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Technical Article Release

Basic Electronics for Environmental Monitoring

By Michael Parks, PE for Mouser Electronics (www.mouser.com)

In the world we live in, it's rare that a day goes by without coming across a news story highlighting the Herculean efforts of scientists monitoring the environment for things such as temperature changes, greenhouse gases, pollutants, or rising sea levels. Their research is helping ensure that the health of our planet is not only improved for today, but that our relationship with the planet is a sustainable one for the sake of future generations. Historically, this research has been measured on a large scale over long time periods by trained scientists using expensive equipment. The average person couldn't get involved aside from watching their home's carbon footprint. However, there is now a growing trend of more robust environmental monitoring by communities and do-it-yourselfers.

Regardless of whether you are a professional researcher or a member of the growing movement of "Citizen Scientists," there are many unique challenges when building devices to monitor the environment. Such equipment is often denied the relative convenience and conditions afforded to more traditional consumer electronics. An apparatus built to monitor the environment must often contend with lack of reliable power, inhospitable ambient conditions, and poor communications channels to name but a few of the challenges. However, there are a few design considerations for engineers to consider when building devices that are destined for service in the relatively unforgiving conditions that can be associated with environmental monitoring.

Why Should We Care?

Figure 1: *Earth (Pale Blue Dot) as seen from Voyager 1 in 1990. Image: NASA*
"Look again at that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives..." **- Carl Sagan**.

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Despite all of the efforts humanity has made to explore the cosmos, we still only have one planet to call home. At this point in time "all of our eggs are in one basket," and as such, there is no backup plan if we lose planet Earth. In essence, environmental monitoring is like a medically necessary physical exam for the planet. Without data about the quality of our air, water, and soil, it's impossible to make educated, proactive decisions on how to maintain an optimal balance of all the attributes that describe the planet's various ecosystems. Environmental monitoring provides that data. Some benefits include:

Food Supply: Understanding the chemical characteristics of the soil allows the world's farmers to make informed decision on crop rotations to help ensure that our burgeoning species is fed.
Human Health: Dr. Rishi Manchanda gave a TED Talk back in 2014 entitled, "What Makes Us Get Sick? Look Upstream." His stories of working as a doctor servicing low income residents of Los Angeles highlighted the fact that human health and our environment are very interconnected. He argued that sometimes in treating medical issues we forget to examine the environmental factors (e.g. mold proliferation) in the places we live, work, learn, and play as being a leading culprit in inducing illness.
Economic: If the other reasons haven't convinced you, consider the economic impact of taking a laissez-faire approach to our environment. On a global level, rising tides may cause huge insurance claims as homes and property are reclaimed by the oceans. On a personal level, an action like over-watering the lawn is not only wasteful, but it also means spending money on utility bills that could have be spent elsewhere.

Sensor Selection Considerations

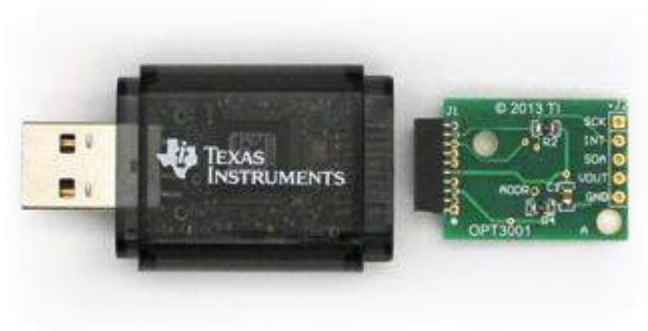

Figure 2: *PT3001 Optical Sensor from Texas Instruments. Image: TI.*

Given the immense importance that a healthy planet has to both our present and our future, good system design for environmental monitoring tools is essential to understanding what is really happening to the Earth. The most fundamental aspect of environmental monitoring is the sensor. Sensors are a type of transducer that converts physical properties (e.g.temperature, humidity, light level, etc.) of the environment into an electrical signal. Selecting the right sensor for an environmental monitoring application is key. There are many parameters to consider when selecting a sensor, such as:

- **Passive versus Active:** Active sensors require a power supply to operate whereas passive sensors directly transform the physical stimulus into an electrical signal.
- **Absolute versus Relative:** An absolute sensor's output is independent of the operating conditions. Conversely, a relative sensor's output requires comparing the output to a known quantity such as a fixed voltage.
- **Range:** What is the minimum and maximum physical attribute that can been detected? For example, if you wanted to measure the ambient light levels you might be interested in the darkest and brightest

levels that are discernable. If you selected the quite capable OPT3001 sensor from Texas Instruments, its datasheet would show you that it has a range of 0.01 lux to 83k lux.

