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EVAL-CN0411-ARDZ Shield Overview

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CN0411 is a total dissolved solids measurement (TDS) system using direct measurement of conductivity of the solution. The system can measure low to high conductivity levels ranging from 1 µS to 0.1 S and can accommodate 2-wire conductivity probes of different cell constants from 0.01 to 10. Temperature compensation is performed using either a 100 Ω or 1000 Ω 2-wire RTD.

CN0411 generates a bipolar square wave excitation across the conductivity probe using the AD5683R, a 16-bit SPI voltage DAC, and the ADG884, ultra-low on-resistance CMOS Dual 2:1 SPDT switch. The frequency of the excitation is controlled by a PWM signal from the microcontroller which can be set to either 2.4 kHz or 94 Hz via the system software.

The range of conductivity measurement can be adjusted using gain resistors switched using the ADG1608, a 16:1 multiplexer.

The conductivity cell signal is measured by the AD8220, a low-input current JFET instrumentation amplifier. Then, A track-and-hold amplifier implemented using AD8628, a zero-drift rail-to-rail single supply op amp, samples the signal for the AD7124-8, a low noise low power 24-bit Sigma-Delta ADC. With the software calibration, the calibrated system accuracy is less than 2% for all conductivity ranges from 1 µS to 0.01 S and less than 7% for conductivity ranges greater than 0.01 S. This makes the system reliable for conductivity measurement used to compute TDS.

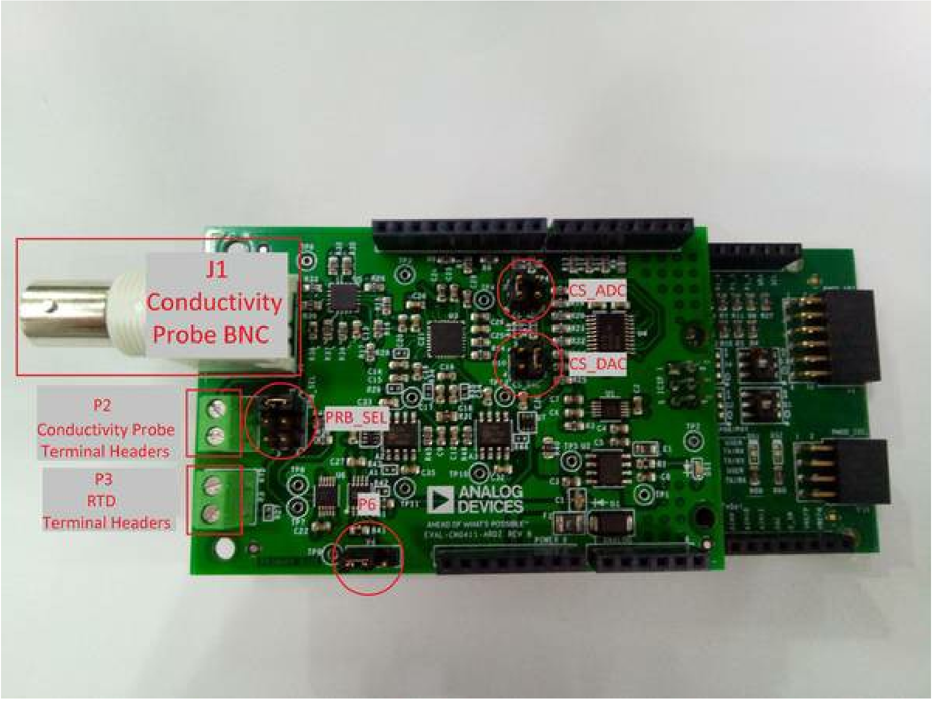
This design uses a combination of components that allow for single supply operation which minimize circuit complexity, making this suitable for low-power and portable instrument applications.
Applications include chemical water analysis for field research, and monitoring water systems and natural bodies of water.

