Anyleaf pH and ORP module

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General Description

The AnyLeaf pH and ORP module is a digital measurement interface for Ion Sensitive Electrodes (ISE). It connects to an electrode, and outputs the measured voltage as a 16-bit value to a microcontroller, over an I²C connection, using a Texas Instruments ADS1115 Analog to Digital Converter. (ADC). It includes an internal analog temperature sensor: a Texas Instrument LM61, for temperature compensation.

Specifications

- **Dimensions:** 50×25×17(height) mm
- **Weight:** 14 grams
- **pH precision:** .01, with a suitable sensor
- **pH Range:** 0 - 14
- **Input voltage:** 2 - 5V
- **Mounting screws:** 4 × M3, 6mm len (included)
- **I²C address:** 0×48 or 0×49, (selectable using a jumper)
- **Sensor interface:** BNC Male (Accepts BNC female sensors)
- **Power consumption**: 375μA

Background on pH-measuring electrodes

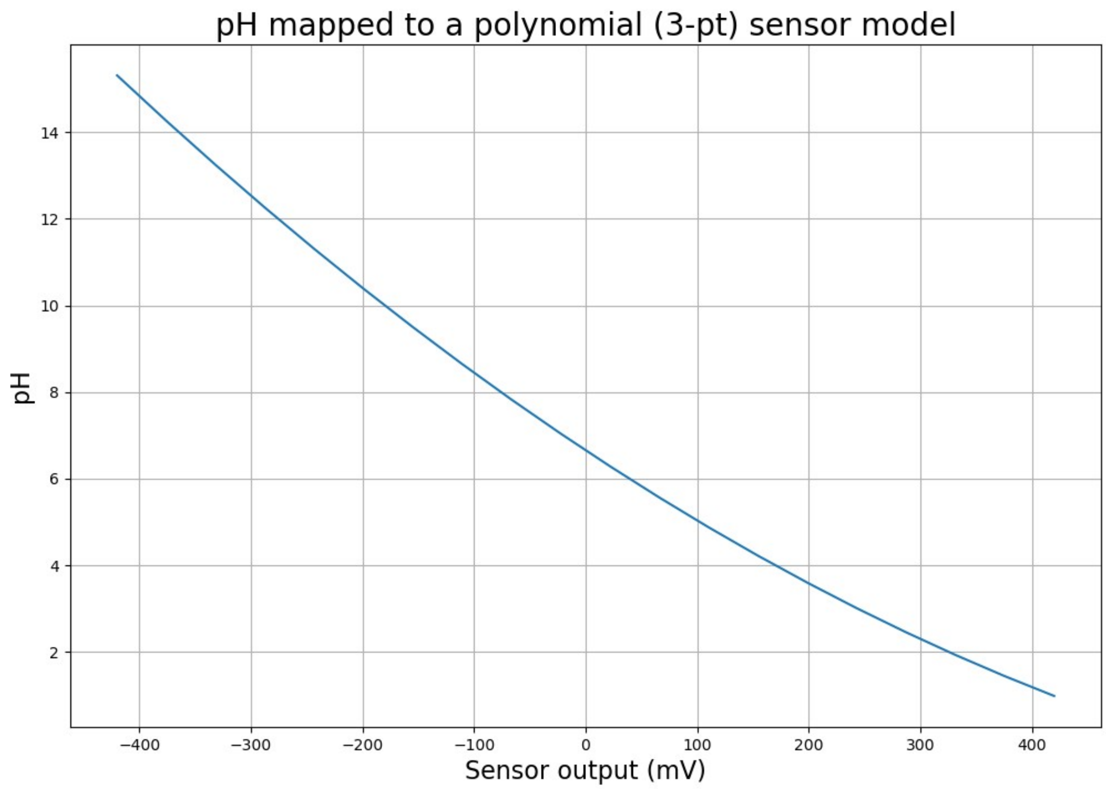
pH measuring electrodes come in a number of variants, most of which output a small voltage that varies nearly linearly with the pH being measured. The most common variety uses a Silver Chloride electrode, and reference electrode in a 4.0M Potassium Chloride solution. It measures pH of the surrounding solution, through a glass membrane. The electrodes have a high impedance, unsuitable for direct use with microcontrollers. In order to convert these readings to a usable form, the AnyLeaf pH module uses a dual operational amplifier (Analog Devices AD8629) in a unity gain configuration to address the impedance mismatch, and an ADC to convert the analog voltage into a digital one that can be read by microcontrollers. Each of the 2 electrodes in the sensor is connected to an ADC input, and the voltage is measured as a differential between the electrodes. The ADC provides an I²C interface, which sends sensor readings to any microcontroller that supports this protocol. More broadly, this principle applies to any ISE, including Oxidation-Reduction Potential (ORP) electrodes.

Relationship between electrode voltage, and pH

The electrode differential output voltage bears a nearly linear relation to pH. Generally, a voltage of 0 corresponds to a pH of 7, a voltage of ~+200mV corresponds to a pH of 4, and a voltage of ~-200mV correspond to a pH of 10. However, neither the module, nor its accompanying drivers make any assumptions about this relationship, other than it's nearly linear.

