

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

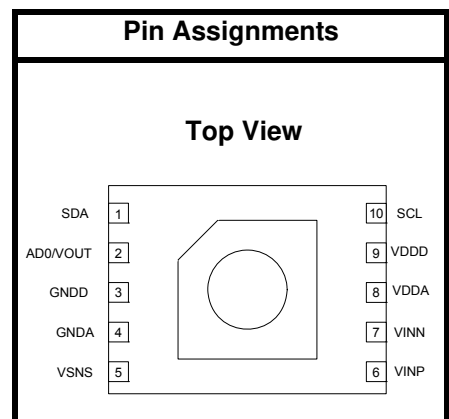
The Si7013 I²C Humidity and 2-Zone Temperature Sensor is a monolithic CMOS IC integrating humidity and temperature sensor elements, an analog-to-digital converter, signal processing, calibration data, and an I²C Interface. The patented use of industry-standard, low-K polymeric dielectrics for sensing 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

Functional Block Diagram

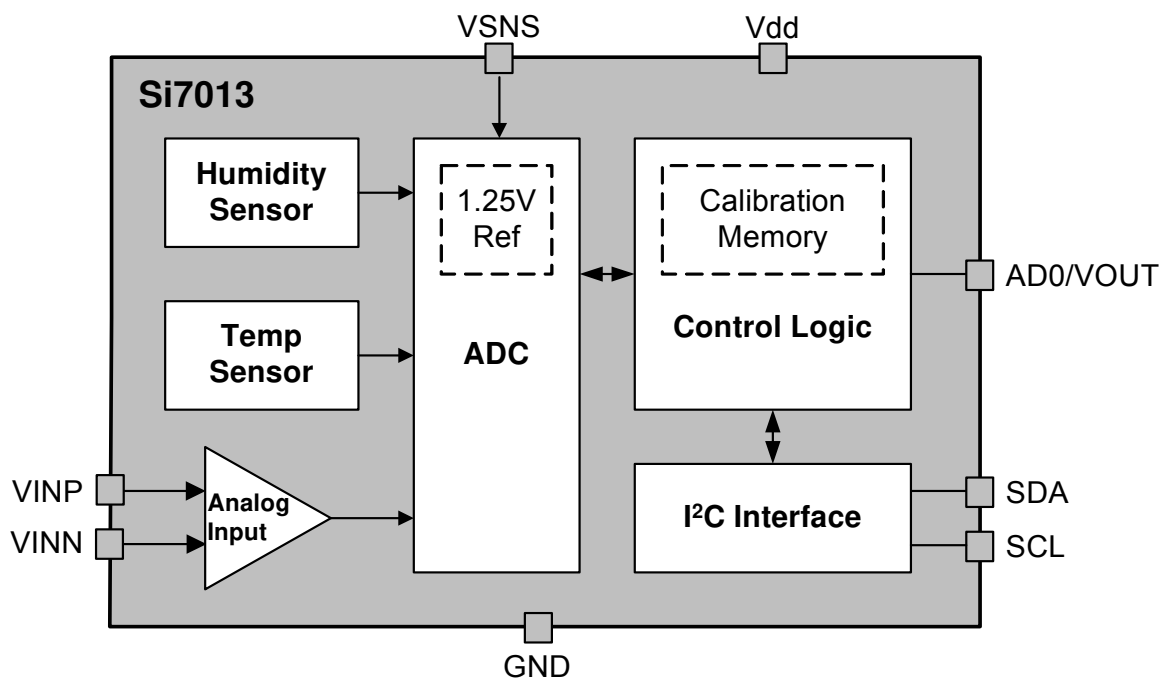


TABLE OF CONTENTS

| <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 | 24 |
| 5.3. Measuring Analog Voltage | 24 |
| 5.4. Nonlinear Correction of Voltage Inputs: | 25 |
| 5.5. Firmware Revision | 29 |
| 5.6. Heater | 29 |
| 5.7. Electronic Serial Number | 30 |
| 6. Control Registers | 31 |
| 6.1. Register Descriptions | 32 |
| 7. Pin Descriptions: Si7013 (Top View) | 35 |
| 8. Ordering Guide | 36 |
| 9. Package Outline | 37 |
| 9.1. Package Outline: 3x3 10-pin DFN | 37 |
| 9.2. Package Outline: 3x3 10-pin DFN with Protective Cover | 38 |
| 10. PCB Land Pattern and Solder Mask Design | 39 |
| 11. Top Marking | 40 |
| 11.1. Si7013 Top Marking | 40 |
| 11.2. Top Marking Explanation | 40 |
| 12. Additional Reference Resources | 41 |
| Document Change List | 42 |
| Contact Information | 43 |

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, RSTb 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 Read Thermistor. Duration is <50 μs for all commands except Read Thermistor, which has <150 μs duration.
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} | RH or Voltage Normal | — | 5.8 | 7 | ms |
| | | RH or Voltage Fast | — | 2.6 | 3.1 | ms |
| | | Temp Normal | — | 4 | 4.8 | ms |
| | | Temp Fast | — | 1.5 | 1.8 | ms |
| 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 |

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 Read Thermistor. Duration is <50 μ s for all commands except Read Thermistor, which has <150 μ s duration.
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 |
| 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 |

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 <10 μ s.
3. Pulses up to and including 50ns will be suppressed.

Si7013

Table 3. I²C Interface Specifications¹

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

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|-------------------------------------|--------------|----------------------------|-----|-----|-----|---------------|
| SDA Valid Time | $t_{VD;DAT}$ | From SCL low to data valid | — | — | 0.9 | μs |
| SDA Acknowledge Valid Time | $t_{VD;ACK}$ | From SCL low to data valid | — | — | 0.9 | μs |
| Suppressed Pulse Width ³ | t_{SPS} | | 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 <10 μs .
3. Pulses up to and including 50ns will be suppressed.

