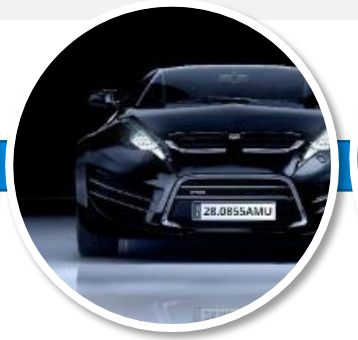
# Si70xx Relative Humidity & Temperature Sensors On Board Training

DANIEL HONNIBALL | MARCH 2018

# Si70xx Humidity & Temperature Sensor Applications

Internet of Things

Industrial Control
Remote monitoring and asset tracking



Automotive

Internet Infrastructure

HVAC
Home Automation
Consumer Devices

Wearable temperature sensing

Healthcare
CPAP machines
Patient Temperature Management

- Silicon Labs' Si70xx temperature and humidity sensors used in many applications
  - Industry-leading low power consumption extends battery life
  - High accuracy meets the needs of demanding applications
  - Fully factory calibrated
  - 14-bit ADC delivers higher precision than MCU-based temperature sensors
  - 0.1°C sensor (Si7051) can be used in applications measuring human body temperature



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# Why Measure Humidity?

- Humidity is meaningful in determining comfort level
  - Heating and air conditioning
  - Can significantly reduce HVAC cost by adding humidity control
  - Automatic activation of vent fans
    - Mold prevention and comfort
  - Weather stations
- Humidity control for high value goods
  - Detect if a sealed case with desiccant has been breached
  - Perishable goods monitoring
  - Electronics cabinets
- Industrial applications
  - Humidity affects paper handling, chemical processing
- Medical applications (Respiratory health, comfort)
- Automotive (cabin comfort and window fog)




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# RH/Temp Sensors Value Proposition

- Accurate sensing
  - RH accuracy as good as ±3% RH
  - Best in class temperature accuracy of +/-0.1°C
  - -40 to +125 °C temperature range
- Industry's lowest power consumption
  - 1 µW @ 1.8 V, 8-bit, 1 sample/second (RH)
  - <0.5uW @ 1.8 V, 8-bit, 1 sample/second (Temp)
- Si70xx feature set provides unmatched ease of use
  - Full factory calibration and internal compensation
  - Industry-standard footprint and software interface
  - Support for 2-zone temperature sensor (Si7013)

TEMPERATURE

HUMIDITY



**The simpler, greener way to measure relative humidity & temperature**



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# Relative Humidity (%RH) and Dew Point

- Moisture (H2O) content in air:
  - Saturated vapor pressure (SVP)
    - Maximum water that the air can hold
    - Very dependent on temperature
  - Absolute vapor pressure (AVP)
    - Actual amount of water present
- Relative Humidity definition
  - %RH = AVP / SVP
- Dew point definition
  - For a given RH and temp, the temperature at which condensation would form if the air were cooled
  - Meaningful as an indicator of comfort
- Key point - heating air just 1°C drops relative humidity by 5%
  - Because the air can hold more humidity (SVP increases)
  - Small amounts of heating can have large effect on relative humidity

%RH is a measurement for how much water is in the air versus how much it can hold


