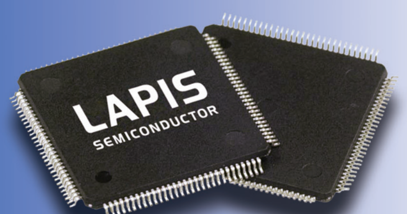
LAPIS
SEMICONDUCTOR

Low Power Microcontrollers for Temperature, Humidity & Carbon Monoxide Instrumentation



ROHM Marketing USA

White Paper

Presented by ROHM Semiconductor

Using Low Cost Microcontrollers for Temperature, Carbon Monoxide, and Humidity Measurement, Display, and Control

In today's energy consumption and safety-conscious world, collecting and using accurate information about ambient temperature and humidity and the concentration of carbon monoxide (CO) is of critical importance. It is equally important to make measurements and provide control information or actions in a cost-effective manner. Advances in single-chip low-power-consuming microcontrollers that utilize a unique RC-type analog-to-digital converter (RC-ADC) now allow designers to meet these challenges in creating products that are used to monitor temperature or humidity and detect dangerous levels of carbon monoxide. These new microcontrollers enable product designers to create products and systems that record, display, and use the data to manage environmental control units and energy consumption as well as monitor perishable product quality—all in real time. In many of these applications the activity of collecting and using environmental data, in the -40°C to 85°C range, is performed by battery operated handheld or remotely installed products. The rising demand for low power consumption in products that monitor the environment and harvest energy from their local environment are perfect applications for these devices due to their low power consumption.

Designers of environmental monitoring products and systems require that their products:

- *monitor temperature, humidity or CO concentration while consuming little power*
- *provide a means of communicating the monitored data, either wired or wirelessly, and*
- *have a high level of integration and a wide variety of associated features to allow designers maximum flexibility in device selection*

Applications requiring environmental monitoring

Environmental monitoring is critical in building controls, test and measurement, and in the transportation and storage of perishable products such as food and pharmaceuticals. In the building controls industry, monitoring temperature, humidity and CO is a key function that has to be performed reliably with a high level of precision and very low power consumption. Without providing low power sensors that collect these types of data, the ability to control the environment in a building is virtually impossible. In the test and measurement industry, end products need to provide accurate temperature and/or humidity information as their principal function or use ambient temperature data to accurately perform various measurements. These measurements are typically conducted using a handheld, battery operated device that requires high accuracy utilizing a simple system design with low power consumption and multiple display and communication options. In the transportation and storage of food and pharmaceutical industry, commonly referred to as "cold chain monitoring," it is critical to monitor the environment that the products are exposed to from the source to the consumer, thus guaranteeing the quality of products that are delivered to the public. Cold chain monitors are typically battery operated, need to provide high accuracy measurements, display information, log data to be read and used later, and indicate variations in measurements outside of a predefined range.

Features of microcontroller-based environmental monitors

Environmental sensing and monitoring products typically require a microcontroller to make measurements, manage collected data, display information, manage user inputs and provide communication of recorded data.

Figure 1. ***A microcontroller featuring an RC analog-to-digital converter is a cost-effective means of calculating temperature and humidity in portable instruments, weather stations and thermostats.***

Measurement Methods

There are a number of ways that allow a microcontroller-based system to monitor temperature, humidity and/or CO for these types of applications. The following are a few of the more commonly used methods.

Dedicated Semiconductor Sensors – A designer can add a dedicated sensing device to their circuit. A separate microcontroller would be used to manage and monitor the sensor. Implementing a system with a discrete measuring device results in a multiple chip solution which in many cases would require even more external discrete components than the microcontroller and dedicated semiconductor device.

Temperature / Humidity / CO Sensors – Temperature, humidity, or CO measurements can be made by measuring the value of a discrete component that has a predictable value at given environmental conditions. These components can be monitored in a variety of ways including a bridge circuit, a simple voltage divider, or electrically determining how the variable value component affects a circuit. A typical way to do this is to use an RC circuit.

Each of these methods has its advantages and disadvantages. One of the typical challenges to making these measurements is precise control over excitation circuits, either current, voltage, or frequency. Accurate measuring circuits and coordination of the resources associated with making measurements are also challenging. RC measurements in particular require the coordination of many discrete functions such as counters, stimulus circuits, and calibration. The ideal solution would be self calibrating, highly integrated, and provide repeatable performance over the entire operating voltage and temperature ranges of the product.

RC-Type ADC - Accurate temperature, humidity, and CO measurements made easy with less power

The most common method to easily measure temperature, humidity, or CO with a discrete component is to use a variable resistance component. An RTD is an example of a component that can be used to determine temperature, as RTDs have a well defined resistance-temperature curve. Figure 2 shows a typical Resistance vs. Temperature curve for an RTD. There are similar devices that have well-defined variable resistive values over humidity and CO concentrations that would be used to measure and monitor those environmental conditions.