Calibration data is used to determine the relationship between voltage and pH. When 2-point calibration is used, the relationship is assumed to be strictly linear. When 3-point calibration is used, the relationship is assumed to be a Lagrange polynomial, fit through the calibration points.

An example response curve, mapping sensor output voltage to pH is shown below:



This module's software-based approach

This module's hardware does not process the voltage any further than this. Instead, it relies on drivers on the microcontroller or computer it connects to. This approach allows for future updates, and full user customization, while offering a high-level interface in several programming languages: C++, Python, and Rust, with the ability to add more as required. This approach also allows for minimal power consumption. If you wish to program it using a different language, you can access the readings through the ADC's registers (Reference the ADS1115 datasheet), or using drivers designed for this ADC, if available. The pH voltage is mapped to a differential from inputs **A0** and **A1**, and temperature voltage is from input **A2**. You may also contact AnyLeaf to request official drivers in your language of choice. See the accompanying Github (*https://github.com/anyleaf*) for drivers, and example code.

Stirring the solution while measuring

For the most accurate readings, especially over time, it's important to stir, or otherwise agitate the solution being measured. (Or, move the probe around in the solution.) This is to avoid reading fluctuations from different regions of the water, and to prevent hydrogen ion concentration in the immediate vicinity of the probe from from affecting readings.

Temperature compensation

Electrode voltage, in relation to pH varies slightly with temperature, so it's important to measure temperature with pH to account for this. This can be thought of as a change to the Voltage/pH slope. The temperature during measurement is compared to that taken during calibration, and the difference is used to bias the resulting pH measurement.

The temperature compensation is implemented via software. The coefficient used in the official drivers is **-0.05694 pH/(V×T)**, where V is in volts, and T is in °C. This is the only measurement-related arbitrary constant in the drivers. You may customize it if desired.

Temperature compensation is not used during ORP measurement.

Calibration

pH electrodes vary slightly in their voltage/pH relationship over time, and between different sensors. Because of this, regular calibration is required. How frequently calibration needs to be done depends on the sensor, and accuracy required. For example, for laboratory use, calibration may be required before each set of measurements, while industrial or hydroponics use may require calibration every week, or month. Calibration is done using buffer solutions of known pH. The AnyLeaf drivers offer 2 calibration APIs: one that allows manual calibration values to be entered, and one where you insert the electrode into a buffer, and automatically have it measure the values. See the accompanying Github (link above) for example use. Calibration value aren't stored on the module; store them using your connected microcontroller or computer.

Each calibration point consists of 3 data points: The nominal pH of the buffer, the voltage measured by the sensor, and the temperature at which the measurement was taken. In the case of 2-pt calibration, a line is fit through the voltage and calibration points, which serves as the model for future readings. In the case of 3-pt, a Lagrange polynomial is fit instead of the line – this is a slightly curvy line. When readings are taken, the voltage output from the sensor is mapped to this model to determine pH.

2-point calibration is suitable for most non-laboratory uses, while 3-point is recommended for laboratory use, as it compensates for the sensor’s slight non-linearity. 2-point calibration may be used for precise measurements if the points are chosen to be near, and bracketing the expected pH being measured.

ORP calibration is done using a single calibration point. It uses a linear model, with the other defining point being at the origin.

Signal processing

In many cases, the raw voltages output from the pH electrode are suitable to be used with no signal processing, but older or lower-quality sensors may produce measurement jitter and fluctuations. The AnyLeaf drivers compensate for this by using a Kalman filter, which attempts to find the true measurement value, even if the electrode’s output is noisy. It does this using This can be bypassed using the API, customized, or replaced with a custom filter. The AnyLeaf drivers disable this filter during large jumps, eg when moving the sensor from one solution to another.

Onboard temperature sensor

The onboard temperature compensation sensor (Texas Instrument LM61) is only suitable for uses in situations where the temperature of the solution being measured is at a similar temperature to the ambient air temperature the module sits in. This is a reasonable approximation in some cases, but is unsuitable for measuring solutions that differ in temperature, such as large bodies of water, or heated/cooled solutions. It’s also unsuitable if the module is placed in an enclosure that is warmer or cooler than the surrounding air. In these situations, or for the most accurate temperature compensation, it’s recommended that you use an external temperature sensor immersed in the substance being measured. The AnyLeaf drivers make it easy to use this measurement when taking readings, and calibrating.

Power consumption

When using the official drivers, this device uses its ADC’s single-shot mode. The device is in a power-down state when idle. When you command a reading, it wakes up, takes the reading, then reverts to this idle state, where it uses minimal power. If you modify the drivers to use the ADC’s continuous mode, power consumption will be higher.

The input voltage for this module can be from 2 – 5V, but you must be careful not to supply it with a voltage higher than your microcontroller can accept on its SDA and SCL pins. For example, supplying this module with 5V input could damage a Raspberry Pi, since its input pins are only rated for 3.3V maximum.

Probe storage

pH and ORP probes, like all glass electrodes, must be stored wet: If the bulb is stored dry for any length of time, it will be permanently damaged. AnyLeaf probes come immersed in a Potassium Chloride (KCl) solution in their cap. If not used in continuous immersion, it's recommended to store it in this cap, and to top up the cap as required. (This solution may be sold as *pH storage solution)*