Circuits from the Lab® Reference Designs

Circuits from the Lab® reference designs are engineered and tested for quick and easy system integration to help solve today's analog, mixed-signal, and RF design challenges. For more information and/or support, visit www.analog.com/CN0349.

Devices Connected/Referenced	
AD5934	250 kSPS, 12-Bit Impedance Converter Network Analyzer
AD8606	Precision, Low Noise, Rail- to- Rail Input/Output, CMOS, Op Amp (Dual)
ADG715	CMOS, Low Voltage, I²C Controlled, Octal SPST Switches
ADuM1250	Dual-Channel I²C Digital Isolator
ADuM5000	2.5 kV, Isolated DC-to-DC Converter

Fully Isolated Conductivity Measurement Data Acquisition System

EVALUATION AND DESIGN SUPPORT

Circuit Evaluation Boards

CN-0349 Circuit Evaluation Board (EVAL-CN0349-PMDZ)
SDP-I-PMOD Interposer Board (SDP-PMD-IB1Z)
System Demonstration Platform, SDP-B (EVAL-SDP-CB1Z)

Design and Integration Files

Schematics, Layout Files, Bill of Materials

CIRCUIT FUNCTION AND BENEFITS

The circuit shown in Figure 1 provides a complete, robust data acquisition solution for processing conductivity cell outputs, including temperature correction. This circuit is ideal for measuring the ionic content of liquids, water quality analysis, and chemical analysis.

This design solution is optimized for high precision and low cost, and it uses only five active devices. The circuit has a total error of less than 1% FSR after calibration. The small footprints of all the components make the circuit ideal for applications where printed circuit board (PCB) real estate is a premium. The digital output of the circuit is fully isolated; therefore, the ground loop interference is eliminated, making it ideal for harsh industrial environments.

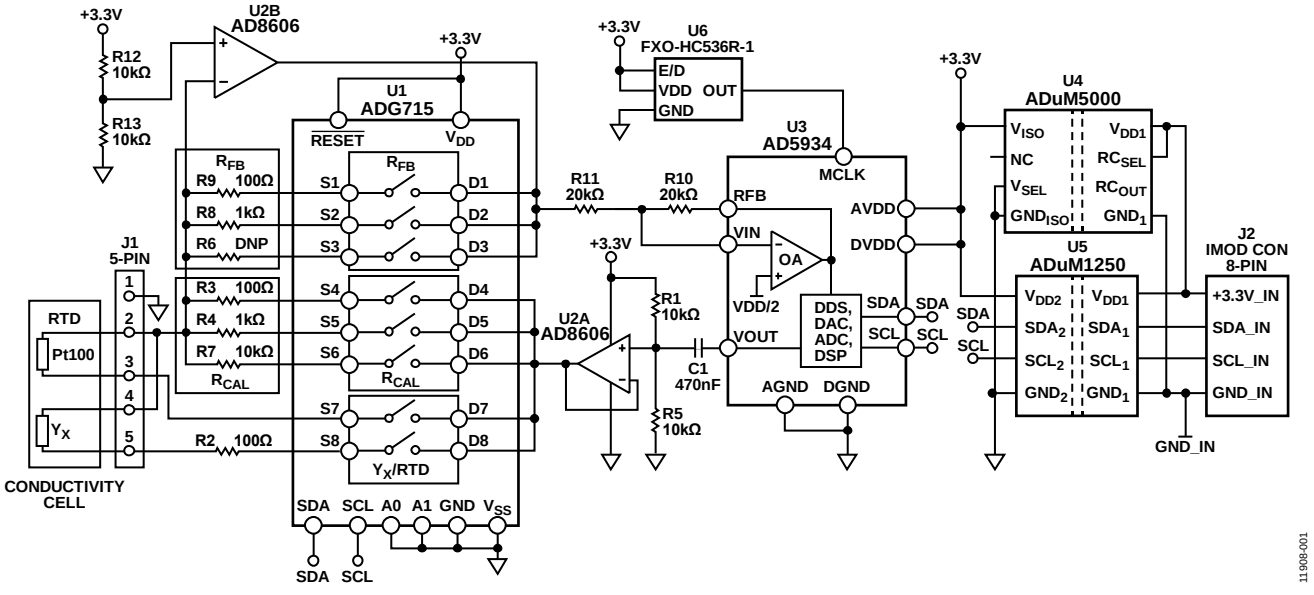

Figure 1. Fully Isolated Data Acquisition System for Conductivity Measurements (Simplified Schematic: all Pins, Connections, and Decoupling not Shown)