- **Sensitivity:** This is the ratio of the output signal versus a measured physical stimulus. In other words, it represents the smallest amount of change of physical stimulus that will result in a change in the electrical signal output.
- **Response Time:** How quickly does the output signal change in response to a change in the physical stimulus?
- **Linearity:** How consistent does the sensor translate a change in stimulus to a change in the output? An ideal sensor has a 1:1, or linear relationship, between a unit change in the stimulus to a unit change in the output signal across the entire supported range. In reality this is not possible, and thus many sensors require designs that employ a variety of methods to correct for the typical non-linear relation of stimulus to output.
- **Resolution:** The smallest increment of change in the stimulus that can be detected.
- **Digital or Analog Output:** Some sensor packages have onboard analog-to-digital conversion capability that can transmit sensor readings in a digital format (I2C and SPI being two of the more popular protocols) to a waiting microcontroller for further processing. On the other hand, some lower cost microcontrollers might lack the hardware capability to readily handle the digital communications, and instead the analog output might be preferable.
- **Accuracy:** What is the maximum deviation between the actual value of the physical stimulus and the value that the sensor is reporting? Be sure to pay careful attention to datasheets, as sometimes it is possible to purchase several sensors in the same family product line with varying accuracy (the tradeoff likely being unit cost or power consumption). As an example, Sensirion provides highly capable temperature and humidity sensors under their SHT3X product line. The SHT31 have an accuracy of within 2% whereas the SHT30 sensors have a +/- 3% accuracy.
- **Drift:** A degradation of the sensor performance over time so that the output will vary even in the presence of the exact same stimulus. Drift is often reported as a change in the unit of measure per unit of time, such Δ°F/year for a temperature sensor.
- **Operating Life:** Sensors have a life expectancy after which their performance degrades and must be replaced.

Figure 3: *Sensirion SHT3X Temperature/Humidity Sensor Development Board. Image: Sensirion.*

When selecting a sensor for an environmental monitoring application it is absolutely critical to understand the operating environment that the device is expected to handle. It's also crucial to understand the expectations for the data gathered: what will it be used for? Some questions you might consider asking include how frequently should a reading occur, whether or not it needs to be date/time stamped, and ascertaining how frequently someone will interact with the device for maintenance. Those answers, coupled with the performance parameters and operating environment, will drive your sensor selection decision making.

Additional Design Considerations

The sensor performance characteristics are not the only considerations one must contemplate when designing a robust environmental monitoring solution. Regarding sensor selection, as mentioned before, understanding the intended use case and operating environment is just as crucial as making smart system architecture decisions with respect to power, communications, and processing capability. Having a super accurate sensor that is to be installed at remote location isn't so great if someone has to trudge out every few days to replace batteries. Energy harvesting technologies coupled with low-power sensors and microcontrollers allow for an environmental monitoring device to be installed in remote locations with confidence that the tool will be able to monitor the conditions continuously.

Understanding realities for communication is another key consideration. If you want to remotely communicate with your device, it is important to determine how the device is intended to share information. Will it talk with other devices over large distances without human interaction? Or will a person interact with the device from a relatively short distance, such as a few meters at most? The answers can drive hardware decisions in one of two ways. On the one hand, long distances with machine-to-machine (M2M) interactions might lead to you exploring an emerging technology, like Long Range Wide Area Networks (also known as LoRaWAN™). An example for implementing transmission can be found in Microchip Technology's RN2903 Long Range Technology Transceiver Module.