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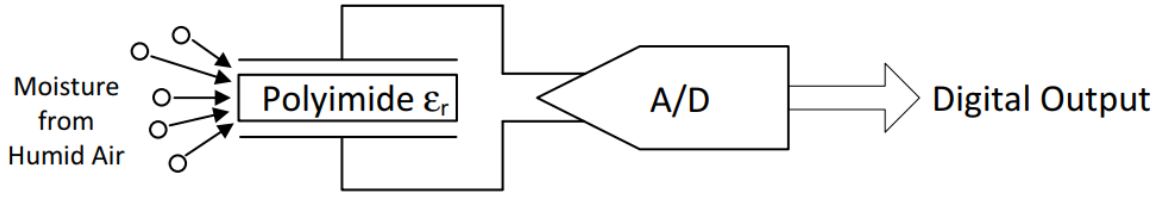
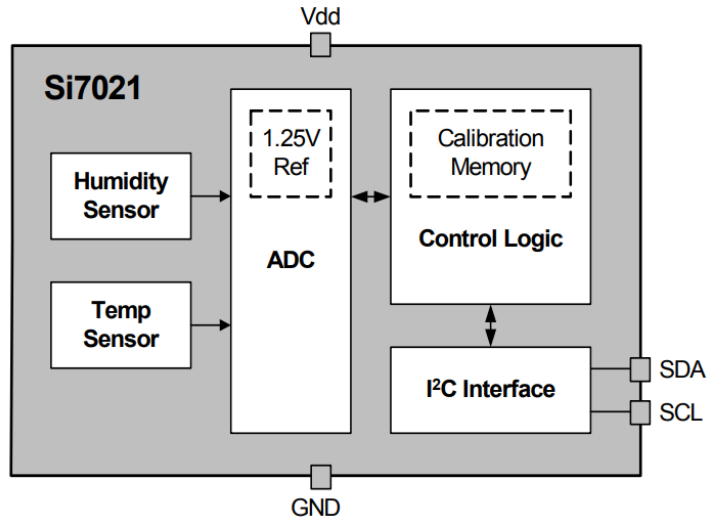
# Functional Description

- Humidity is sensed by measuring the capacitance change of a polyimide film applied to the surface of the die
  - Polyimide film is exposed through a cavity in the package
- Capacitance of polyimide film increases as the ambient air becomes more humid
  - Permittivity of dielectric material is proportional to the amount of moisture it has absorbed
- Temperature is sensed by a precision Vbe referenced circuit on the die
  - Thermal input is through the DFN exposed paddle (ePAD) under the package
- Both temperature and humidity are measured in extremely close proximity on the same monolithic device




εr increases as moisture is absorbed



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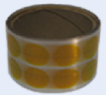
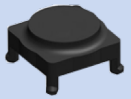
# Humidity Sensor Protective Cover

- Select Si70xx humidity sensors are available with an optional hydrophobic protective cover
  - Pre-installed by Silicon Labs
- Available on Si7006, Si7013, Si7020 & Si7021
- Made of expanded polytetrafluoroethylene
  - (ePTFE) aka Gore-Tex®
- Protects sensor from liquids, dust, light & ESD
  - <1 µm pore blocks dust & liquid, passes $H_2O$ vapor
  - IP67 rated to block liquid water up to 1m depth
  - SMT and reflow compatible
    - Solder and flux resistant (up to 260 °C)
- Cover has minimal impact on response time

Si7013 with cover


Si7013 without cover

| Option | Protection During PCB Assy. | Protection During Operation | Additional Labor Cost |
|---|---|---|---|
| **Si70xx Filter Cover**  | **Yes IP67** | **Yes IP67** | **None** |
| Competitors Kapton Tape  | Yes | None | ~$0.40 |
| Competitors Plastic Cap  | None | Yes | ~$0.20 |

# Design-in Challenges with All RH Sensors

- **RH sensors have unique design and use considerations**
  - Must be calibrated, protected, and work over extended periods of time

| Issue(s) | Legacy Solutions | Silicon Labs Si70xx |
|---|---|---|
| Calibration | Discretes/analog circuits require calibration; not interchangeable | Factory calibrated and interchangeable |
| Protection during PCB assembly; rehydrating the sensor afterward | Use of Kapton® tape or sockets or optional pre-installed tape; forced rehydration required | Convenient cover protects before, during and after assembly; rehydrates at ambient conditions |
| Lifetime protection from damage/contamination | Disclaimed in data sheet; optional filters offered by a few vendors | |
| Impact of long exposure to extremes of temperature/RH | Readings can drift/shift; known characteristic of polymers; disclaimed in data sheets | Can be reduced using on-chip heater |
| Temperature correction and linearization of RH readings | Polynomial correction on MCU host | On chip for Si7013/20/21 |
| Compatibility with pick-and-place and/or solder reflow | Many MCMs/hybrids/modules/ discretes are incompatible | Standard SMT manufacturing flow with pick-and-place |