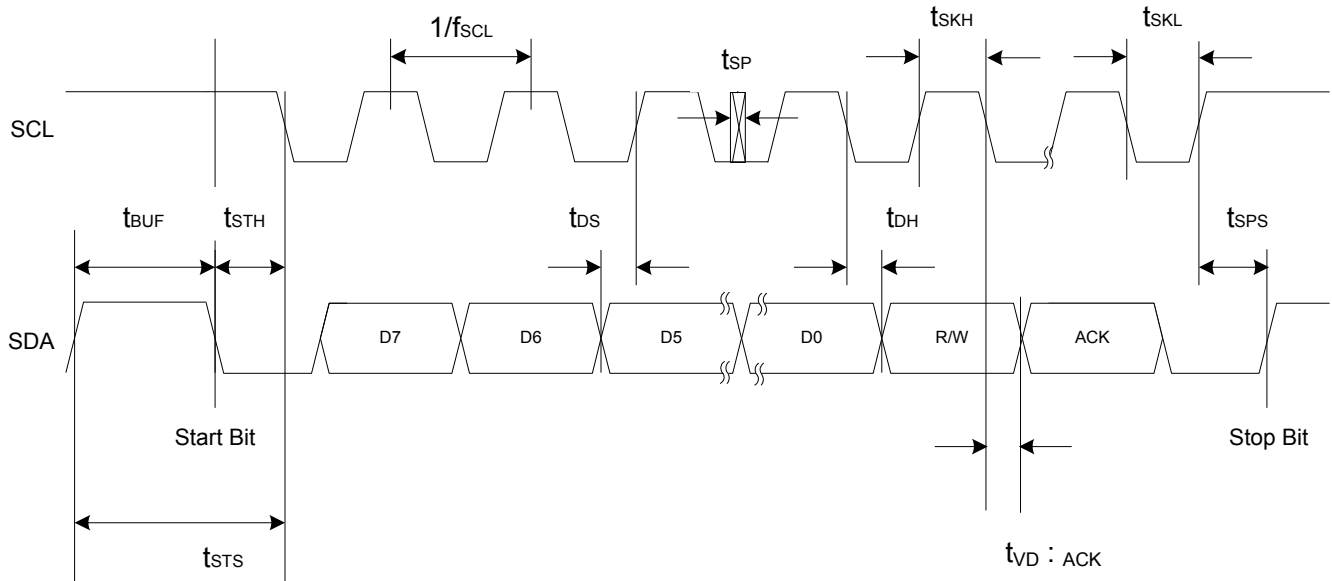


Figure 1. I²C Interface Timing Diagram

Table 4. Humidity Sensor1.9 ≤ V_{DD} ≤ 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 ^{3, 4} | | 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 ⁵ | T _{63%} | 1 m/s airflow | — | 18 | — | S |
| Drift vs. Temperature | | | — | 0.05 | — | %RH/°C |
| Hysteresis | | | — | ±1 | — | %RH |
| Long Term Stability ⁴ | | | — | ≤ 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. See conversion time specifications in Table 2.
3. 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.
4. 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”
5. Response time to a step change in RH. Time for the RH output to change by 63% of the total RH change.