Rev. 0

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CIRCUIT DESCRIPTION

The circuit shown in Figure 1 incorporates the AD5934 12-bit impedance converter, the ADG715 octal single-pole, single-throw (SPST) switch, the AD8606 rail-to-rail op amp, the ADuM1250 dual I²C isolator, and the ADuM5000 isolated dc-to-dc converter to create a complete data acquisition system for conductivity measurements. The circuit has an 8-pin IMOD connector on board that can be used for connection to a customer microprocessor or a field programmable gate array (FPGA).

The AD5934 is a high precision impedance converter system solution that combines an on-chip, programmable direct digital synthesizer (DDS) with a 12-bit, 250 kSPS analog-to-digital converter (ADC). The tunable frequency generator allows an external complex impedance to be excited with a known frequency. The AD5933 is a similar device with a 1 MSPS ADC. The on-board ADC monitors the voltage and current of the unknown impedance. An on-board digital signal processor (DSP) engine calculates the discrete Fourier transform (DFT). The DFT algorithm returns a real (R) and an imaginary (I) data-word at each output frequency.

The AD8606 op amp was chosen because of its low offset voltage (65 µV maximum), low bias current (1 pA maximum), and low noise (12 nV/√Hz maximum).

The ADG715 is a complementary metal oxide semiconductor (CMOS), octal SPST switch that is controlled via a 2-wire serial interface that is compatible with the I²C interface standard. Low power consumption, a low operating supply range of 2.7 V to 5.5 V, low on-resistance (typically 2.5 Ω), and a small 24-lead TSSOP package make this device ideal for many applications.

The ADuM5000 is an isolated dc-to-dc converter with a 3.3 V or 5 V output, based on the Analog Devices *iso*Power® technology, and packaged in a 16-lead SOIC.

The ADuM1250 is a hot swappable, digital isolator with non-latching, bidirectional communication channels that are compatible with I²C interfaces, based on the *i*Coupler chip scale transformer technology from Analog Devices, Inc., and packaged in an 8-lead SOIC.

Conductivity Theory

The resistivity, ρ, of a material or liquid is defined as the resistance of a cube of the material with perfectly conductive contacts on opposite faces. The resistance for other shapes can be calculated by

$$R = \rho L/A$$

where:
L is the distance between the contacts.
A is the area of the contacts.

Resistivity is measured in units of Ω cm. A 1 Ω cm material has a resistance of 1 Ω when contacted on opposite faces of a 1 cm × 1 cm × 1 cm cube.

Conductance is the reciprocal of resistance, and conductivity is the reciprocal of resistivity.

All aqueous solutions conduct electricity to some degree. The measure of the ability of a solution to conduct electricity is called conductance, and it is the reciprocal of resistance. The unit of measurement of conductance is Siemens (S). Adding electrolytes such as salts, acids, or bases to pure water increases the conductance (and decreases resistance). Resistivity is expressed in Ω cm, and conductivity is expressed in S/cm, mS/cm, or µS/cm.

For the purposes of this circuit note, Y is used as the general symbol for conductivity measured in S/cm, mS/cm, or µS/cm. However, in many cases, the distance term is dropped for convenience, and the conductivity is simply expressed as S, mS, or µS.

A conductivity system measures conductance by means of electronics connected to a sensor immersed in a solution. The analyzer circuitry impresses an alternating voltage on the sensor and measures the size of the resulting current, which is related to the conductivity. Because conductivity has a large temperature coefficient (up to 4%/°C), an integral temperature sensor is incorporated into the circuitry to adjust the reading to a standard temperature, usually 25°C (77°F). When measuring solutions, the temperature coefficient of the conductivity of the water itself must be considered. To compensate accurately for the temperature, a second temperature sensor and compensation network must be used.