- **Si70xx solves these key customer issues**
  - Reducing design risk, manufacturing time, and cost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# Thermal Isolation

- One of the more common customer issues is thermal isolation
- The Si70xx parts measure the environment they are in
  - Just 1C of heating reduces humidity by 5%
- If the system produces heat the Si70xx must be thermally isolated from the system
- Also, mount the Si70xx on a paddle to thermally connect it to the outside environment
- Please refer to AN607 and AN1026 for more detail
- Best accuracy is achieved by isolating the sensor. In some cases, compensation for the system heating as well as thermal mass of the system must be done as well

EFM32 STK


EFM32 STK's have an example of a recommended PCB design for good thermal isolation

Thunderboard Sense




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# Handling Requirements for Humidity Sensors

- All humidity sensors including competitive parts have these issues
- Improper handling is a major source of customer issues
  - While this is covered in data sheets and AN607 it is worth emphasizing
- Use reflow soldering only
  - Hand soldering, wave soldering and other methods like vapor phase reflow can cause accuracy issues
- Avoid board washing after soldering
  - Organic solvents will cause issues
  - Low pressure water spray can be done with care but is best avoided
- Be careful about conformal coating
  - Don’t get it on the part
  - Use low VOC conformal coating materials
  - Dry in a well ventilated area
  - Check the conformal coating process
- Be careful about storage
  - Store devices and completed boards in a temperature and humidity controlled area
  - Avoid organic fumes – paint, glue etc.
  - Do not use polyethylene bags (typically pink, yellow or blue antistatic bags)
    - Metallic sealable moisture barrier bags work well


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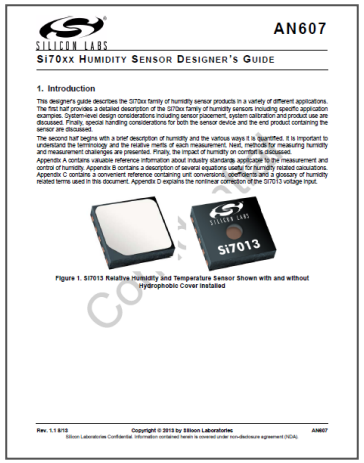
# Temperature and Humidity Sensor Collateral Links

- Collateral
  - Si7006/7/13/20/21/22/23/34 data sheets
  - AN607: Si70xx Humidity Sensor Designer's Guide
  - AN1026: Si70xx Temperature Sensor Designer's Guide
  - White Paper: *Compact Digital Humidity Sensor IC Extends Battery Life and Reduces Design Complexity*
- Software
  - Evaluation Software GUI supports all Si70xx devices
    - Si7013USB-DONGLE, Si7006-07-EVB, Si7022-23-EVB, Si7034-EVB
  - Thunderboard™ iOS & Android apps for React and Sense
  - Weather station demo in Simplicity Studio
  - Linux driver example code (*Lm-sensors* framework)

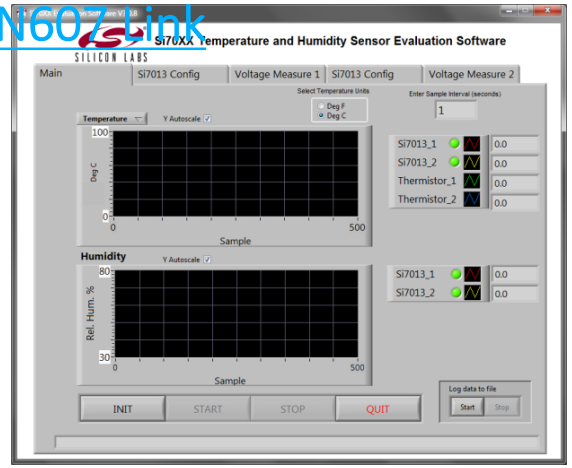
**All Si70xx collateral and software is available at**
**www.silabs.com/products/sensors/humidity-sensors/**