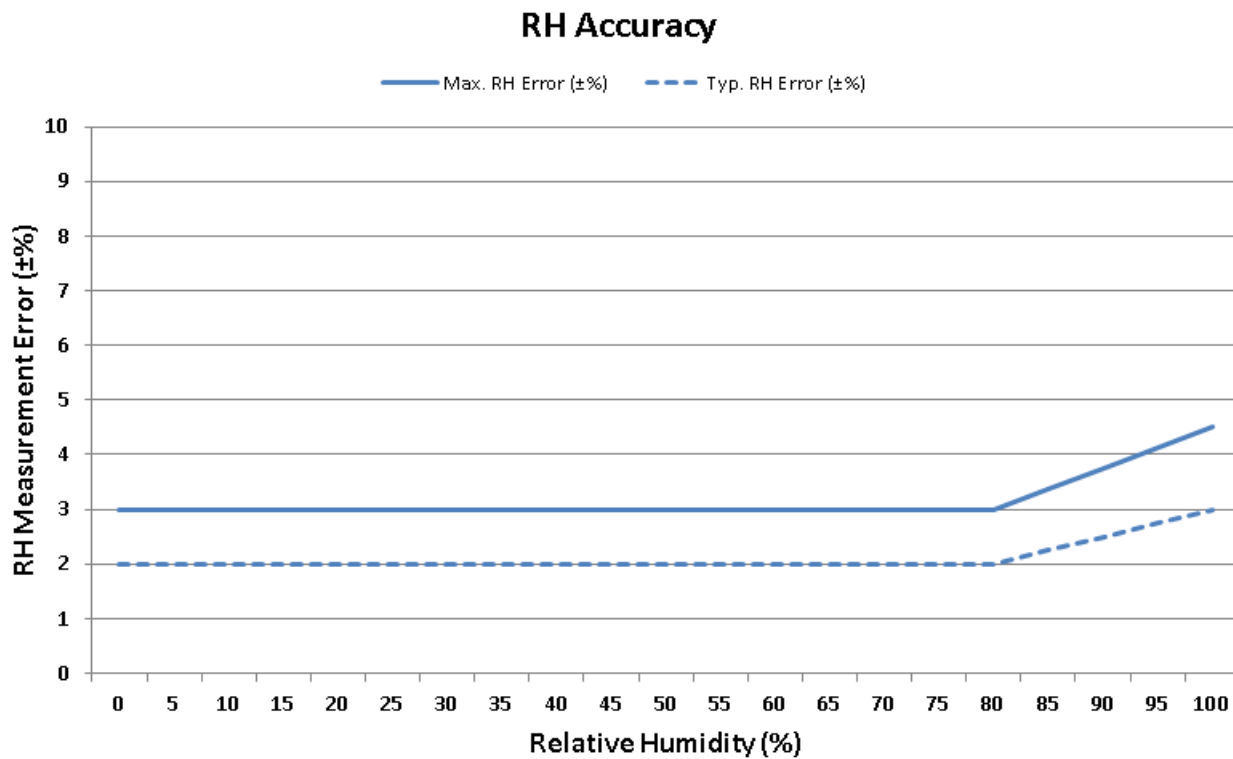


Figure 2. RH Accuracy at 30 °C

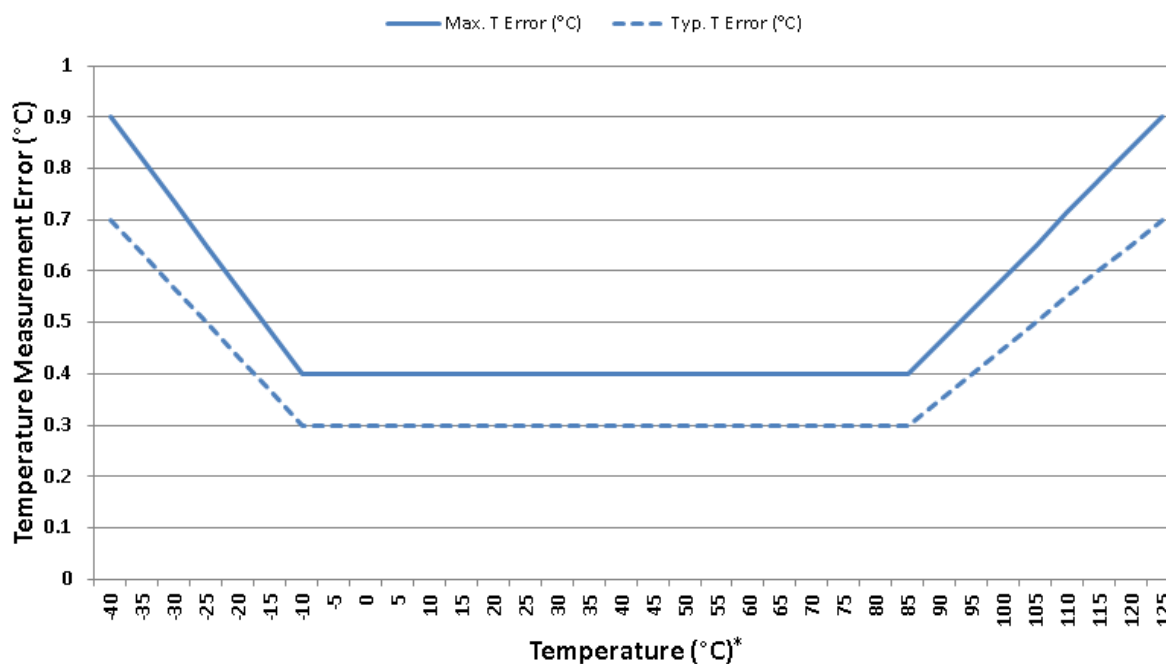
Table 5. Temperature Sensor

$1.9 \leq V_{DD} \leq 3.6$ 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.

Temperature Accuracy**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 (Y grade); default 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 | — | 25 | — | μV_{RMS} |
| Input Offset (Buffered Mode) | V_{OS} | $ VINP-VINN = 0$ | — | — | 10 | mV |
| Input Offset (Unbuffered Mode) | 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:

- In unbuffered mode, $R_{IN} \cdot C_{IN}$ should be < 0.5 usec. C_{IN} minimum is around 10 pF.
- In buffered mode, V_{INP} and V_{INN} must be > 0.5 V and $< V_{DD}$ for best performance.

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 Ratings¹

| Parameter | Symbol | Test Condition | Min | Typ | Max | Unit |
|------------------------------------|--------|----------------|------|-----|----------|------|
| Ambient temperature under bias | | | -55 | — | 125 | °C |
| Storage Temperature Figure 2 | | | -65 | — | 150 | °C |
| Voltage on I/O pins | | | -0.3 | — | VDD+0.3V | V |
| Voltage on VDD with respect to GND | | | -0.3 | — | 4.2 | 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.

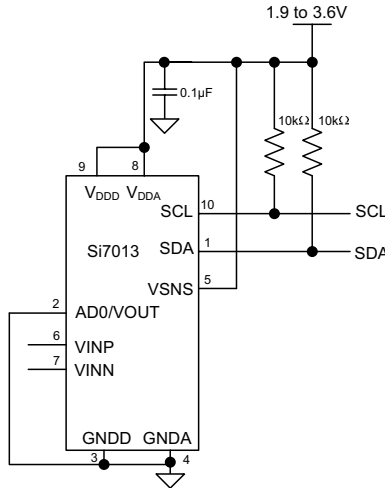


Figure 4. Typical Application Circuit for Relative Humidity and Temperature Measurement

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

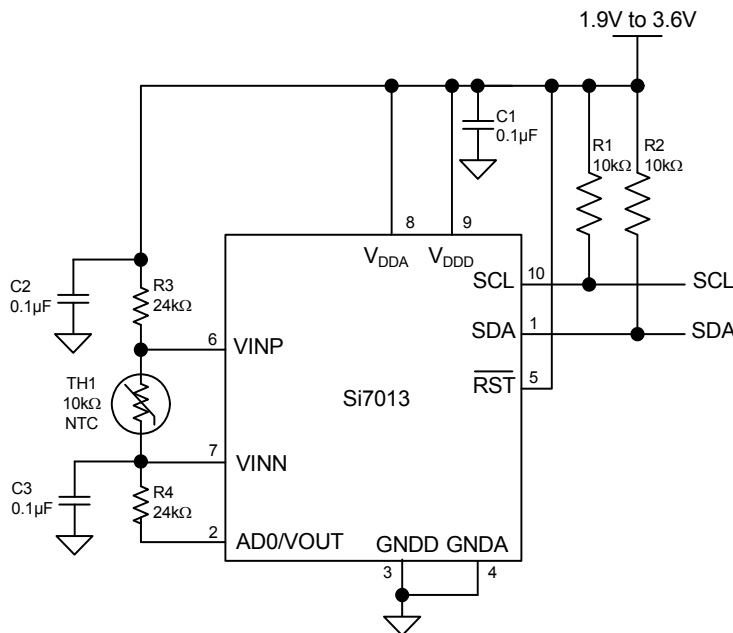


Figure 5. Typical Application Circuit for Thermistor Interface with AD0 = 1

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.