Total Dissolved Solids Measurement

The measurement of the total dissolved solids in a solution relies primarily on the conductivity and the temperature of the solution. Furthermore, the TDS factor, used to compute the TDS from the temperature-compensated conductivity value, varies at a defined range for different types of solutions based on the type of dissolved solids. The temperature coefficient used for compensation also depends on the type of the dissolved solid. Thus, total dissolved solids remains a general measure for water quality and cannot distinguish between the constituents of the dissolved solids in the solution.

Hardware Connection and Jumper Configurations

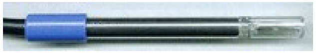
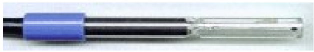
The CN0411 connects to the EVAL-ADICUP360 using the Arduino mating headers. Shown below is the CN0411, connected to the EVAL-ADICUP360, with labels for the hardware connections and jumper headers.



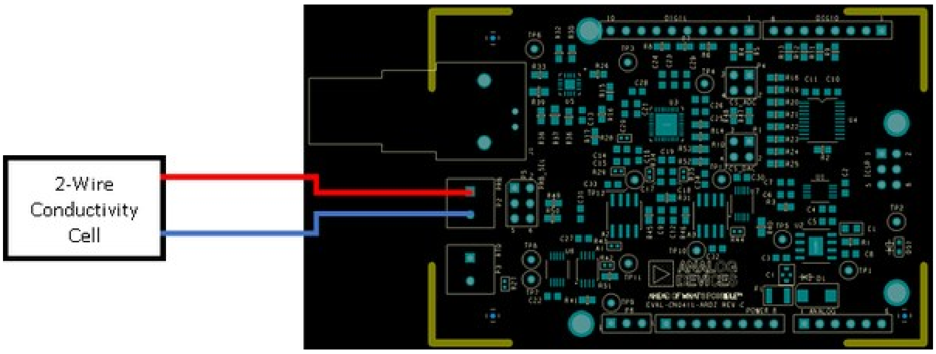
Sensor Connections

The CN-0411 has three hardware connectors which have no polarity and can connect directly to the sensors:

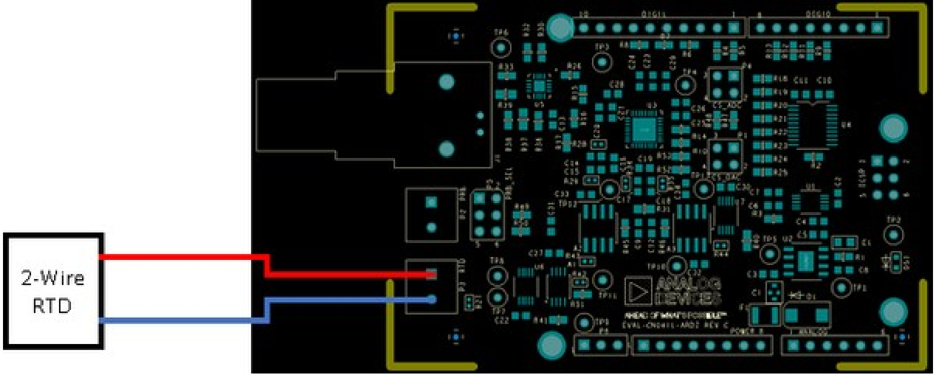
J1 is for 2-wire conductivity probes with a BNC plug. This is compatible with common commercial probes. Below are recommended probes of different cell constants.