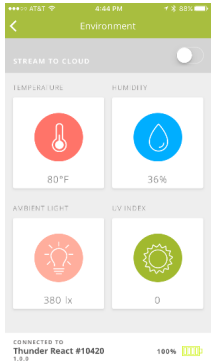

AN607
SILICON LABS
Si70xx Humidity Sensor Designer's Guide
1. Introduction
Figure 1. Si7013 Relative Humidity and Temperature Sensor Shown with and without Hydrophobic Cover Installed

%RH App Note

Temperature AN1026 Link

AN607 Link



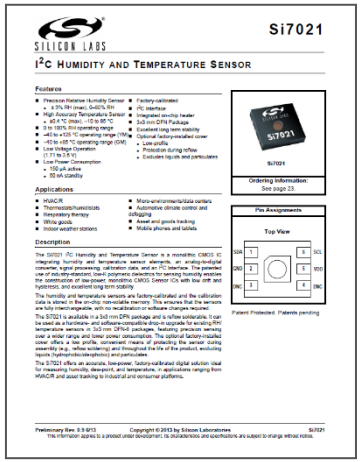




Si7021 Datasheet Link

Si7020 Datasheet Link

Si7006 Datasheet Link

Si7013 Datasheet Link


Si7021
SILICON LABS
I²C Humidity and Temperature Sensor
Features
Applications
Description
Pin Assignments
Top View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# Temperature and Humidity portfolio

## Temperature Sensors

| Part Number | Temp Accuracy (max) | Package | VDD (V) |
|---|---|---|---|
| Si7050-A20-IM | ±1.0 °C | 3x3 mm QFN | 1.9 – 3.6 |
| Si7051-A20-IM | ±0.1˚C (36-41˚C) | 3x3 mm QFN | 1.9 – 3.6 |
| Si7053-A20-IM | ±0.3 °C | 3x3 mm QFN | 1.9 – 3.6 |
| Si7054-A20-IM | ±0.4 °C | 3x3 mm QFN | 1.9 – 3.6 |
| Si7055-A20-IM | ±0.5 °C | 3x3 mm QFN | 1.9 – 3.6 |
| Si7057-A10-IM | ±0.35 °C | 2x2 mm QFN | 1.67 – 1.98 |
| Si7058-A10-IM | ±0.5 °C | 2x2 mm QFN | 1.67 – 1.98 |
| Si7059-A10-IM | ±1.0 °C | 2x2 mm QFN | 1.67 – 1.98 |
| Si7060/65-B01-IV | +/-1°C | SOT23-5 | 1.71-5.5V |

## Humidity Sensors

| Part Number | Accuracy (Max) | Package Size | VDD (V) |
|---|---|---|---|
| Si7034 | ±4% RH<br>±0.4 °C | 2x2 mm QFN | 1.67 – 1.98 V |
| Si7013 (w/2-zone temp sensor)<br>Si7021 (I2C)<br>Si7023 (PWM) | ±3% RH<br>±0.4 °C | 3x3 mm QFN | 1.9 – 3.6 V |
| Si7020 (I2C)<br>Si7022 (PWM) | ±4% RH<br>±0.4 °C | 3x3 mm QFN | 1.9 – 3.6 V |
| Si7006 (I2C)<br>Si7007 (PWM) | ±5% RH<br>±1.0 °C | 3x3 mm QFN | 1.9 – 3.6 V |

