ADI Water Analysis Solution for pH Meters and Conductivity Meters

Application Introduction

In this article, we will talk about two of the most popular applications in the water analysis field: pH meters and conductivity meters.

pH is a measure of the acidity or alkalinity of a solution. As we know, most living things depend on a proper pH level to sustain life. The measurement of pH is critical in many fields ranging from chemical processing, pulp and paper, food, beverage, pharmaceutical, and so on.

Conductivity is a measure of how well a solution conducts electricity, which is an extremely widespread and useful method for quality control purposes. Surveillance of water purity, control of drinking water and process water quality, and estimation of the total number of ions in a solution can all be performed using conductivity measurements. In general, the measurement of conductivity is a rapid and inexpensive way of determining the total concentration of ions in a solution. However, it is a nonspecific technique, unable to distinguish between different types of ions, giving instead a reading that is proportional to the combined effect of all the ions present.

System Design Considerations

Stability: Drift with time and temperature are very important factors during pH meter and conductivity meter design. To achieve this objective, low drift and an accurate signal chain would be required, which ADI is very good at.

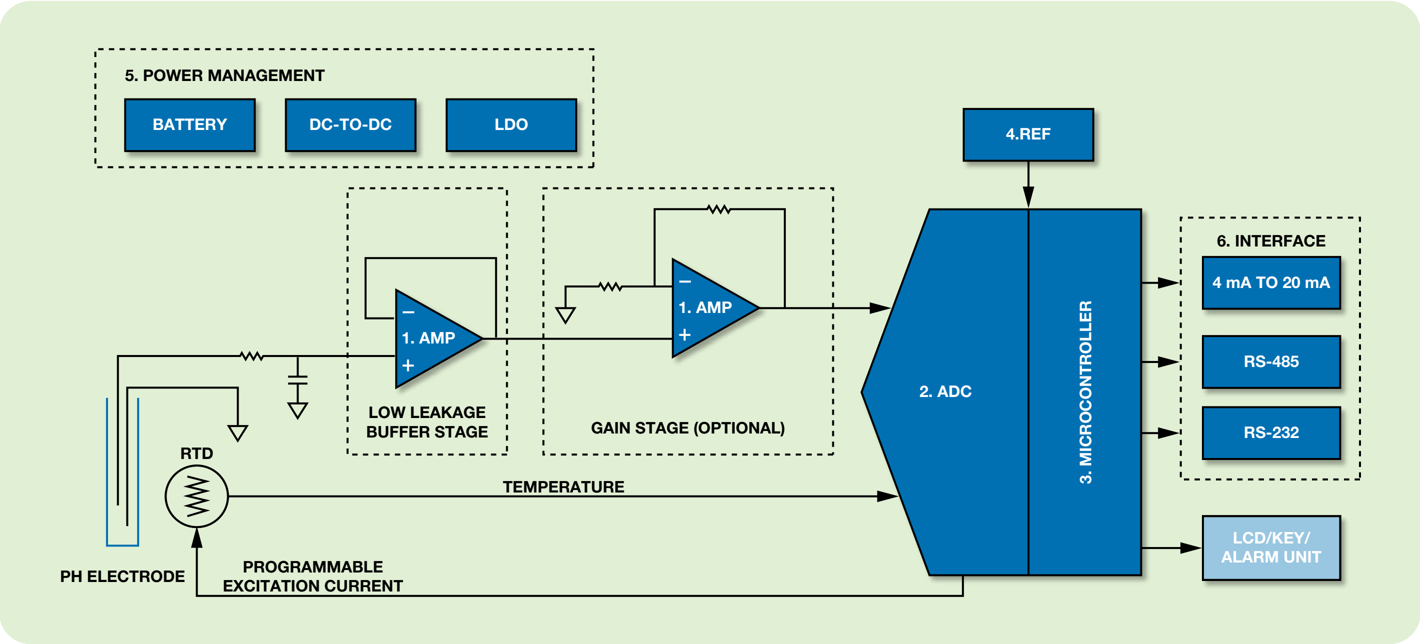
Resolution: To take full advantage of sensor dynamic range, low noise and high resolution should be taken into consideration during signal chain and power design, especially for laboratory instruments.