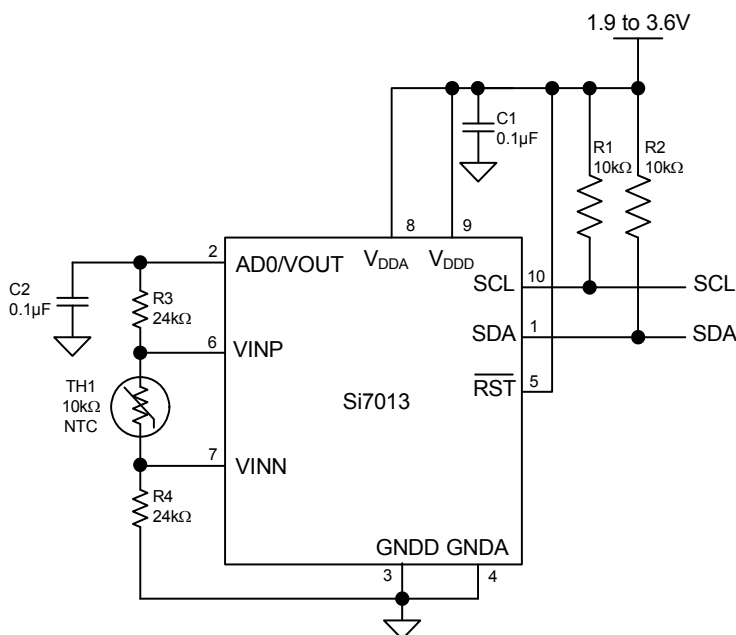


Figure 6. Typical Application Circuit for Thermistor Interface with AD0 = 0

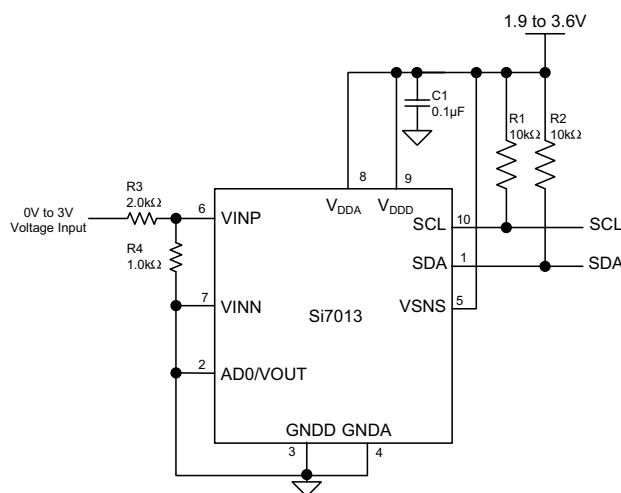


Figure 7. Typical Application Circuit for Single Ended 0 to 3 V Measurement

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 k Ω and 2 k Ω 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 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 | 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 | 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 | Silicon Labs |

4. Functional Description

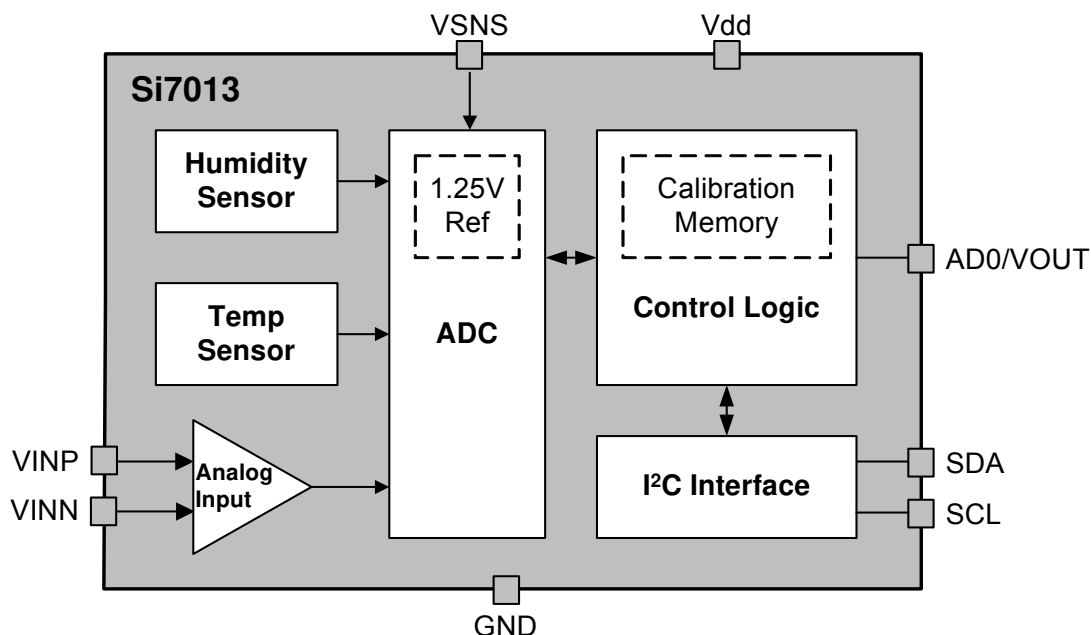


Figure 8. Si7013 Block Diagram

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.

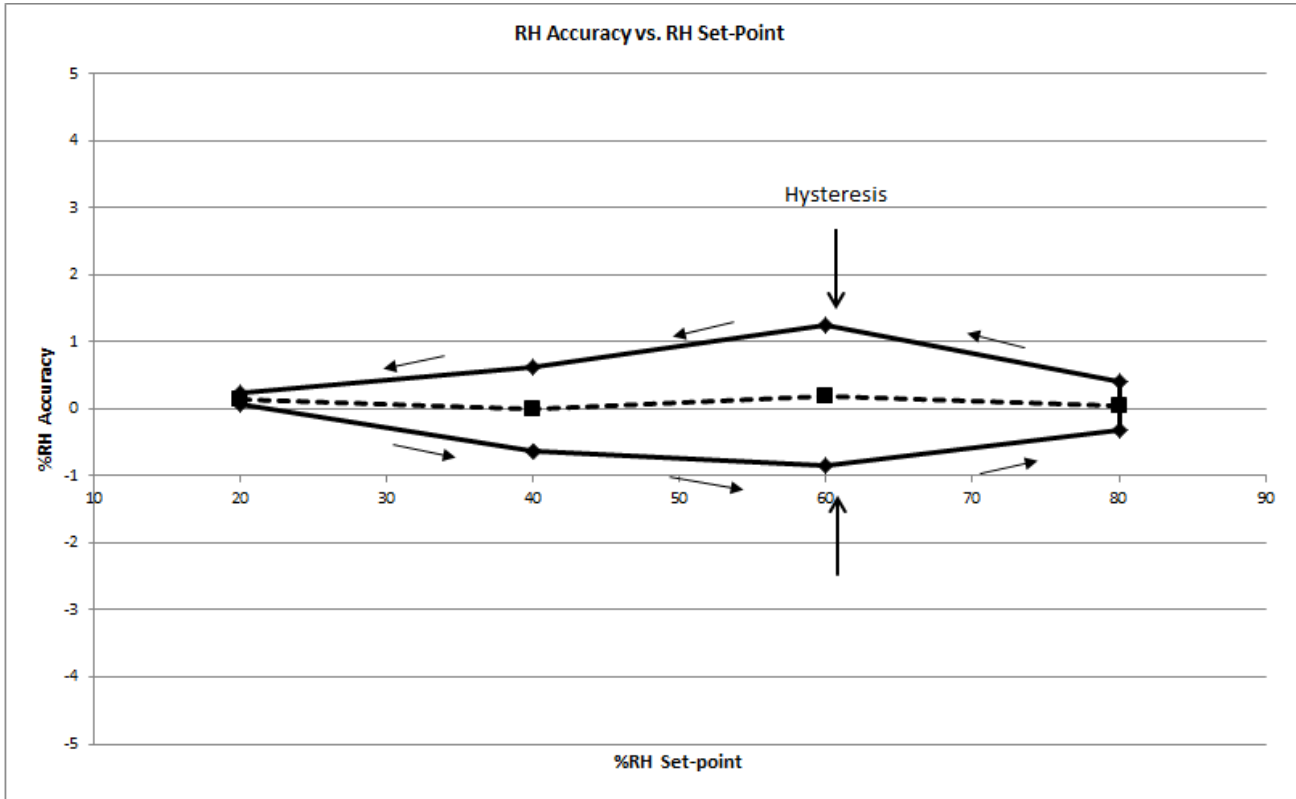


Figure 9. Measuring Sensor Accuracy Including Hysteresis

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 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 5 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.