- Si7060 new family of temperature sensors
  - Equipped with output alert pin



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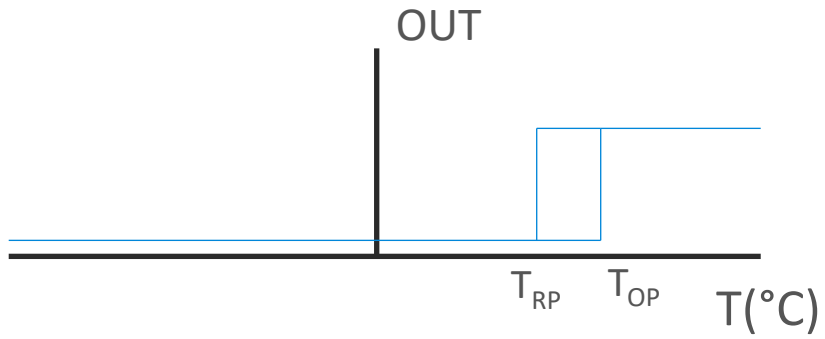
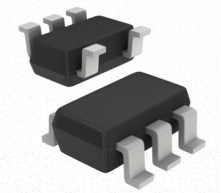
# Si7060 Temp Sensor: Autonomous Sampling w/ Output Alert

- Accuracy: ±1.0˚C (max) [0°C to 70°C]
  - ±2.0°C (max) [-40°C to 125°C]
- I2C configurable
- 4x I2C address options (configured at factory)
- Configure output threshold over I2C
- Full Sleep-Mode with 50nA Supply Current
- Autonomous Mode: Autonomously monitor temperature with an output alert sampling at 5Hz Idd(avg) = 0.4uA
- Active Mode: Temperature conversions performed on I2C command. Numerical measurements read out as 15-bit value

**Configurable Output Alert**




**SOT23 5-pin Package**



SOT23-5



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# Si7051 High Accuracy Temperature Sensor

- Medical and Consumer Medical applications require ±0.1 ˚C
  - Typical digital temperature sensors have an accuracy of ± 0.5˚C
  - More advanced products (e.g. Si7053) have accuracies ± 0.3˚C
    - Still not good enough for the human body temperature applications

  - Si7051 meets the requirement of ±0.1˚C max
    - Only a few very high end products from competitors meet this
    - Usually thermometers must go through expensive secondary calibration step
    - Si7051 typically lower priced than competing alternatives

  - Exceeds ASTM E1112 “Standard Specification for Electronic Thermometer for Intermittent Determination of Patient Temperature”
    - ±0.1°C (35.8°C to 41°C)
    - ±0.13°C (20°C to 70°C)
    - ±0.25°C (-40°C to +125°C)


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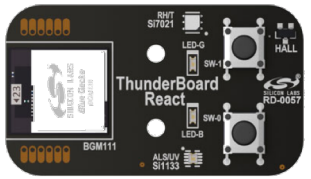
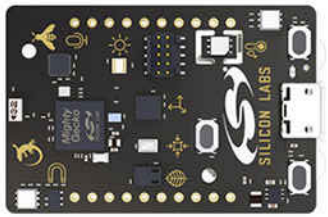
# Temperature and Humidity Sensor Tools

| P/N | Description |
|---|---|
| Si7013USB-DONGLE | General-purpose evaluation platform for Si7013, Si7020 & Si7021 |
| Si7022-23-EVB | General-purpose evaluation platform for Si7022 and Si7023 |
| Si7006-07-EVB | General-purpose evaluation platform for Si7006 and Si7007 |
| Si7034-EVB | General-purpose evaluation platform for Si7034 |
| Si7050/1/3/4/5-EVB | Evaluation Kits for Si7050 through Si7055 |
| Si7057-EVB | Evaluation Kit for Si7057/8/9 |
| Thunderboard™ React | BLE module Sensor Evaluation Platform with Si7021 |
| Thunderboard™ Sense | Multi protocol SOC Sensor Evaluation Platform with Si7021 |
| SLSTK3201A | EFM32 Zero Gecko Starter Kit with Weather Station Demo |