Low Power Consumption: Portability is one major trend in instruments recently. pH meters and conductivity meters also have portable versions, which should work a pretty long time outdoors with limited battery resources. In this condition, low power consumption is required during the design phase.

Solutions from ADI

System Block Diagram

1. Below is the system block diagram of a pH meter including pH electrodes, low leakage input stage, gain stage (optional), microcontroller (ADC and reference integrated), power management, and a communication interface.



Note: The signal chains above are representative of the system block diagram of a system block diagram of pH meter design. The technical requirements of the blocks vary, but the products listed in the table below are representative of ADI's solutions that meet some of those requirements.

1. Amplifier	2. ADC	3. Microcontroller	4. Reference	5. Power Management	6. Interface
ADA4505-2/AD8626 ADA4665-2/ADA4692-2	AD7792/AD7793	ADuCM361/ADuC7061	ADR4525/ ADR3425/ ADR291	ADP2503/ADP2370/ ADP160/ADP7102	AD5412/AD5422/ ADM2484E/ADM3251E

pH measurement can be achieved by determining the hydrogen ion concentration in solution through measuring an electrode and reference electrode. The purpose of the reference electrode is to provide a constant reference potential regardless of the solution in which it is immersed. The function of the measuring electrode is to develop a potential difference against the reference electrode, which is proportional to the pH value of the solution. A low bias current amplifier should be applied as a buffer to achieve accurate pH measurement since pH electrodes have a very large output resistance. After the low leakage buffer stage, the signal is presented at the gain and low pass filter stage to achieve more resolution. It finally goes into the Σ-Δ ADC, which is also responsible for temperature measurement of the solution for compensation.

Stability: ADI is committed to providing accurate signal chain products like low bias current and low offset drift amplifiers, low noise/drift/hysteresis references, and highly accurate ADCs, all of which help designers to build accurate and stable pH measurement systems.

The amplifiers in the table above with around 1 μV/°C offset drift and around 1 pA, not only at room temperature but also from 0°C to 50°C, can make environmental testing easy.