Cell Constant	Description	Images
0.1	CS SK21T 2-Electrode Glass Cell	
1	CS SK20T 2-Electrode Glass Cell	
10	CS SK23T 2-Electrode Glass Cell	

P2 is a terminal block connector for conductivity probe's with no BNC plug. The connection diagram is shown below

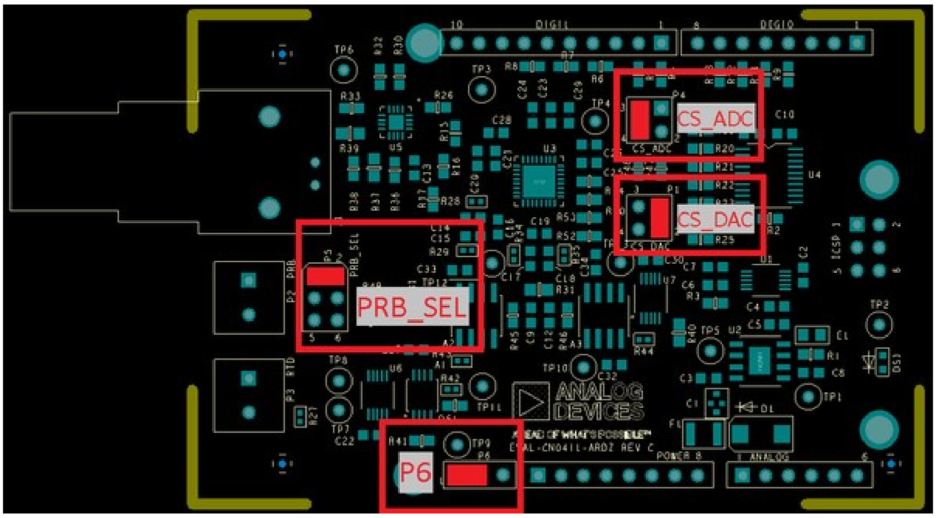


P3 is a terminal block connector for a 2-wire RTD. The software is compatible with Pt100 and Pt1000 RTDs. The connection diagram is shown below



Jumper Configurations

The CN0411 has four jumper headers which configure different settings as shown below. Also, the default shunt positions are highlighted.



Sensor Select

PRB_SEL selects the connection to the conductivity sensor. By default, the shunt is placed connecting pin 1 and 2 to measure the conductivity of the solution.

PRB_SEL Shunt Position	Conductivity Sensor Connection
1 and 2	Conductivity Probe
3 and 4	200Ω Precision Resistor
5 and 6	20Ω Precision Resistor

* Connecting Pins 1 and 2 allows the system to measure the conductivity of the solution.

- Connecting Pins 3 and 4 allows the system to calibrate in the 0.01 S range
- Connecting Pins 5 and 6 allows the system to calibrate in the 0.1 S range

Signal Input Select

P6 selects selects the input to the AD8220 instrumentation amplifier. By default, the shunt position connects pins 1 and 2 to sample the conductivity sensor.

P6 Shunt Position	AD8220 Instrumentation Amplifier Input
1 and 2	Conductivity Signal
2 and 3	AGND

* By connecting Pins 1 and 2, the AD8220 instrumentation amplifier samples the signal from the connected conductivity sensor.

- Connecting Pins 2 and 3 allows the system to perform zero-scale calibration of the system.

ADC Chip Select

CS_ADC selects the chip select GPIO pin for the AD7124-8. This allows for multiple board stack-up of CN0411 for customer applications requiring 2 conductivity readings. By default, the shunt position connects pins 3 and 4 to set the chip select to GPIO30.

CS_ADC Shunt Position	AD7124-4 Chip Select
1 and 2	DIGI1 Pin 1 or GPIO28

CS_ADC Shunt Position	AD7124-4 Chip Select
3 and 4	DIGI1 Pin 2 or GPIO30

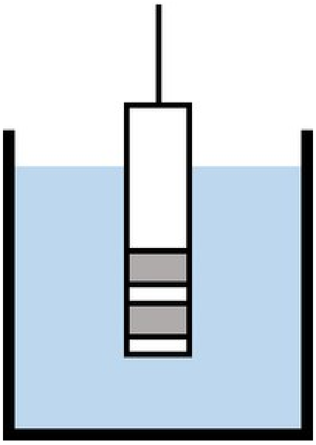
DAC Chip Select

CS_DAC selects the chip select GPIO pin for the AD5683R. This allows multiple board stack-up of CN0411 for customer applications requiring the interface of 2 conductivity sensors. By default, the shunt position connects pins 1 and 2 to set the chip select to GPIO26.