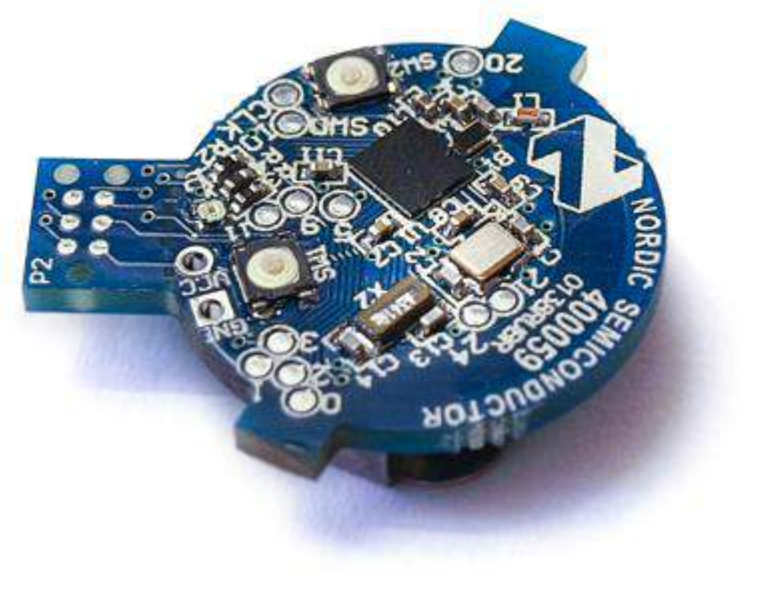

Figure 4: *Bluetooth® Low Energy allows environmental sensors to efficiently communicate to a smartphone. Shown: The Nordic Semiconductor nRF51822 Bluetooth Smart Beacon Kit. Image: Nordic Semiconductor.*

Conversely, if the notion of developing a device that interacts with a user's smartphone or tablet is enticing, then perhaps the communications solution will employ Bluetooth Low Energy (BLE) instead. In fact, it is even possible to use power development boards that incorporate BLE and a suite of sensors geared towards environmental monitoring out-of-the-box such as the Broadcom WICED™ Sense Kit. This can translate into less time spent in the laboratory doing research and development, and more time testing in the real-world.

Enabling Citizen Science through DIY Electronics

Over the past decade there has been a growing interest in STEAM (science, technology, engineering, art, and mathematics) topics around the globe. The more familiar Maker Movement has reignited people's interest in hands-on, do-it-yourself projects. There has also been a rise in Citizen Science, which is a parallel movement that is attempting to crowdsource scientific research by ensuring that people have the knowledge and tools to scientifically investigate topics of personal and local interest. Interest in environmental monitoring sits at the crossroads of these two initiatives.

Many of those involved in Citizen Science are leveraging the popular Arduino 101 microcontroller board. Maintaining the footprint of the immensely popular AVR-powered Arduino Uno, the updated Arduino 101 packs in more computing power, and is perfect for scientific experiments. Leveraging the robust Intel® Curie™ System-on-a-Chip (SoC) architecture, the Intel® Arduino 101 development board contains a powerful 32-bit Quark™ SE microcontroller, Bluetooth Low Energy communications, an onboard Real Time Clock (RTC), a 6-axis accelerometer/gyroscope, and battery charging circuitry.

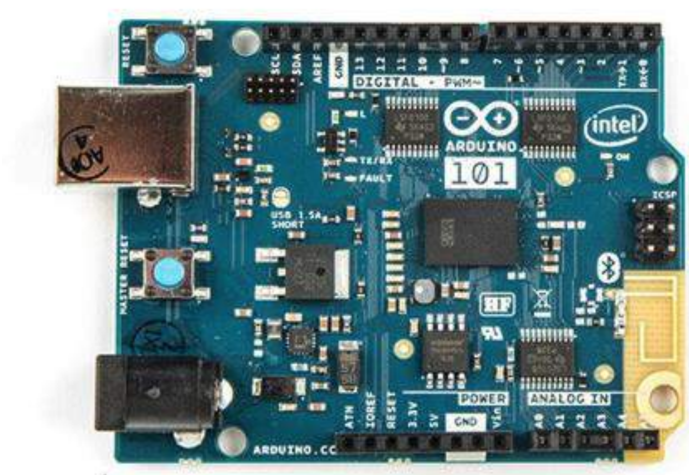

Figure 5: *Figure 5: Arduino 101 enables Makers to join with Citizen Science to the monitor local environment.*

That built-in functionality enables a low cost tool to monitor specific environmental conditions if an off-the-shelf tool isn't available. The RTC functionality is of particular importance for scientific research so that each data point can be date/time stamped for future analysis when looking for correlations or relationships with data from other sensors. As sensors and embedded platforms become increasingly affordable and easier to interface with, people sharing their work and working together will be able to easily and quickly create functional solutions that professional environmental researchers could have only dreamt of a few decades ago.

A Better Tomorrow, By Design

For the foreseeable future, humankind will continue to call Earth home. Caring for the environment becomes more important as the population grows and resources become scarce. Local actions can have a tremendous global impact. Data is key to understanding that impact and having as much information as possible allows us to make better decisions towards the goal of increased sustainability. Thus the importance of being able to detect and track actual changes in our environment.

Proliferation of capable, low-cost environmental monitoring technologies help to expand our understanding without further taxing the already constrained institutions that are dedicated to protecting the environment. As the cost of technology steadily drops, sensing will be become increasingly ubiquitous. Accessibility through lower cost means we are more able to boost awareness of our exhaustible environment and perhaps through awareness be better able to manage our surroundings and resources.

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