Compact Digital Humidity Sensor IC Extends Battery Life and Reduces Design Complexity

In today's emerging "Internet of Things" era, the traditional approach to humidity measurement using large-footprint legacy discrete circuits or bulky humidity sensing modules consuming 4-20 mA is no longer suitable to meet system designers' demands for smaller, lighter and lower-power end products.

A compact, single-chip digital humidity sensor IC provides a more appropriate solution for meeting the requirements of applications, such as portable weather stations, nebulizers, data-loggers for goods and assets in transit, smart-phone/feature-phone accessories and remote environmental sensing nodes.

To better understand the application benefits of using digital humidity sensors, let's consider some of the principles of humidity sensing and compare the merits of using single-chip relative humidity (RH) sensors versus traditional discrete RH sensing solutions.

Background

Humidity is a measure of moisture in air or other gases. There are several ways to express humidity measurements.

- Absolute humidity (expressed in gm^{-3})
- Absolute vapor pressure (a measure of the actual moisture content in the air, expressed in kPa)

- Saturated vapor pressure (the maximum pressure of water vapor that can exist at a given temperature)

If the moisture content exceeds the saturated vapor pressure, condensation occurs, and the moisture content is reduced to the saturated vapor pressure. Dew point (the temperature at or below which condensation or fog starts to form as a gas cools) is also used as a measure of the absolute moisture content of air.

Numerous techniques are available for measuring relative humidity, ranging from simple mechanical indicators using spring-loaded fabrics to highly complex and expensive analytical instruments, such as chilled-mirror optical hygrometers. In general, measuring humidity, whether it is relative humidity, dew point, absolute humidity or equivalent wet bulb temperature, is not an easy task.

According to the National Physical Laboratory (UK), humidity is a relatively difficult quantity to measure in practice and can be measured in an uncontrolled environment with an uncertainty of, at best, ±3 percent. Because RH is highly temperature-dependent, we need to know the precise temperature of the air to accurately establish its relative humidity. As little as 0.2 °C variation in temperature can cause a 1 percent error in RH.

Discrete resistive and capacitive RH sensors have filled the gap between mechanical and optical RH sensing for many years. They are used in conjunction with discrete temperature sensors, such as thermistors and resistance temperature detectors (RTDs), to establish RH and dew point.

Resistive sensors use a polymer membrane that changes conductivity according to absorbed moisture.

Capacitive RH sensors employ a polymer dielectric between the capacitor plates and measure RH by detecting the change in dielectric-constant (εr) and capacitance caused by moisture absorbed in the porous polymer dielectric layer. An εr of 3.0 to 4.0 would be a typical variation of dielectric constant as RH varies from 0 to 100 percent. Figure 1 shows a typical discrete component sensor schematic.

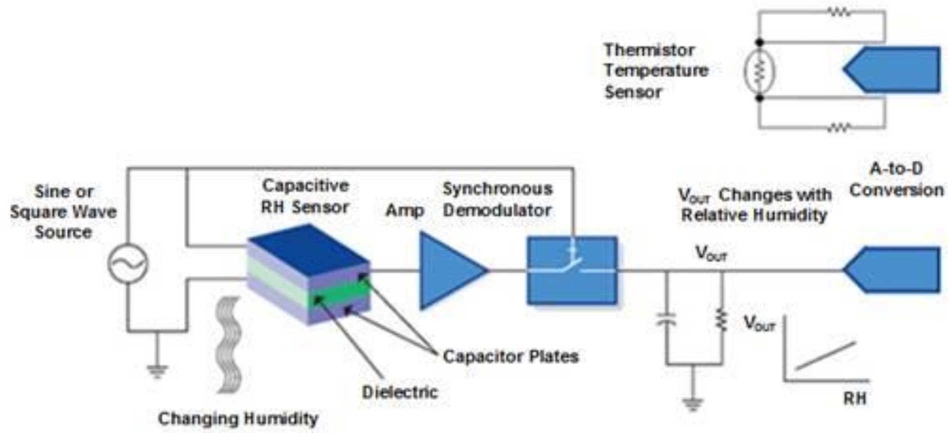

Figure 1. Typical Discrete Component RH and Temperature Sensor

Discrete solutions are smaller and easier to calibrate than mechanical systems, but they require many supporting components to linearize, calibrate and convert the RH values. This approach requires added board space, higher power and labor-intensive production line calibration of each unit before it is shipped to a customer. Furthermore, discrete sensor components cannot be reflow-soldered for high-volume assembly. These discrete sensors also suffer from poor accuracy, high lot-to-lot variation, significant hysteresis and severe sensor drift over temperature and time. This adds complexity to the production testing and calibration and often means that regular calibration is required in the end application throughout the product’s lifetime.