CS_DAC Shunt Position	AD5683R Chip Select
1 and 2	DIGI1 Pin 3 or GPIO26
3 and 4	DIGI0 Pin 3 or GPIO15

Conductivity Measurement

The system measures conductivity using a 2-wire conductivity probe to be immersed in the solution as shown below.



It is preferable that the conductivity probe be positioned at the center of the container to maximize the accuracy of the measurement. The cell constant of a 2-wire conductivity probe is the distance between its two cells or electrodes divided by their inner surface area. The cell constant of the conductivity probe sets the range of conductivity measurements it is suitable to use. Proper selection of the probe makes it easier for the system to measure at a certain conductivity range. Below is the table listing the range of conductivity measurements appropriate for the probe's cell constant.

Cell Constant	Range of Measured Conductivity
0.01	< 0.1 μS/cm
0.1	0.1 μS/cm to 100 μS/cm
1	100 μS/cm to 10 mS/cm
10	10 mS/cm to 1 S/cm

Conductivity probes have different rated voltages. Before connecting the probe to the CN0411, check the excitation voltage setting in the software and configure it to within the specified rating.

The frequency of the excitation signal across the conductivity cells depends on the range of conductivity measurement. The system can switch between 94 Hz, suitable for measurements in the μS range, and 2.4kHz suitable for measurements in the mS range and above.

Temperature Measurement

The system can use either Pt100 or Pt1000 RTD sensors and is configurable through the software. Most commercial probes in the market have these RTDs built in the conductivity probe.
The temperature coefficient depends on the type of solution and can be configured in the software. The system has built-in stored values for sodium chloride (NaCl) and potassium chloride (KCl) solutions as shown in the table below.

Salt Solution	Temperature Coefficient (α)
Potassium Chloride (KCl)	1.88
Sodium Chloride (NaCl)	2.14

