7013-A20-GM	Digital temperature/ humidity sensor	±0.4 °C	± 3%	DFN 6	–40 to +85 °C	N	Tube
Si7013-A20-GMR	Digital temperature/ humidity sensor	±0.4 °C	± 3%	DFN 6	–40 to +85 °C	N	Tape & Reel
Si7013-A20-GM1	Digital temperature/ humidity sensor	±0.4 °C	± 3%	DFN 6	–40 to +85 °C	Y	Cut Tape
Si7013-A20-GM1R	Digital temperature/ humidity sensor	±0.4 °C	± 3%	DFN 6	–40 to +85 °C	Y	Tape & Reel
Si7013-A20-IM	Digital temperature/ humidity sensor— industrial temp range	±0.4 °C	± 3%	DFN 6	–40 to +125 °C	N	Tube
Si7013-A20-IMR	Digital temperature/ humidity sensor— industrial temp range	±0.4 °C	± 3%	DFN 6	–40 to +125 °C	N	Tape & Reel
Si7013-A20-IM1	Digital temperature/ humidity sensor— industrial temp range	±0.4 °C	± 3%	DFN 6	–40 to +125 °C	Y	Cut Tape
Si7013-A20-IM1R	Digital temperature/ humidity sensor— industrial temp range	±0.4 °C	± 3%	DFN 6	–40 to +125 °C	Y	Tape & Reel
Si7013-A20-YM0	Digital temperature/ humidity sensor— automotive	±0.4 °C	± 3%	DFN 6	–40 to +125 °C	N	Tube
Si7013-A20-YM0R	Digital temperature/ humidity sensor— automotive	±0.4 °C	± 3%	DFN 6	–40 to +125 °C	N	Tape & Reel
Si7013-A20-YM1	Digital temperature/ humidity sensor— automotive	±0.4 °C	± 3%	DFN 6	–40 to +125 °C	Y	Cut Tape
Si7013-A20-YM1R	Digital temperature/ humidity sensor— automotive	±0.4 °C	± 3%	DFN 6	–40 to +125 °C	Y	Tape & Reel

**Note:** The "A" denotes product revision A and "20" denotes firmware revision 2.0.

## 9. Package Outline

### 9.1. Package Outline: 3x3 10-pin DFN

Figure 11 illustrates the package details for the Si7013. Table 22 lists the values for the dimensions shown in the illustration.



**Figure 11. 10-pin DFN Package Drawing**

**Table 23. 10-Pin DFN Package Dimensions**

Dimension	Min	Nom	Max	Dimension	Min	Nom	Max
A	0.70	0.75	0.80	H2	1.39	1.44	1.49
A1	0.00	0.02	0.05	L	0.50	0.55	0.60
b	0.18	0.25	0.30	aaa	0.10		
D	3.00 BSC.			bbb	0.10		
D2	1.20	1.30	1.40	ccc	0.05		
e	0.50 BSC.			ddd	0.10		
E	3.00 BSC.			eee	0.05		
E2	2.40	2.50	2.60	fff	0.05		
H1	0.85	0.90	0.95				

**Notes:**

1. Dimensioning and Tolerancing per ANSI Y14.5M-1994.
2. Recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components.

## 9.2. Package Outline: 3x3 10-pin DFN with Protective Cover

Figure 12 illustrates the package details for the Si7013 with the optional protective cover. Table 23 lists the values for the dimensions shown in the illustration.