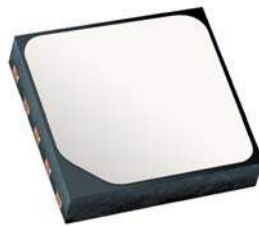


Figure 10. Si70xx with Factory-Installed Protective Cover

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, and excludes particulates down to 0.35 microns in size. 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 | ePTFE |
| Water Entry Pressure | 2.7 bar |
| Pore Size | 0.35 μ |
| Operating Temperature | -40 to 125 °C |
| Maximum Reflow Temperature | 260 °C |
| Oleophobicity (AATCC 118-1992) | 7 |
| 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, Hold Master Mode | 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 |

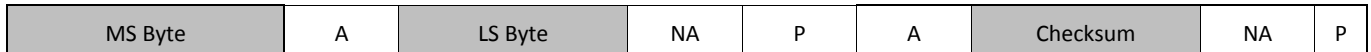
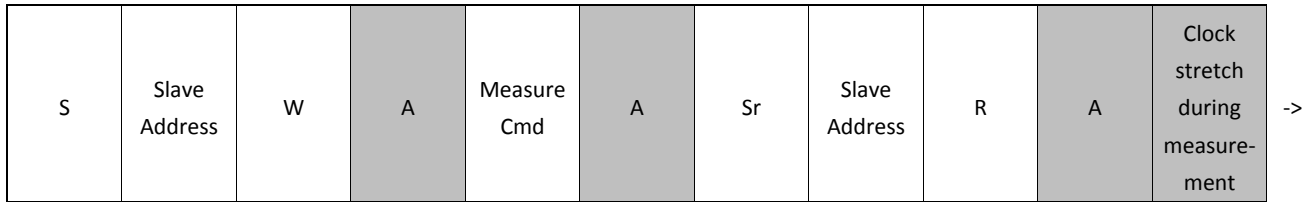
5.1. Issuing a Measurement Command

The measurement commands instruct the Si7013 to perform one of four possible measurements; Relative Humidity, Temperature, Auxiliary Temperature, or Analog Voltage. The procedure to issue any one of these commands is identical. 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; the chosen command code determines which mode is used.

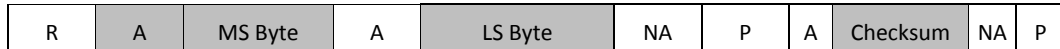
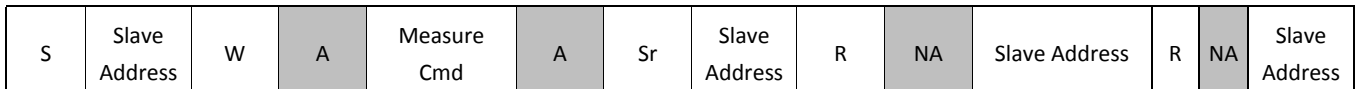
Optionally, a checksum byte can be returned from the slave for use in checking for transmission errors. The checksum byte will follow the least significant measurement byte if it is acknowledged by the master. The checksum byte is not returned if the master “not acknowledges” the least significant measurement byte. The checksum byte is calculated using a CRC generator polynomial of $x^8 + x^5 + x^4 + 1$ with an initialization of 0x00.



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)



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.

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.

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.

Si7013

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.

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 15. V_{REFP} is internally connected to V_{DDA} or to an internal 1.25 V reference voltage.

Table 15. Analog Input Ranges

| | V_{INP} Input Range | | V_{INN} Input Range | |
|------------------|-----------------------|-----|-----------------------|-----|
| | Min | Max | Min | Max |
| Buffered Input | 0.5 V | VDD | 0.5 V | VDD |
| Unbuffered Input | 0 V | VDD | 0 V | VDD |

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 1. Note that humidity measurements should not be performed when this bit is set.

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 10th 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 in > in2, out = out1 + slope1 * (in - in1) / 256

Else if in > in3, out = out2 + slope2 * (in - in2) / 256

Else if in > in4, out = out3 + slope3 * (in - in3) / 256

Else if in > in5, out = out4 + slope4 * (in - in4) / 256

Else if in > in6, out = out5 + slope5 * (in - in5) / 256

Else if in > in7, out = out6 + slope6 * (in - in6) / 256

Else if in > in8, out = out7 + slope7 * (in - in7) / 256

Else if in > in9, out = out8 + slope8 * (in - in8) / 256

Else out = out9 + slope9 * (in - in9)

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 16. 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 |

The command code 0xC5 is used for programming, so 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> 0x40R ACK 0x4C NACK <Stop Condition> where 0x4C is the expected return value of the read transaction.

5.4.3. Example Thermistor Calculations

For the Si7013 evaluation board with a 10 K ohm thermistor and two 24.3 K ohm 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:

$$V_{in} = V_{DD} * R_{thermistor} / (R_{thermistor} + 46.4 \text{ K})$$

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

$$\text{A/D counts} = 32768 * R_{thermistor} / (R_{thermistor} + 46.4 \text{ K})$$

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

Temperature °C = (Output_Code*175.72/65536 – 46.85), 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 –15C, –5C, 5C, 15C, 25C, 35C, 45C, 55C, 65C and 75C results in the following. The values in gray are the table entries for Si7013:

Table 17. 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 | | |

Si7013

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

Table 18. 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 upper nibble of the FWREV byte corresponds to the major firmware revision number, while the lower nibble of the FWREV byte corresponds to the minor firmware revision number. Therefore, firmware revision 1.0 would be encoded as 0x10 in the FWREV byte.

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 HEATER[2:0], the three least-significant bits in User Register 3. Turning on the heater will reduce the tendency of the humidity sensor to accumulate an offset due to "memory" of sustained high humidity conditions. Five different power levels are available. The various settings are described in Table 18.

Table 19. 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 VDD = 3.3 V. | |

Si7013

5.7. Electronic Serial Number

The Si7013 provides a serial number individualized for each device that can be read via the I²C serial interface. Two I²C 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 | 0x3A | 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 | 0x3C | ACK | 0X09 | 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 20. 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 | | MEASURE_MODE1 | MEASURE_MODE0 | 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 must always be written as zero; the result of a read operation on these bits is undefined.