Conductivity Sensors

The contacting type sensor usually consists of two electrodes that are insulated from one another. The electrodes, typically Type 316 stainless steel, titanium palladium alloy, or graphite, are specifically sized and spaced to provide a known cell constant. Theoretically, a cell constant of 1.0/cm describes two electrodes, each sized one square centimeter in area, and spaced one centimeter apart. Cell constants must be matched to the analyzer for a given range of operation. For instance, if a sensor with a cell constant of 1.0/cm is used in pure water with a conductivity of 1 µS/cm, the cell has a resistance of 1 MΩ. Conversely, the same cell in seawater has a resistance of 30 Ω. Because the resistance ratio is so large, it is difficult for ordinary instruments to accurately measure such extremes with only one cell constant.

When measuring the 1 µS/cm solution, the cell is configured with large electrodes spaced a small distance apart. For example, a cell with a cell constant of 0.01/cm results in a cell resistance of approximately 10,000 Ω, which can be measured quite accurately. Therefore, the measuring instrument can operate over the same range of cell resistance for both ultra-pure water and high conductivity seawater, by using cells with different cell constants.

Temperature Compensation

Conductivity measuring system accuracy is only as good as its temperature compensation. Because common solution temperature coefficients vary in the order of 1%/°C to 3%/°C, or more, measuring instruments with adjustable temperature compensation must be used. Solution temperature coefficients are somewhat nonlinear and usually vary with the actual conductivity as well. Thus, calibration at the actual measuring temperature yields the best accuracy.

The circuit shown in Figure 1 yields accurate conductivity measurements, extending from the low µS range to several hundred mS, and it also optimizes the overall accuracy of the AD5934 over a wide range of admittance. Temperature measurement using a Pt100 resistance temperature detector (RTD) is also incorporated. The circuit can be connected to the evaluation microprocessor board using the 8-pin IMOD (I^2C interface) connector for rapid prototyping (Digilent, Pmod™ Specifications).

The circuit consists of four major blocks. The first block is an impedance-to-digital converter containing the AD5934 (U3) impedance converter, a follower (one half of the AD8606, U2A) to bias the ac signal to VDD/2, and a current-to-voltage converter configuration using the second half of the AD8606, U2B. Details of the operation of the AD5934 can be found in Circuit Note CN-0217 and in the AD5934 data sheet.

The second block is the programmable resistor feedback (R6, R8, R9) and calibration (R3, R4, R7) circuitry and the octal SPST switches ADG715 (U1). The measurement range and calibration procedures are realized by controlling the ADG715 via the I^2C serial interface.

The third block is the ADuM1250 (U5) hot swappable, digital isolator for transmitting the serial data from the AD5934 (U3) to the IMOD CON (J2). The fourth block is the ADuM5000 (U4) isolated dc-to-dc converter with a 3.3 V output voltage to supply the power for the circuit.

The third and fourth blocks are optional; however, they provide galvanic isolation between the circuit and the evaluation microprocessor board. They are not required unless isolation is needed.

The circuit is connected to the conductivity cell with a built-in Pt100 RTD temperature sensor using the CON1 (J1) connector.

The frequency of the clock applied to the MCLK pin is set to 1 MHz using a stable, low jitter, FXO-HC536R-1 (U6) quartz crystal oscillator. This oscillator allows the AD5934 to excite the conductivity cell with a frequency of 2 kHz, which is well suited for conductivity measurements.

Circuit Design

Figure 2 shows the optimized signal chain for conductivity and temperature measurements used in the circuit. The AD5934 has four programmable output voltage ranges. Each range has an associated output impedance. For example, the output impedance for a 1.98 V p-p output voltage is typically 200 Ω (see the AD5934 data sheet). The output impedance affects the impedance measurement accuracy, particularly in the low ohms range. A simple buffer in the signal chain prevents the output impedance from affecting the unknown impedance measurement. A low output impedance amplifier, with sufficient bandwidth to accommodate the AD5934 excitation frequency, is selected. An example of the low output impedance that can be achieved is shown in Figure 2 for the AD8605/AD8606/AD8608 family of CMOS op amps. The output impedance for this amplifier, for a gain of 1 is less than 1 Ω up to 100 kHz, which corresponds to the maximum operating range of the AD5934.