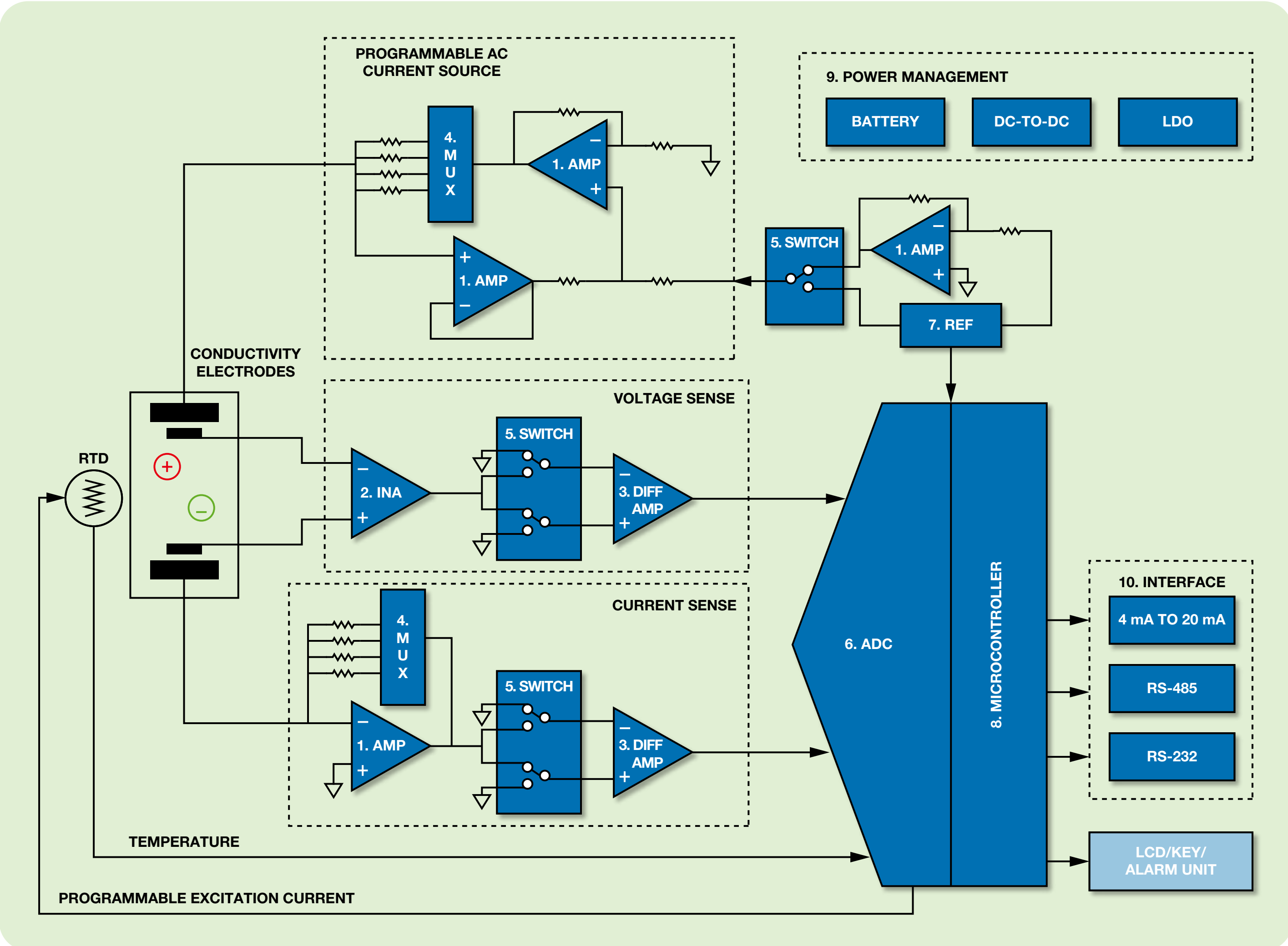
The reference in the table above is also not only good at low drift and low noise but also the hysteresis in a wide temperature range helps to pass environmental tests, too.

The ADCs in the table above feature not only low noise but also temperature measurement, which is used to compensate pH measurement. The internal current programmable excitation and potential bias are great fit to RTD and TC temperature measure.

Resolution: Most pH meters deliver 3½ digits resolution, which means a 16-bit Σ-Δ ADC is enough for this application. Some laboratory pH meters can go up to 5½ digits resolution, which means a 24-bit Σ-Δ ADC like the AD7793 and low flicker noise amplifier ADA4505-2/AD8626 should be applied.

Low power consumption: As we know, one trend of instrumentation is smaller and portable. The products in the table above for every category get low power consumption, like ADA4505-2/AD8626, ADR291, AD7792/3, ADuCM361, ADP2503, ADP160.

2. Below is the system block diagram of a conductivity meter including conductivity electrode, programmable AC current source, voltage sense, current sense, microcontroller (ADC and reference integrated), power management, and communication interface.



Note: The signal chains above are representative of the system block diagram of a conductivity meter design. The technical requirements of the blocks vary, but the products listed in the table below are representative of ADI's solutions that meet some of those requirements.