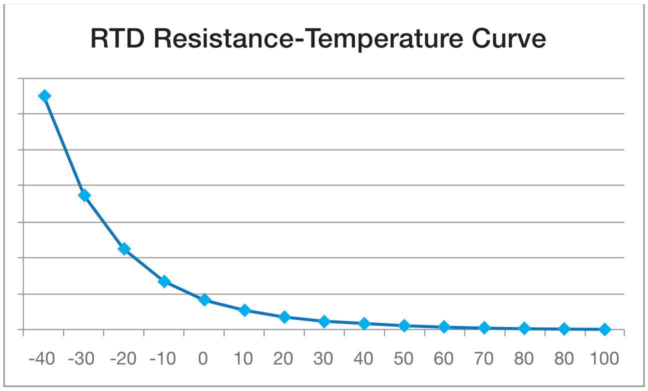


Figure 2. Typical Resistance vs. Temperature curve of an RTD

The major functional blocks required by an RC-ADC are two counters, one driven by an internal clock and one by a variable rate counter whose frequency is based on the RC loading on specific pins of the device. Reaching terminal count for either of these counters would generate an interrupt to the CPU. When TC is reached the other counter is stopped and its count is recorded. The count of the second counter is proportional to the value being measured, the issue to be solved is relating that value to an accurate measurement.

The advantage of using this type of ADC is that it can be designed so that it uses a known value component to calibrate the circuit at the time of measurement, then measure the variable value component to determine the relative effect of the two components on the circuit. The challenge to designers is implementing this method of measurement and calibration without a dedicated resource on a microcontroller.

Figure 3 shows a block diagram of how the RC-ADC interfaces with external components. As you can see, external component count is minimal and the types of components required are passive and small. The typical range for CS is 700 to 1000 pF. The power consumed while using the RC-ADC is normally no more than 0.90 mW (0.30 mA at 3.0V Vdd) and a measurement takes less than 2 seconds.

Capacitor CS1 is discharged and then is charged by passing a load-sensitive oscillating signal through RT1, a fixed value resistor. The product of the values of the resistance and capacitance affects the rate at which the signal oscillates. The amount of time that it takes to charge CS1 is recorded. The ADC then discharges CS1 and charges it with the same oscillating signal through the variable value component, RS1. In this case, RS1 is a component whose resistive value is dependent upon an environmental condition. The amount of time it takes to charge the cap to the same predetermined level through RS1 is recorded. A temperature, humidity or CO concentration sensitive device could easily be used as RS1 to make the associated measurement.

Since the frequency of the charging signal is a function of the product of the resistors and CS1, the exact value of CS1 factors out of the equation:

K * CS1 * RT1 = Time Ref -> RT1 = Time Ref / (K * CS1)

K * CS1 * RS1 = Time Variable -> RS1 = Time Variable / (K * CS1)

RS1/RT1 = (Time Variable / (K * CS1)) / (Time Ref /(K * CS1))   = Time Variable /Time Ref

RS1/RT1 = Time Variable /Time Ref

RS1 = (Time Variable /Time Ref) * RT1

As you can see, the ratio of the amount of time it takes to charge through RS1 compared to RT1 is the ratio of the values of RS1 to RT1, and since RT1 is a known value, RS1 can be calculated. As such, the temperature (or humidity or CO concentration) at RS1 is known

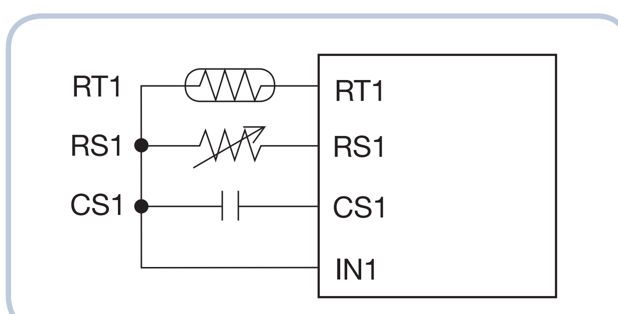


Figure 3. Simple external circuitry is the key to the low cost of the RC analog-to-digital converter technique.

because the value of RS1 is determined. Using this method the variability of the value of the cap CS1, differences between devices, or variations due to the voltage applied to the device are taken out of the equation. In other words, this self-calibrating method takes out component and process variability. Implementing an RC-ADC of this type provides the ability to design monitoring products with relatively high precision and accuracy.

Features of LAPIS Semiconductor's Low Power Microcontrollers

As shown above, there are many ways to monitor temperature, humidity, or CO. The key issue is how to do it with the lowest power consumption, the fewest number of components, with an acceptable level of accuracy, and use the information collected appropriately?

Lapis Semiconductor's Low Power Microcontrollers offer a variety of solutions that have integrated RC-ADCs which provide high accuracy temperature, humidity, or CO monitoring using very little power and few external components. The devices include many of the features required for low power environmental monitors. The latest additions to the LAPIS Semiconductor ML610400 microcontroller family give designers even more options to design products and systems that monitor, record, display, and communicate temperature, humidity, or CO data while consuming little power using few components.

