

## General Description

The AnyLeaf conductivity (EC) module is a digital measurement interface for electrical conductivity probes. It can measure a wide range of conductivities with high accuracy, when paired with probes of appropriate conductivity cell constant (K). The module may be connected to any microcontroller that supports the I2C interface. It includes an internal analog temperature sensor: a Texas Instrument LM61, for temperature compensation.

The measurement design follows principles described in the [Analog Devices CN0411](#) reference design. Reference that document for details of design and operation; note that details not directly related to measurement have been modified. Conductivity is calculated from measuring the voltage drop through a divider, where the two resistances are from a known source, and the probe.

## Specifications

- **Dimensions:** 60×27×17(height) mm
- **Weight:** 14 grams
- **Precision:** 3%
- **Compatible cell constants:** K=0.01, K=0.1, K=1.0, K=10
- **Conductivity range:** 0.01  $\mu\text{S/cm}$  to 1 S/cm
- **Input voltage:** 3.3V
- **Mounting screws:** 4 × M3, 6mm len (included)
- **Protocol:** UART
- **Sensor interface:** BNC Male (Accepts BNC female sensors)
- **Power consumption:** 375 $\mu\text{A}$

### The following sequence of event are used in the measurement:

- A signal of known voltage is generated by a Digital-to-Analog converter (DAC).
- The signal is passed to a precision (0.1% tolerance) reference resistor, selected by an Analog Devices ADG1608 multiplexer.
- The signal is then connected to both the probe, and an Analog-to-Digital converter (ADC).
- The signal connected to the probe passes through its two terminals, then to ground. The direction through the terminals is chosen using an Analog Devices ADG884 switch. The switch rapidly inverts polarity to balance capacitive and ionization effects.

- The ADC measures voltage of the signal connected to it. This voltage is the same as the voltage drop across the probe terminals. The module's microcontroller (MCU) calculates current, and resistance through the probe, to determine conductivity. It outputs conductivity digitally, through the module's I2C terminals.

## MCU

This module uses an STM32F303 MCU control measurement processes, and calculate conductivity. Functions include selecting gain, selecting excitation voltage, selecting polarity-switching frequency, and measuring voltage drop across the divider. It also conducts all calculations required to find conductivity. To save power, the MCU enters a low-power state while measurements are not being taken.

## Auto-ranging

In order to provide accurate results across a wide range of conductivity, and limit voltage across the probe terminals, the module selects several parameters automatically during the measurement process:

- One of 7 precision gain resistors is selected using the multiplexer: The one with the closest resistance to that across the probe terminals is used.
- Excitation voltage is chosen by the DAC to provide a target voltage of 150mV across the probe terminals. This is sufficient for measurement, and is in the safe range of most probes.
- Excitation current polarity-switching frequency is selected based on the measurement range: 2.4KHz is used for measurements above 1,200 $\mu$ S/cm. 94Hz is used for measurements below 400 $\mu$ S/cm. 900Hz is used for measurements between. This provides an optimal balance of negative capacitive effects (These occur more strongly at high frequencies), and polarization effects (These occur more strongly at lower frequencies).

## Compatible cell constants, and ranges

The following conductivity cell constants are compatible, and are suitable for measuring the following ranges:

K = 0.01: < 0.1  $\mu$ S/cm

K = 0.1: 0.1  $\mu$ S/cm to 100  $\mu$ S/cm

K = 1.0: 100  $\mu$ S/cm to 10 mS/cm

K = 10: 10 mS/cm to 1 S/cm

## Interference with other measurements

This module may interfere with other measurements, due to the excitation current it uses. To mitigate these effects, space other sensors out, and don't measure simultaneously with them. BY default, it activates excitation current only while measuring, to mitigate this. This can be changed in software-based

## Interfacing

This module communicates using a UART serial connection. Connect its TX pin to a UART RX pin on your microcontroller, and its RX pin to a UART TX pin on your microcontroller. The easiest way to make measurements is using AnyLeaf software. If you'd like to interface directly, the table below for the commands. Each command signal is 11 bytes long. The first two bytes signal the start of a command, and are 100 and 150 respectively. The final byte is 200.

Command	Byte code	Data format	Response
Read conductivity	10	(None)	Reading in $\mu\text{S}/\text{cm}$ / K (16-bit)
Read temperature	11	(None)	Air temperature in $^{\circ}\text{C}$ , $\times 10$ (16-bit)
Set excitation current mode	12	0: Only while reading (default) 1: Always on	Success or failure
Set cell constant (K)	13	0b00: K=0.01 0b01: K=0.1 (default) 0b10: K=1.0 0b11: K=10	Success or failure

Responses are enclosed in the same starting and ending bytes as the commands. Measurements (conductivity and temperature) are returned as 16-bit integers. The byte-code [99, 99, 99] indicates an error, and [50, 50, 50] indicates a success.

Example: Send bytes [100, 150, 10, 0, x, x, x, x, x, 200]. This Sets cell constant (K) to 0.01. A response of [100, 150, 50, 50, 50, 200] indicates this was successfully accomplished.

The conductivity response scaling with the cell constant allows for sliding precision with the cell constant, reflecting how the measurement is taken. Temperature compensation, and conversion to TDS are not handled by the module; they're handled in processing the measurements, for example in the AnyLeaf software.

## 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.

© 2020 AnyLeaf LLC