Single-Chip Digital RH Sensor ICs

An emerging sensing solution combines RH and temperature sensors directly on a single-chip CMOS IC with a digital I^2C interface. Because both sensors are in close proximity on the same monolithic die and at the same temperature, the RH reading is always more accurate than that from a discrete solution.

A prime example of a single-chip sensing solution is the Si70xx digital RH and temperature sensor family from Silicon Laboratories. The Si70xx sensors measure humidity with a polymer film on the surface of the die, and temperature is measured by an on-chip diode band-gap circuit. Each Si70xx sensor is factory calibrated, so customer calibration is unnecessary. The sensors are packaged in industry-standard DFN packages with a small opening to expose the moisture-sensing polymer film. A version with a low-profile protective cover is also available as an ordering option. The cover provides added protection against soldering flux, dust, chemicals and other pollutants during the sensor's lifetime, as well as added protection during reflow soldering. Table 1 summarizes the benefits of using a monolithic solution versus a legacy discrete approach.

Conversion from capacitance to RH and fine tuning of the RH accuracy is achieved by:

- Calibrating the capacitance for each device
- Performing an on-chip gain and offset correction to calculate RH

Table 1. Benefits of Monolithic Sensors Compared to Legacy Discrete Designs

Key Monolithic Sensor IC Feature	Benefits
Higher integration than discretes, hybrids or multi-chip modules (MCMs)	• Considerably lower component count reduces design complexity • Smaller overall footprint and minimal height and weight • Faster time to market
Standard CMOS fabrication and DFN package	• Industry-standard CMOS provides higher yield and reliability • Low-profile DFN enables automated pick-and-place high-volume assembly and manufacturing
IC factory calibration with individual coefficients stored in on-chip memory	• Shorter customer production/test time and lower solution cost • Production line and field replaceable/interchangeable
Optional hydrophobic protective cover	• Protects the exposed sensor before, during and after assembly • No materials or labor cost to install the protective cover post-reflow or need to apply/remove protective tape

Single chip humidity sensors like the Si70xx family from Silicon Labs provide the following benefits over traditional legacy discrete, hybrid and MCM solutions:

High integration -- Measured humidity and temperature values are converted to a digital format by the on-chip signal conditioning circuitry and analog-to-digital converter (ADC). No external signal conditioning or conversion to digital is required to output a voltage or frequency. The BOM consists of only three external passive components versus the dozens of components that might be required to implement the same functionality with a discrete sensor. The humidity sensor has a much smaller footprint and minimal height and weight compared to discrete sensors, modules or hybrids/MCMs. The result is lower total solution cost, less design effort, less space and weight, higher reliability and faster time to market.

Plug-and-play ease of use -- Digital output and factory calibration eliminate the need to calibrate a single-chip CMOS device, making each sensor interchangeable. No software/firmware changes or recalibration is required to switch from one unit to another. No time or labor is spent adjusting each unit on the production line, which makes production rework and field servicing more convenient.

Protective cover -- The addition of an optional factory-installed protective cover makes the Si70xx temperature and humidity sensors very robust and easy to use. This low-profile hydrophobic/oleophobic membrane protects the sensor before, during and after board assembly. It remains in place for the life of the product, protecting against liquids/condensation and particulates, such as dust. Measurement sensitivity is unaffected by the presence of the cover.

Powering the Si70xx Humidity and Temperature Sensors

The Si70xx sensor family offers industry-leading low power consumption. In order to achieve this, the sensors remain in a very low-power standby state when they are not converting a temperature or RH sample into output data. For the I2C devices like Si7013, a temperature and RH conversion is triggered by an I2C command sequence. When sampled with a 1 Hz rate, the Si70xx I2C devices are capable of operating with just 2.2 µW of average current. With an operating voltage of 1.9 to 3.6 V, the Si70xx devices can be connected directly to a coin cell or other type of battery for highest efficiency.

Conclusion

The market demand for low-power portable humidity sensors is increasing, driven by new portable and mobile systems for emerging Internet of Things applications. Single-chip digital humidity sensors, such as the Si70xx device from Silicon Labs, provide an ideal sensor choice for such systems. The Si70xx family features a compact, high-performance sensor that minimizes component count and BOM cost. On-chip calibration, a choice of PWM or I2C host interface, an optional protective cover, and a choice of cost-effective evaluation boards and development kits enable developers to implement feature-rich portable humidity sensor systems quickly and easily. These systems are capable of achieving a minimum of 5 to 10 years battery life.

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