Dedicated RC-ADCs are unique in that they are designed specifically for these types of measurements and LAPIS Semiconductor provides sample software (in the C language) that customers can use as-is or modify as necessary.

In addition to the low power consuming architecture of the 8 bit RISC CPU core at the heart of the ML610400 devices, the family includes a wide selection of non-volatile memory configurations and a range of LCD

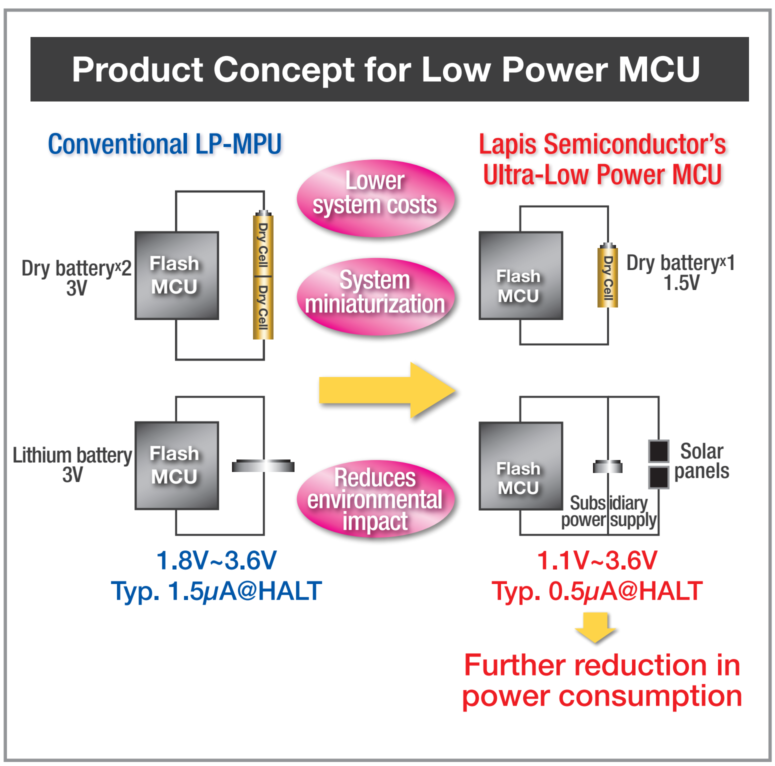


***Figure 4.** ROHM's Ultra-Low Power Microcontrollers can operate from a low battery voltage or solar panel and have significantly lower power consumption in Halt and Stop modes.*

controllers to choose from. All devices in the Low Power Microcontroller family are based on a low leakage process (see Figure 4), allowing for as low as 0.5uA consumption in Halt mode and 0.15uA in Stop mode. Almost all include an on-board LCD controller. The LCD controllers available span from as few as 45 LCD segments up to 1536 segments. All have non-volatile memory, ranging from 8 KB to 128KB. Devices with FLASH memory are designated by a “Q” in the part number; the lack of a Q indicates that there is a ROM option available.

All devices have background debugging capabilities, accessible by a USB-based debugging pod referred to as uEASE, and the same code development and debugging tools are used for all devices in the Low Power Microcontroller family. More details about the individual products in the family and a complete Product Selector Guide can be found online:

http://www.rohm.com/us/low-power-micro.html

There are a number of ways that an RC-ADC can be used to determine the value of a variable value component, and those methods are described in the User’s Manuals which can be found on the Low Power Microcontroller website listed above and in the application notes that accompanies the Demo Kit. Customers can purchase a Demo Kit to evaluate the features of the ML610400 family of devices. Information about the Demo Kit is also available at http://www.rohm.com/us/low-power-micro.html

Summary

LAPIS Semiconductor Low Power Microcontrollers are ideal for all types of battery operated products, especially those that require high accuracy temperature, humidity, or CO measurement. This is because the devices are inherently low power consuming and include among their many peripherals RC-ADCs which are specially designed to measure variable value components such as RTD, Humidity and CO Sensors.

To learn more about Low Power Microcontrollers, please contact:

http://www.rohm.com/us/low-power-micro.html

http://www.rohm.com/us/contact_us/lapissemi/USA-Sales.html

Figure 5. The Demo Kit provides an effective means of evaluating the features of the ML610400 family of devices.

Figure 6. The ML610Qxx uEASE Tool Kit.

LAPIS Semiconductor is a ROHM Group company

LAPIS Semiconductor
6815 Flanders Drive, Suite 150
San Diego, CA 92121

http://www.lapis-semi.com/en | 1.888.775.7646

Pb Free ROHM Electronic Components

RoHS Directive Compliance

NOTE: For the most current product information, contact a LAPIS Semiconductor sales representative in your area.