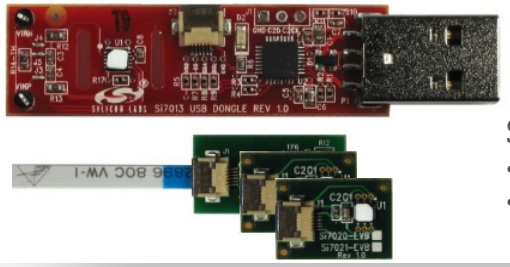

**Thunderboard™ React**

- Si7021 RHT Sensor
- Si1133 UV and Ambient Light Sensor
- iOS and Android demo apps



**Thunderboard™ Sense**

- Si7021 RHT Sensor
- Si1133 UV and Ambient Light Sensor
- iOS and Android demo apps

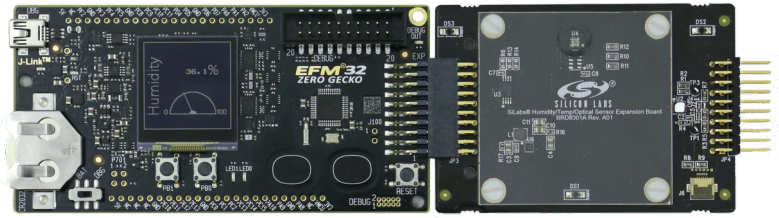


**Si7013USB-DONGLE**

- USB Dongle with Si7013
- “Postage stamp” boards for Si7013, Si7020 and Si7021

**SLSTK3201A – Weather Station Demo**

- EFM32 Zero Gecko Starter Kit
- Sensor expansion card with Si7013 and Si1147
- Weather station demo software





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# Temperature and Humidity Sensors - Takeaways

- New Temperature sensors
  - Si7057/8/9 Launched Mid June – 1.8V temp sensors in 2x2 QFN
- Si7051 is best in class for body temperature monitoring or high accuracy applications
  - Meets ±0.1 ˚C requirement for medical and body temp monitoring
  - Asset tracking with high accuracy <0.5°C requirements
  - Exceeds requirements of ASTM E1112
  - Lowest power and cost competitive
- Si7060 is best for lower cost, lower accuracy applications needing an alert pin
- For humidity sensors our main differentiation is lowest power
  - Several competitors now offer the filter covers and similar performance
  - Simple design in due to pin and software compatibility with Sensirion devices