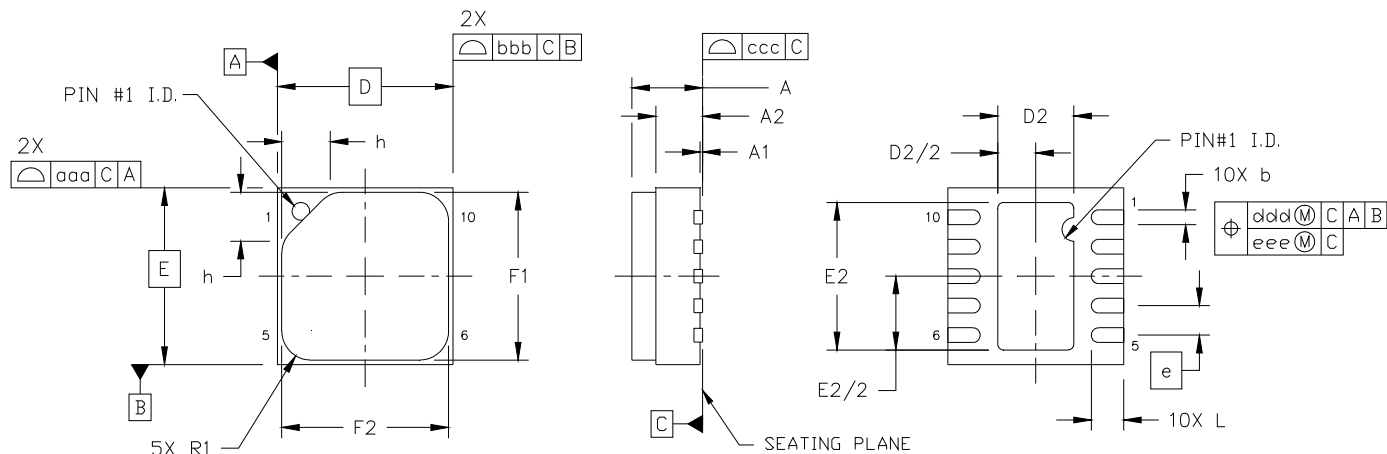
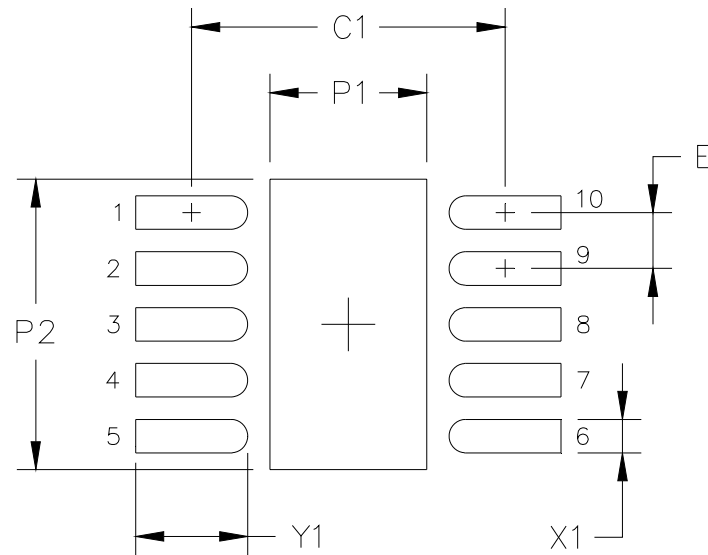


Figure 12. 10-pin DFN with Protective Cover

Table 24. 10-pin DFN with Protective Cover Diagram Dimensions

Dimension	Min	Nom	Max	Dimension	Min	Nom	Max
A	—	—	1.21	F1	2.70	2.80	2.90
A1	0.00	0.02	0.05	F2	2.70	2.80	2.90
A2	0.70	0.75	0.80	h	0.76	0.83	0.90
b	0.18	0.25	0.30	L	0.50	0.55	0.60
D	3.00 BSC.			R1	0.45	0.50	0.55
D2	1.20	1.30	1.40	aaa	0.10		
e	0.50 BSC.			bbb	0.10		
E	3.00 BSC.			ccc	0.05		
E2	2.40	2.50	2.60	ddd	0.10		
				eee	0.05		
<b>Notes:</b> 1. All dimensions shown are in millimeters (mm). 2. Dimensioning and Tolerancing per ANSI Y14.5M-1994.							

## 10. PCB Land Pattern and Solder Mask Design



**Table 25. PCB Land Pattern Dimensions**

Symbol	mm
C1	2.80
E	0.50
P1	1.40
P2	2.60
X1	0.30
Y1	1.00

**Notes:**

**General**

1. All dimensions shown are at Maximum Material Condition (MMC). Least Material Condition (LMC) is calculated based on a Fabrication Allowance of 0.05 mm.
2. This Land Pattern Design is based on the IPC-7351 guidelines.

**Solder Mask Design**

3. All metal pads are to be non-solder mask defined (NSMD). Clearance between the solder mask and the metal pad is to be 60  $\mu$ m minimum, all the way around the pad.

**Stencil Design**

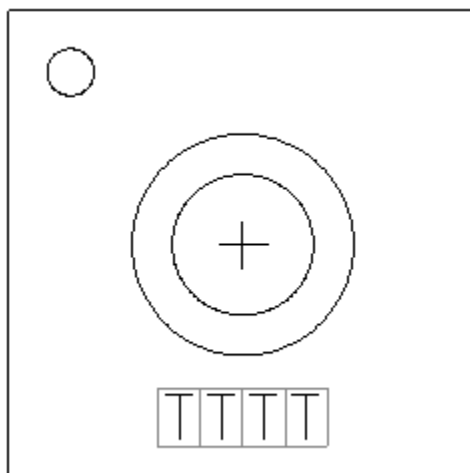
4. A stainless steel, laser-cut and electro-polished stencil with trapezoidal walls should be used to assure good solder paste release.
5. The stencil thickness should be 0.125 mm (5 mils).
6. The ratio of stencil aperture to land pad size should be 1:1 for all perimeter pins.
7. A 2x1 array of 0.95 mm square openings on 1.25 mm pitch should be used for the center ground pad to achieve a target solder coverage of 50%.

**Card Assembly**

8. A No-Clean, Type-3 solder paste is recommended.
9. The recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components.

## 11. Top Marking

### 11.1. Si7013 Top Marking



### 11.2. Top Marking Explanation

<b>Mark Method:</b>	Laser
<b>Pin 1 Indicator:</b>	Circle = 0.30 mm Diameter Upper-Left Corner
<b>Font Size:</b>	0.30 mm
<b>Line 1 Marking:</b>	TTTT = Mfg Code

## 12. Additional Reference Resources

- AN607: Si70xx Humidity Sensor Designer's Guide

## DOCUMENT CHANGE LIST

### Revision 0.9 to Revision 0.91

- Updated Table 2 on page 4.