Si7013

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 | VDD Status: 0: V _{DD} OK 1: V _{DD} Low The minimum recommended operating voltage is 1.9 V. A transition of the VDD status bit from 0 to 1 indicates that VDD is between 1.8 V and 1.9 V. If the VDD 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 | MEASURE_MODE1 | MEASURE_MODE0 | 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:D5 | MEASURE_MODE [1:0] | Measurement Mode. Selects the mode of the voltage measurement function. <table border="1" data-bbox="651 485 1450 957"> <thead> <tr> <th>D6</th> <th>D5</th> <th>Function</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>Voltage measurement hold master mode without thermistor correction. This is the recommended mode when temperature or humidity measurements are done.</td> </tr> <tr> <td>0</td> <td>1</td> <td>Voltage measurement hold master mode with thermistor correction. No humidity or internal temperature measurements are allowed in this mode.</td> </tr> <tr> <td>1</td> <td>0</td> <td>Voltage measurement no hold master mode with no thermistor correction.</td> </tr> <tr> <td>1</td> <td>1</td> <td>Voltage measurement no hold master mode with thermistor correction. No humidity or internal temperature measurements are allowed in this mode.</td> </tr> </tbody> </table> <p>Note: If no hold master mode is selected, ALL commands are no hold.</p> | D6 | D5 | Function | 0 | 0 | Voltage measurement hold master mode without thermistor correction. This is the recommended mode when temperature or humidity measurements are done. | 0 | 1 | Voltage measurement hold master mode with thermistor correction. No humidity or internal temperature measurements are allowed in this mode. | 1 | 0 | Voltage measurement no hold master mode with no thermistor correction. | 1 | 1 | Voltage measurement no hold master mode with thermistor correction. No humidity or internal temperature measurements are allowed in this mode. |
| D6 | D5 | Function | | | | | | | | | | | | | | | |
| 0 | 0 | Voltage measurement hold master mode without thermistor correction. This is the recommended mode when temperature or humidity measurements are done. | | | | | | | | | | | | | | | |
| 0 | 1 | Voltage measurement hold master mode with thermistor correction. No humidity or internal temperature measurements are allowed in this mode. | | | | | | | | | | | | | | | |
| 1 | 0 | Voltage measurement no hold master mode with no thermistor correction. | | | | | | | | | | | | | | | |
| 1 | 1 | Voltage measurement no hold master mode with thermistor correction. No humidity or internal temperature measurements are allowed in this mode. | | | | | | | | | | | | | | | |
| D4 | CONV_TIME | Conversion Time. Selects conversion time and noise floor of the voltage ADC. <table border="1" data-bbox="641 1150 1385 1297"> <tbody> <tr> <td>0</td> <td>Conversion time 7 ms max noise floor 25 μV typical with $V_{REF} = 1.25$ V.</td> </tr> <tr> <td>1</td> <td>Conversion time 3.1 ms max noise floor 50 μV typical with $V_{REF} = 1.25$ V.</td> </tr> </tbody> </table> | 0 | Conversion time 7 ms max noise floor 25 μ V typical with $V_{REF} = 1.25$ V. | 1 | Conversion time 3.1 ms max noise floor 50 μ V typical with $V_{REF} = 1.25$ V. | | | | | | | | | | | |
| 0 | Conversion time 7 ms max noise floor 25 μ V typical with $V_{REF} = 1.25$ V. | | | | | | | | | | | | | | | | |
| 1 | Conversion time 3.1 ms max noise floor 50 μ V typical with $V_{REF} = 1.25$ V. | | | | | | | | | | | | | | | | |
| 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 Note: Default is powerup state of VOUT pin | | | | | | | | | | | | | | | |
| <p>*Note: VOUT is generally used for driving an external thermistor interface. Default setting is the same as the power up setting.</p> | | | | | | | | | | | | | | | | | |

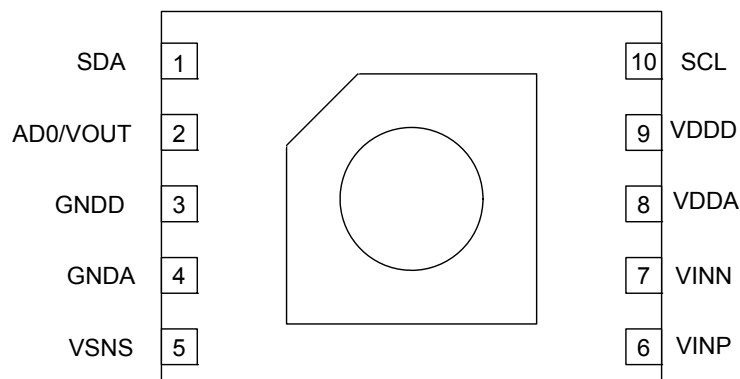
Register 3. User Register 3

| 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 | 94.20 mA | |
| D7,D6, D5,D4 | RSVD | Reserved | | | | |

7. Pin Descriptions: Si7013 (Top View)



| Pin Name | Pin # | Pin Description |
|------------------|--------|---|
| SDA | 1 | I ² 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 VDD.* |
| 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 ² C clock |
| T _{GND} | 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 21. Device Ordering Guide