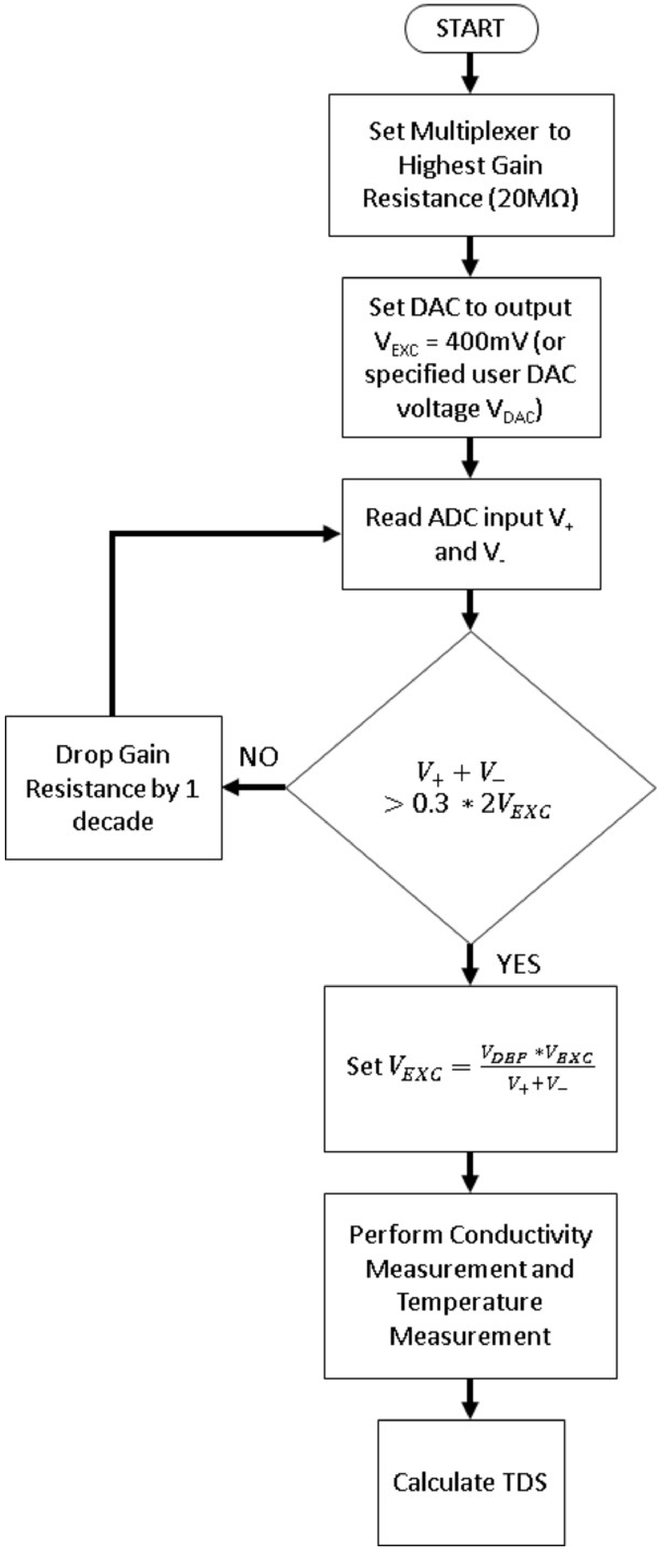
Total Dissolved Solids Measurement

The total dissolved solids in the solution is computed from the temperature-compensated conductivity measurement by the TDS factor which varies per type of dissolved solid. This can be configured through software and the system has built-in stored values for NaCl and KCl solutions.

Salt Solution	Range of TDS Factor (ke)
Potassium Chloride (KCl)	0.50 to 0.57
Sodium Chloride (NaCl)	0.47 to 0.50

Calibration and Auto-ranging

The system can automatically select the proper gain resistance from the user-defined excitation voltage when commanding the system to measure TDS. Below is the procedure used to select the gain resistance appropriate to the measured conductivity range.


START
Set Multiplexer to Highest Gain Resistance (20MΩ)
Set DAC to output V_{EXC} = 400mV (or specified user DAC voltage V_{DAC})
Read ADC input V_+ and V_-
$V_+ + V_- > 0.3 * 2V_{EXC}$
NO
Drop Gain Resistance by 1 decade
YES
Set $V_{EXC} = \frac{V_{DBF} * V_{EXC}}{V_+ + V_-}$
Perform Conductivity Measurement and Temperature Measurement
Calculate TDS

To decrease the effect of system noise to the measurement, the zero-scale calibration should be performed once per board. Every measured voltage level will be referenced to the zero-scale calibration voltage. Below are the steps to perform zero-scale calibration.

1. Place the shunt position of jumper header P6 to connect pins 2 and 3.
2. Command the software to perform zero-scale calibration.
3. Wait for the command to finish
4. Place the shunt position of the jumper header P6 back to pins 1 and 2

To increase the accuracy of the system in the 0.01 S range or 0.1 S range, reference-resistor calibration should be performed once per board. This calibrates the system to a known 200 Ω and 20 Ω precision resistance, respectively. Below are the steps to perform reference-resistor calibration.

1. Place the shunt position of PRB_SEL to connect pins 3 and 4 for a 0.01 S range calibration or to connect pins 5 and 6 for a 0.1 S range calibration.
2. Command the software to perform a reference resistor calibration
3. Wait for the command to finish
4. Place the shunt position of the jumper header PRB_SEL back to pins 1 and 2

Software

- ADICUP360 + CN0411 Demo Software and Setup

Schematic, PCB Layout, Bill of Materials

EVAL-CN0411-ARDZ Design & Integration Files

- Schematics
- PCB Layout
- Bill of Materials
- Allegro Project

End of Document