### Revision 0.91 to Revision 1.0

- Updated document revision to 1.0.

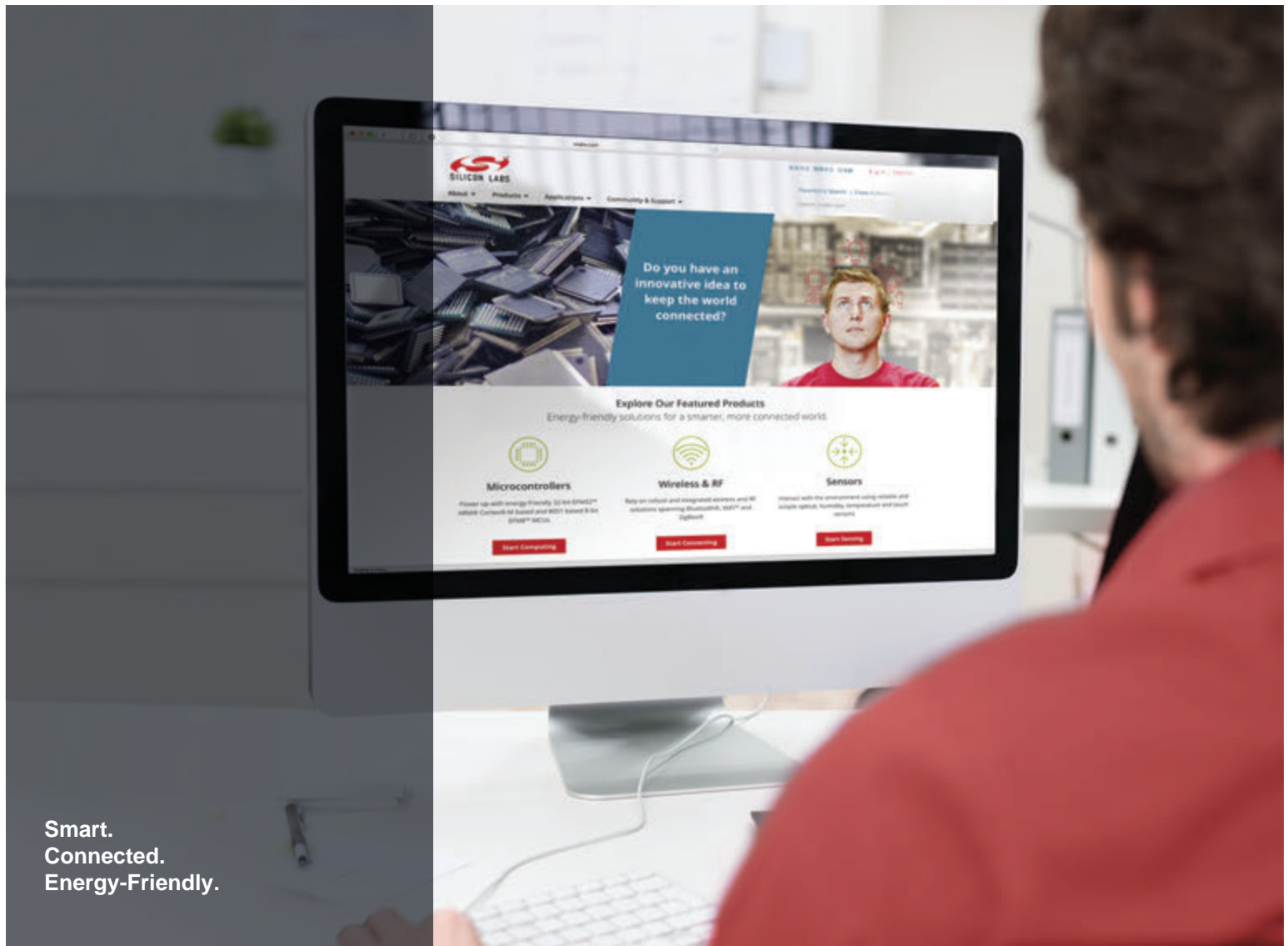
### Revision 1.0 to Revision 1.1

- Updated Footnote 2 in Table 3 on page 5
- Updated Section “4.5. Protecting the Sensor”
- Updated Table 12 on page 19
- Corrected a typo in the I<sup>2</sup>C sequence for no-hold mode in Section “5. I2C Interface”
- Corrected a typo in Table 15 on page 22
- Updated Table 24 on page 40 dimensions F1 and F2

### Revision 1.1 to Revision 1.2

February 16, 2016

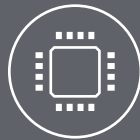
- Added notes in Section 5.4 that device must be power cycled before external voltage measurement coefficients will take effect.
- Corrected error in thermistor calculation formula (changed 46.4k to 48.6k).



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Silicon Laboratories Inc.  
400 West Cesar Chavez  
Austin, TX 78701  
USA

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