1. Amp	2. INA	3. Difference Amplifier	4. Mux	5. Switch
AD8626/ADA4692-2 AD8603/AD8605	AD8220/AD8228/AD8421	AD8271/AD8278	ADG704/ADG708/ADG1609	ADG733/ADG1636
6. ADC	**7. Ref**	**8. MCU**	**9. Power Management**	**10. Interface**
AD7792/AD7793	ADR4525/ADR3425 ADR291	ADuCM361/ADuC7061	ADP2503/ADP2370 ADP160/ADP7102	AD5412/AD5422 ADM2484E/ADM3251E

Conductivity is a measure of the total concentration of ions in solution which can be achieved by applying alternating current. This current forces the ions to flow forth and back to produce alternating potential between conductivity electrodes. The conductivity meter measures the voltage with two nodes mode and four nodes mode depending on system accuracy requirements. With Ohm's law, the conductance of the solution can be calculated with measured voltage and current. As shown in the block diagram, the current is generated in the programmable AC current source with reference, op amp and multiplexer. The voltage across the electrodes is sensed by an instrumentation amplifier followed by switch and difference amplifier. The current through the electrodes is sensed by an I/V circuit followed by a switch and difference amplifiers, too. The switch and difference amplifier demodulation circuit can transfer AC signals to DC signals that present at the input of Σ-Δ ADCs.

Stability: Like pH meters, ADI precision signal chain products can help designers to build an accurate and stable conductivity measurement system. Precision references, low bias drift op amp, and low on resistance multiplexers compose a precision programmable current source. Low bias current instrumentation amplifiers, low on resistance switches, and difference amplifiers make accurate voltage measurement. To get accurate conductivity results, temperature measurement based RTD is done which can be facilitated by an ADI ADC with internal current source.

Low power consumption: Like pH meters, the products in the table above for almost every category get low power consumption, which can compose a low power consumption system.