| P/N | Description | Max. Accuracy | | Pkg | Operating Range (°C) | Protective Cover | Packing Format |
|-----------------|---|---------------|------|-------|----------------------|------------------|----------------|
| | | Temp | RH | | | | |
| Si7013-A10-GM | Digital temperature/ humidity sensor | ±0.4 °C | ± 3% | DFN 6 | -40 to +85 °C | N | Tube |
| Si7013-A10-GMR | Digital temperature/ humidity sensor | ±0.4 °C | ± 3% | DFN 6 | -40 to +85 °C | N | Tape & Reel |
| Si7013-A10-GM1 | Digital temperature/ humidity sensor | ±0.4 °C | ± 3% | DFN 6 | -40 to +85 °C | Y | Cut Tape |
| Si7013-A10-GM1R | Digital temperature/ humidity sensor | ±0.4 °C | ± 3% | DFN 6 | -40 to +85 °C | Y | Tape & Reel |
| Si7013-A10-IM | Digital temperature/ humidity sensor— industrial temp range | ±0.4 °C | ± 3% | DFN 6 | -40 to +125 °C | N | Tube |
| Si7013-A10-IMR | Digital temperature/ humidity sensor— industrial temp range | ±0.4 °C | ± 3% | DFN 6 | -40 to +125 °C | N | Tape & Reel |
| Si7013-A10-IM1 | Digital temperature/ humidity sensor— industrial temp range | ±0.4 °C | ± 3% | DFN 6 | -40 to +125 °C | Y | Cut Tape |
| Si7013-A10-IM1R | Digital temperature/ humidity sensor— industrial temp range | ±0.4 °C | ± 3% | DFN 6 | -40 to +125 °C | Y | Tape & Reel |
| Si7013-A10-YM | Digital temperature/ humidity sensor— automotive | ±0.4 °C | ± 3% | DFN 6 | -40 to +125 °C | N | Tube |
| Si7013-A10-YMR | Digital temperature/ humidity sensor— automotive | ±0.4 °C | ± 3% | DFN 6 | -40 to +125 °C | N | Tape & Reel |
| Si7013-A10-YM1 | Digital temperature/ humidity sensor— automotive | ±0.4 °C | ± 3% | DFN 6 | -40 to +125 °C | Y | Cut Tape |
| Si7013-A10-YM1R | Digital temperature/ humidity sensor— automotive | ±0.4 °C | ± 3% | DFN 6 | -40 to +125 °C | Y | Tape & Reel |

9. Package Outline

9.1. Package Outline: 3x3 10-pin DFN

Figure 11 illustrates the package details for the Si7013. Table 21 lists the values for the dimensions shown in the illustration.

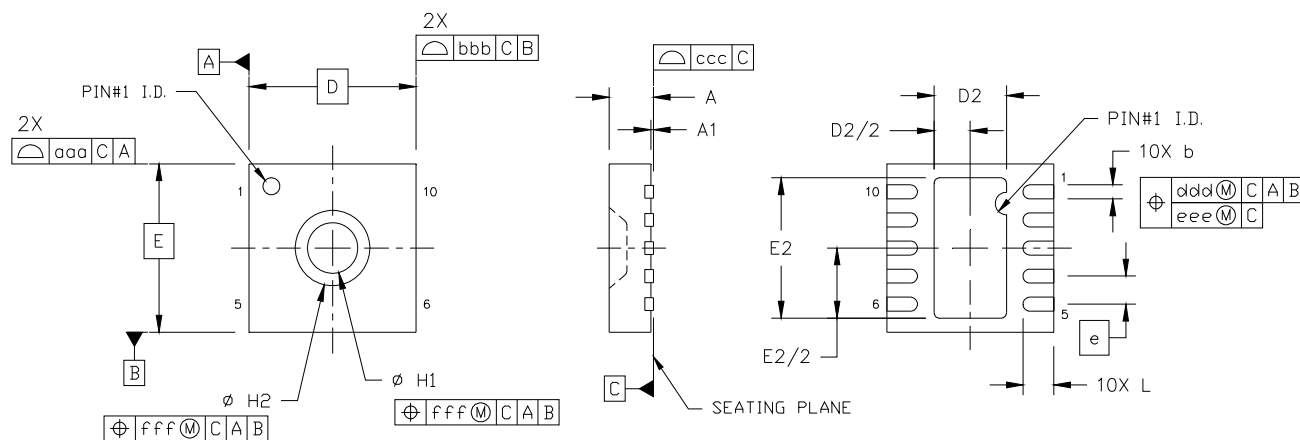


Figure 11. 10-pin DFN Package Drawing

Table 22. 10-Pin DFN Package Dimensions

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

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 22 lists the values for the dimensions shown in the illustration.

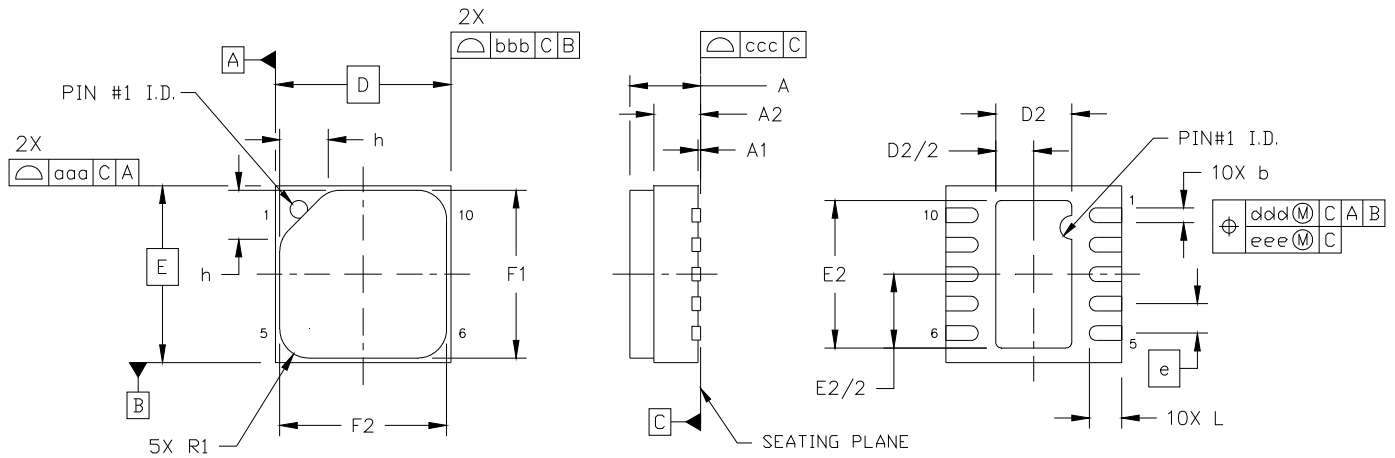


Figure 12. 10-pin DFN with Protective Cover

Table 23. 10-pin DFN with Protective Cover Diagram Dimensions

| Dimension | Min | Nom | Max |
|-----------|-----------|------|------|
| A | — | — | 1.21 |
| A1 | 0.00 | 0.02 | 0.05 |
| A2 | 0.70 | 0.75 | 0.80 |
| b | 0.18 | 0.25 | 0.30 |
| D | 3.00 BSC. | | |
| D2 | 1.20 | 1.30 | 1.40 |
| e | 0.50 BSC. | | |
| E | 3.00 BSC. | | |
| E2 | 2.40 | 2.50 | 2.60 |

| Dimension | Min | Nom | Max |
|-----------|------|------|------|
| F1 | 2.80 | 2.85 | 2.90 |
| F2 | 2.80 | 2.85 | 2.90 |
| h | 0.76 | 0.83 | 0.90 |
| L | 0.50 | 0.55 | 0.60 |
| R1 | 0.45 | 0.50 | 0.55 |
| aaa | 0.10 | | |
| bbb | 0.10 | | |
| ccc | 0.05 | | |
| ddd | 0.10 | | |
| eee | 0.05 | | |