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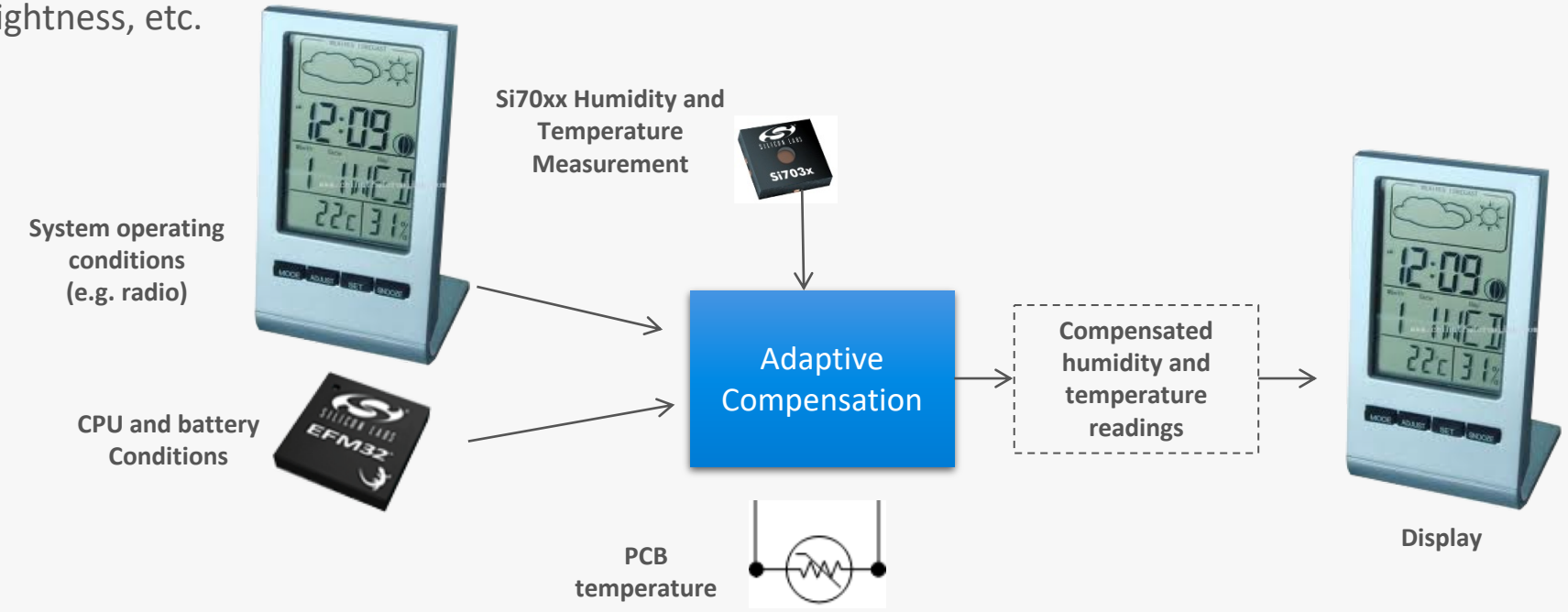
# Thank you

WWW.SILABS.COM

# Adaptive Compensation Improves Accuracy

- Combines data from multiple sources
  - External thermistor for PCB temperature measurement
  - CPU and battery temperature
  - System operating conditions
    - Battery charging, display brightness, etc.



# Adaptive compensation development process

- Silicon Labs reviews sensor placement and makes recommendations
  - Opening for humidity and good thermal contact with the environment
- Silicon Labs and customer agree on performance objectives and host processor requirements
- Customer develops prototype with data logging capability
  - Sensor readings are logged periodically (typically once per second)
  - This data is used to develop a model for the system
- Either customer or Silicon Labs runs tests at various temperature and humidity points
  - The system is quickly moved from one condition to another
  - The humidity and temperature in both conditions must be accurately monitored
  - Several conditions are required
    - Low temperature to room, High temperature to room, Low RH to room, High RH to room
- Algorithm is tested adjusted as needed

# RH Sensor References

- U.K. National Physics Laboratory Guide to RH measurement
  - http://www.npl.co.uk/publications/good-practice-online-modules/humidity/
- Wikipedia:
  - Relative Humidity
  - Dew Point
  - $I^2C$
  - IP Rating
  - Polymers
  - Wave Soldering

# RH Sensor Glossary

- Absolute vapor pressure: A measure of the actual amount of water present in the air.
- Boutique: A small firm that provides a limited range of very specialized goods or services at premium prices.
- Dew Point: For a given RH and temperature, the temperature at which condensation would form if the air were cooled; meaningful as an indicator of comfort.
- Hydrophobic: Water repellent/resistant.
- IP Rating: Ingress Protection Rating; first digit indicates level of protection against particle; the second digit represents level of protection against liquids.
  - IP67: An ingress protection rating indicating that the assembly is dust tight (6) and can withstand up to 1 m of water pressure (7).
- Kapton: A polyimide film developed by DuPont that is stable over a wide temperature range (up to ≈ +400 °C). It is available in sheet, tape and “dot” form and is used to protect selected components during solder reflow.
- Oleophobic: Oil repellent/resistant.
- Relative Humidity: Absolute_Vapor_Pressure ÷ Saturated_Vapor_Pressure; expressed as a percentage.
- Saturated vapor pressure: The maximum amount of water that the air can hold; dependent on temperature.