Main Products

Part Number	Description	Benefits
Operational Amplifier		
ADA4505-2	0.5 pA bias current @ typ room temperature, less than 1 pA bias current @ typ 50°C, low offset drift 2 μV/°C, 10 μA quiescent current, rail-to-rail both input/output, zero input crossover distortion amplifiers; PSRR: 100 dB minimum; CMRR: 105 dB typical	Low bias current @ 0°C to 50°C, low offset drift, suitable for pH meter, low power consumption, suitable for portable instrumentation, higher PSRR brings little affection to accuracy even without regulator
AD8626	0.25 pA bias current @ typ room temperature, less than 2 pA bias current @ typ 50°C, low offset drift 2 μV/°C, up to ±13 V power supply, high bandwidth 5 MHz, rail-to-rail output	Wider power supply range, low bias current @ 0°C to 50°C, low offset drift, suitable for pH meter, high bandwidth for AC current source
ADA4665-2	0.1 pA bias current @ typ room temperature, 0.2 pA bias current @ typ 50°C, low offset drift 3 μV/°C, up to ±8 V power supply, rail-to-rail input/output	Wider power supply range, low bias current @ 0°C to 50°C, low offset drift, suitable for pH meter
ADA4692-2	0.5 pA bias current @ typ room temperature, 0.5 pA bias current @ typ 50°C, low offset drift 1 μV/°C, 3.6 MHz bandwidth, rail-to-rail output	Low bias current @ 0°C to 50°C, low offset drift, low noise and high bandwidth, suitable for pH meter and AC current source.
AD8603	1 pA max @ 25°C, micropower: 50 μA, low offset voltage: 50 μV max, rail-to-rail input/output	Low bias current at room temperature, low power and low offset opamp
AD8605	1 pA max @ 25°C, low offset voltage: 65 μV max, 10 MHz bandwidth, high output current: 80 mA, rail-to-rail input/output	Low bias current at room temperature, high speed, high output current, low offset opamp
Instrumentation Amplifier		
AD8220	JFET input, low bias current 10 pA @ typ, high bandwidth 1.5 MHz @ G = 1, gain range 1 to 1000	Low bias current, enough bandwidth, suitable for conductivity meter
AD8228	Low bias current 0.5 nA, low gain drift 1 ppm/°C, low noise 15 nV/√Hz	Fixed gain with internal resistor save cost and improve gain accuracy
AD8421	Low bias current 0.1 nA, low noise 3 nV/√Hz, high bandwidth 10 MHz @ G = 1, low offset drift 0.2 μV/°C, Slew rate 35 V/μs	Low noise and low bias current, high speed instrumentation amplifier
Difference amplifier		
AD8271	Gain = ½, 1, 2; gain drift 10 ppm/°C; 15 MHz; 30 V/μs slew rate	Low gain drift and high speed, suitable for the drive ADC in conductivity application
AD8278	Low power consumption 100 μA, G = ½ or 2, bandwidth 1 MHz,	Low power consumption, enough bandwidth for conductivity meter
Mux		
ADG704	4-channel multiplexer, low on resistance 2.5 ohm @ typ, low leakage current 10 pA @ typ, low power consumption 1 μA	Low leakage and low on resistance help to build high accurate system
ADG708	8-channel multiplexer, low on resistance 3 ohm @ typ, low leakage current 10 pA @ typ, low power consumption 1 μa	Low leakage and low on resistance help to build high accurate system
ADG1609	4-channel multiplexer, ±8 V power supply, low on resistance 4.5 ohm @ typ, low leakage current 20 pA @ typ, low power consumption 1 μA	Wider power supply range, low leakage and low on resistance help to build high accurate system
Switch		
ADG733	Double SPDT switch, low on resistance 2.5 ohm @ typ, low leakage current 10 pA @ typ, low power consumption 1 μA	Low leakage and low on resistance help to build high accurate system
ADG1636	Double SPDT switch, ±8 V power supply low on resistance 2.5 ohm @ typ, low leakage current 10 pA @ typ, low power consumption 1 μA	Wider power supply range, low leakage and low on resistance help to build high accurate system
ADC		
AD7792	400 μA quiescent current, 3-channel 16-bit peak-to-peak resolution, up to 470 Hz output update rate, on chip reference, internal bias voltage, internal current excitation	Low power consumption and high integrated Σ-Δ ADC, high resolution and high accuracy, suitable for precision measurement especially temperature
AD7793	400 μA quiescent current, 3-channel 24-bit Σ-Δ ADC, up to 470 Hz output update rate, on-chip reference, internal bias voltage, internal current excitation	Low power consumption and high integrated Σ-Δ ADC, high resolution and high accuracy, suitable for precision measurement especially temperature

Main Products (Continued)