Notes:

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

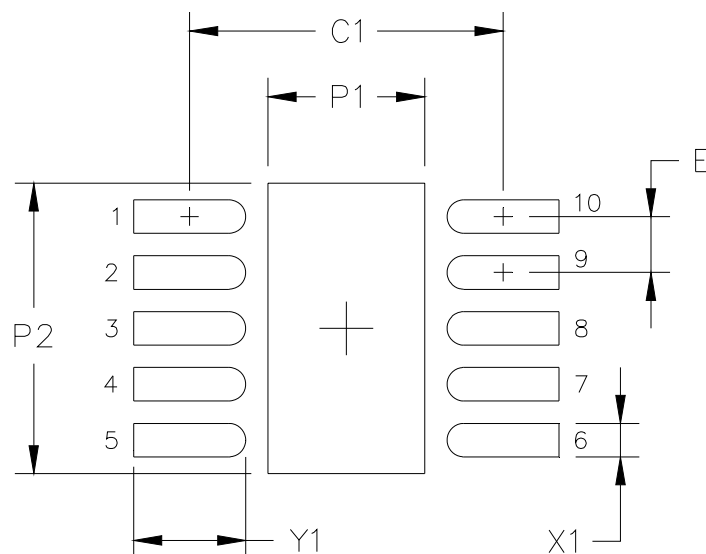


Table 24. PCB Land Pattern Dimensions

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

Notes:

General

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

Solder Mask Design

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

Stencil Design

- A stainless steel, laser-cut and electro-polished stencil with trapezoidal walls should be used to assure good solder paste release.
- The stencil thickness should be 0.125 mm (5 mils).
- The ratio of stencil aperture to land pad size should be 1:1 for all perimeter pins.
- 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%.

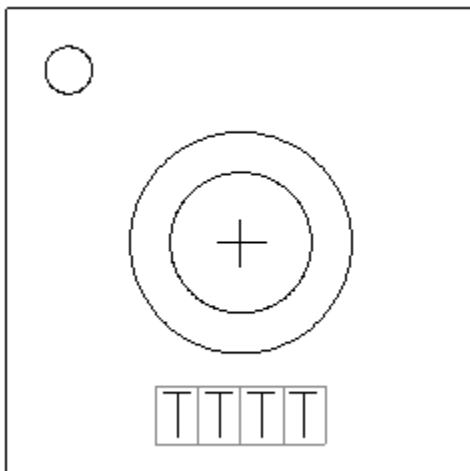
Card Assembly

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

Si7013

11. Top Marking

11.1. Si7013 Top Marking



11.2. Top Marking Explanation

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

12. Additional Reference Resources

- AN607: Si70xx Humidity Sensor Designer's Guide

DOCUMENT CHANGE LIST

Revision 0.1 to Revision 0.6

- Updates to Section 1. Electrical Specifications.
- Updated Table 2. General Specifications.
- Updated Figure 1. I2C Interface Timing Diagram.
- Updated Table 6. Voltage Converter Specifications.
- Updated Table 7. Thermal Characteristics.
- Updated Section 2. Typical Applications Circuits.
- Updated Figure 5. Typical Application Circuit for Thermistor Interface with AD0 = 1.
- Updated Table 15. I2C Command Table.
- Updated Section 4.4 PCB Assembly.
- Updated Section 5.3 Measuring Relative Humidity.
- Updated Section 5.4 Measuring Temperature.
- Updated Section 5.6 Nonlinear Correction of Voltage Inputs.
- Updated Section 5.7 Heater.
- Removed Section 5.8 Device Identification and added device identification information to Section 5.9.
- Updated Section 6. Control Registers.
- Updated Section 9. Package Outline.
- Updated Section 11. Top Marking.

- Added Section 5.5. Firmware Revision
- Updated Section 6. Control Registers
- Updated Table 21. Device Ordering Guide

Revision 0.6 to Revision 0.95

- Updated Table 1. Recommended Operating Conditions
- Updated Table 2. General Specifications
- Updated Table 3. I2C Interface Specifications
- Updated Table 4 Humidity Sensor
- Updated Table 5. Temperature Sensor
- Updated Table 8. Absolute Maximum Ratings
- Updated Figure 5. Typical Application Circuit for Thermistor Interface with AD0 = 1
- Updated Figure 6. Typical Application Circuit for Thermistor Interface with AD0 = 0
- Updated Figure 8. Si7013 Block Diagram
- Updated Section 4.1. Relative Humidity Sensor Accuracy
- Updated Section 4.4.1. Soldering
- Updated Table 15. Analog Input Ranges
- Updated Section 5.1. Issuing a Measurement Command
- Updated Section 5.2. Reading and Writing User Registers
- Updated Section 5.4. Nonlinear Correction of Voltage Inputs

CONTACT INFORMATION

Silicon Laboratories Inc.

400 West Cesar Chavez
Austin, TX 78701
Tel: 1+(512) 416-8500
Fax: 1+(512) 416-9669
Toll Free: 1+(877) 444-3032

Please visit the Silicon Labs Technical Support web page:
<https://www.silabs.com/support/pages/contacttechnicalsupport.aspx>
and register to submit a technical support request.

Patent Notice

Silicon Labs invests in research and development to help our customers differentiate in the market with innovative low-power, small size, analog-intensive mixed-signal solutions. Silicon Labs' extensive patent portfolio is a testament to our unique approach and world-class engineering team.

The information in this document is believed to be accurate in all respects at the time of publication but is subject to change without notice. Silicon Laboratories assumes no responsibility for errors and omissions, and disclaims responsibility for any consequences resulting from the use of information included herein. Additionally, Silicon Laboratories assumes no responsibility for the functioning of undescribed features or parameters. Silicon Laboratories reserves the right to make changes without further notice. Silicon Laboratories makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Silicon Laboratories assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. Silicon Laboratories products are not designed, intended, or authorized for use in applications intended to support or sustain life, or for any other application in which the failure of the Silicon Laboratories product could create a situation where personal injury or death may occur. Should Buyer purchase or use Silicon Laboratories products for any such unintended or unauthorized application, Buyer shall indemnify and hold Silicon Laboratories harmless against all claims and damages.

Silicon Laboratories and Silicon Labs are trademarks of Silicon Laboratories Inc.
Other products or brandnames mentioned herein are trademarks or registered trademarks of their respective holders.