# Frequently asked Questions

- Why do these parts require special handling?
  - The sensor works by detecting water vapor absorbed in a porous polyimide film. Alcohol cleaning, solder flux, organic fumes and long term exposure to hot humid conditions can affect accuracy.
  - Competitive parts have similar sensitivity and all require the same handling precautions
  - The optional cover for Si70xx sensors provides lifetime protection against liquids and dust which is an advantage vs competitive parts, but the cover does not block fumes
- I tried soldering your Si7021 into a board that already has SHT21 and the accuracy seems poor?
  - The recommended procedure for soldering is reflow in a convection oven with no clean flux.
  - Hand soldering often results in excessive heat or flux contamination of the sensor
- Do I take the filter cover off after soldering?
  - No it is solder resistant
- I noticed the cover shrank during soldering is that normal?
  - Minor shrinkage of the cover is allowable and occurs at peak solder temperature near the 260C maximum. If significant shrinkage is observed the soldering temperature is too high.

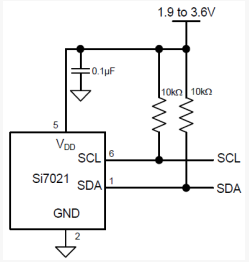
# Frequently asked Questions

- How can I use more than one Si70xx on an I2C bus?
  - The Si7013 has a pin selected i2C address so two devices can be used on one I2C bus
  - For more than two devises on the bus, some customers switch the I2C bus with an analog switch on the SDA line
- Are these parts ESD sensitive?
  - At normal IC level threshold of 2KV they are not ESD sensitive
  - However, the sensor must be exposed to the environment and could be subjected to ESD levels of 15KV. The best practice is to arrange exposed ground metal between the system opening that lets air into the sensor and the IC itself so that ESD will preferentially arc to ground
- Will heat from other components affect accuracy?
  - The Si702x will accurately sense the humidity and temperature of the environment it is in.
  - However, just 1 degree C of heat reduces humidity by approximately 5% for humid air. So while the humidity is correct, it might not be the ambient humidity. In these situations, dew point is still accurate or if the amount of heating is known it can be corrected

# Frequently asked Questions

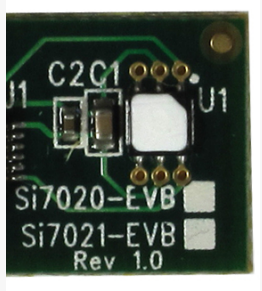
- I have a USB dongle evaluation board with a “postage stamp” and I notice the readings of the two sensors are different. Why?
  - Be careful to use the extension cord for the USB dongle to keep it away from heat from the PC
  - There is about 1C of heating from the USB MCU so the sensor on the board will tend to read slightly high in temperature and up to 5% low in humidity (for humid air).
  - Moisture and head from your hands will affect readings. So be cautious to allow adequate settling time after handling.
- I checked the accuracy and it does not agree with my instrument?
  - Humidity measurement is very difficult. The very best instruments are over $10,000 and can still only measure humidity over a limited range to approximately 1% accuracy. Common humidity measurement devices are only about 5% accurate and should be suspect.
- Do you have example code and device drivers available?
  - Yes!  Enter a support request of what you are looking for at www.silabs.com or in Salesforce and we will provide them.

# Adding RH and Temp Sensing is Easy with Si70xx




**Schematic**

- Si70xx needs just 3 external components
- $I^2C$ interface connects easily to MCUs




**Layout**

- Place Si70xx close to the outside edge of the board away from heat sources

**Assembly**

- Si70xx is compatible with SMT pick-and-place and reflow soldering processes
- Si70xx is fully calibrated

Simplicity Studio

**Software**

- Download example code and drivers from www.silabs.com
- Si70xx fully supported in Simplicity Studio