Part Number	Description	Benefits
Reference		
ADR4525	2.5 V reference, very low drift: 2 ppm/°C (max), low noise: 1.25 μV pp @ 0.1 Hz to 10 Hz, long time stability: 25 ppm/√1000hr, hysteresis: 50 ppm	Low drift, very good stability and low noise reference, low hysteresis, many other choices for output voltage in ADR45xx family
ADR3425	2.5 V reference, low drift 8 ppm/°C (max), long time stability 30 ppm/√1000hr, 100 μA max quiescent current, small size SOT-236 package	Low drift, good stability, many other choices for output voltage in ADR34xx family
ADR291	2.5 V reference,12 μA quiescent current	Low power consumption, pretty good drift and stability
Microcontroller		
ADuCM361	Precision analog microcontrollers, ARM Cortex™-M3 32-bit processor, 6 differential channels, single (24-bit) ADCs, single 12-bit DAC, power consumption 1.0 mA, 290 μA/MHz, 19-pin GPIO, 128k bytes flash/EE memory, 8k bytes SRAM. Small package, low drift internal reference 5 ppm typical, integrated programmable current source	Low power consumption, high precision 24-bit Σ-Δ ADC, 4 mA to 20 mA loop applications, small package
ADuC7061	A precision analog microcontroller based on a 10 MHz ARM7 and a highly precise dual sigma-delta ADC front-end, 24 bits of resolution and 16-bit ENOB and sub-100 Hz output rates; memory footprint includes a 32 kB flash and 4 kB SRAM; other key specs includes sub-3 mA operation (with MCU core at 1 MHz) making the part suitable for 4 mA to 20 mA loop applications, a 12-bit DAC and small packaging, 5 mm × 5 mm 32-lead LFCSP	Low power consumption, low cost 24-bit Σ-Δ ADC, 4 mA to 20 mA loop applications, small package
Power Management		
ADP2503	38 μA quiescent current; 2.5 MHz buck-boost dc-to-dc converters, has ability to operate at input voltages greater than, less than, or equal to the regulated output voltage	Low power consumption to achieve long battery life, small package and few external parts around cost small PCB space
ADP2370	3.0 V to 15 V input buck regulator, 800 mA output current, 1.2 MHz or 600 KHz PWM frequency, low quiescent current 14 μA, high efficiency larger than 90%, current-mode control architecture	Small 3 mm × 3 mm LFCSP package, few peripHeral components, and small solution size
ADP160	2.2 V to 5.5 V input LDO, 150 mA maximum output current, ultralow quiescent current: 10 μA when output 10 mA, up to 15 fixed-output voltage options available from 1.2 V to 4.2 V	Low power consumption, integrated output discharge resistor, small package with only two 1 μF external capacitor
ADP7102	20 V input LDO, 300 mA output current, low noise 15 μV rms, 7 fixed version and adjustable version	High input voltage, low noise LDO
Interface		
AD5422	Current output ranges: 0 mA to 24 mA, voltage output range: 0 V to 5 V, 0 V to 10 V, ±5 V, ±10 V, 16-bit resolution, 0.01% FSR typical total unadjusted error; 3 ppm/C typical output drift; on-chip reference (10 ppm/°C maximum)	16-bit resolution and monotonicity, supports HART communication
AD5412	Current output ranges: 0 mA to 24 mA, voltage output range: 0 V to 5 V, 0 V to 10 V, ±5 V, ±10 V, 12-bit resolution, 0.01% FSR typical total unadjusted error; 3 ppm/°C typical output drift; on-chip reference (10 ppm/°C maximum)	12-bit resolution and monotonicity, supports HART communication
ADM2484E	Full/half-duplex isolated RS-485/RS-422 transceiver, 500 kbps data rate, 256 nodes, 5 V or 3.3 V operations, 15 kV ESD protection 5 kV isolation	Highly integrated isolated RS-485 transceiver
ADM3251E	Isolated RS-232 transceiver, 460 kbps data rate, 5 V or 3.3 V operations, 15 kV ESD protection, 2.5 kV isolation	Highly integrated isolated RS-232 transceiver

Design Resources

Application Notes/Articles

- Dual-Channel Colorimeter with Programmable Gain Transimpedance Amplifiers—*www.analog.com/CN0312*
- Programmable-Gain Transimpedance Amplifiers Maximize Dynamic Range in Spectroscopy Systems —*www.analog.com/library/analogdialogue/archives/47-05/pgtia*

Design Tools/Forums

- ADuCM361 Design Tools—*ftp://ftp.analog.com/pub/MicroConverter*
- Analog Photodiode Wizard—*www.analog.com/en/content/photodiode_wizard/fca*
- Analog Filter Wizard™: ADI Active Filter Design Tool—*www.analog.com/en/segment/dt-input-stage-filter-design/Filter_Wizard/resources/fca*
- ADIsimPower™: ADI Voltage Regulator Design Tool—*www.analog.com/adisimpower*
- ADIsimOpAmp™: ADI OpAmp Design Tool—*www.analog.com/adisimopamp*
- EngineerZone®: Online Technical Support Community—*ez.analog.com*

To view additional gas detector resources, tools, and product information, please visit: *instrumentation.analog.com*

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