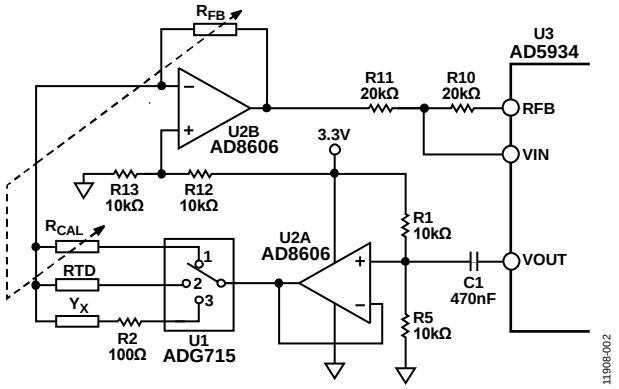

Figure 2. Optimized Signal Chain for Conductivity and Temperature Measurements

The four programmable output voltage ranges in the AD5934 have four associated bias voltages (see the AD5934 data sheet). For example, the 1.98 V p-p excitation voltage requires a bias of 1.48 V. However, the current-to-voltage (I-V) receiver stage of the AD5934 is set to a fixed bias of VDD/2. Therefore, for a 3.3 V supply, the transmit bias voltage is 1.48 V, and the receive bias voltage is 3.3 V/2 = 1.65 V. This potential difference polarizes the measured solution, Y_X, and can cause significant inaccuracies in the conductivity measurement. One solution is to add a simple high-pass filter with a corner frequency in the low Hz range (see the Circuit Note CN-0217). Removing the dc bias from the transmit stage and rebiasing the ac signal to VDD/2 keeps the dc level constant throughout the signal chain. Use precision 0.1% resistors for both of the biasing resistors, R1 and R5 (10 kΩ), to reduce inaccuracies.

The I-V amplifier stage of the AD5934 can also add minor inaccuracies to the signal chain. The I-V conversion stage is sensitive to the amplifier bias current, to the offset voltage, and to the common-mode rejection (CMR). Accuracy is improved by selecting the proper external discrete amplifier (U2B) to perform the I-V conversion. The AD8606 is chosen because of its low offset voltage (65 µV maximum), low bias current (1 pA maximum), high CMRR (95 dB typically), and low noise (12 nV/√Hz maximum). The internal amplifier can then be configured as a simple inverting gain stage. Selection of the R_{FB} resistor depends on the gain through the system, as described in the AN-1252 Application Note. The input and output of the I-V converter must be accurately biased to VDD/2. Use precision 0.1% resistors for both of the biasing resistors, R12 and R13 (10 kΩ).

The accuracy is very much dependent on how large the unknown impedance range (conductivity range) is, relative to the calibration resistor, R_{CAL} (see Circuit Note CN-0217 and Application Note AN-1252). Choosing an R_{CAL} close to the unknown impedance achieves a more accurate measurement; that is, the closer the unknown impedance range is centered around R_{CAL}, the more accurate the measurement. Consequently, for large unknown impedance ranges, it is possible to switch between various R_{CAL} resistors, as is shown in Figure 2. The on-resistance (R_{ON}) error of the switch is removed by calibration during the R_{CAL} gain factor calculation. Using various feedback resistor (R_{FB}) values (see Figure 2) can optimize the dynamic range of the signal seen by the ADC.

To improve the accuracy in the large range of conductance shown in Figure 1, three calibration resistors, R_{CAL} (100 Ω, 1 kΩ, and 10 kΩ), and two feedback resistors, R_{FB} (100 Ω and 10 kΩ), are used, controlled by the software and the ADG715 octal switches. The circuit is set to operate in two ranges:

- Low range: µS to mS, R_{FB} = 1 kΩ, R_{CAL} =1 kΩ and 10 kΩ
- High range: mS to S, R_{FB} = 100 Ω, R_{CAL} = 100 Ω and 1 kΩ

Using these two ranges, the total measuring range is 25 µS to 200 mS, with an accuracy higher than 1% FSR, as shown in the test data. Other values of R_{CAL} and R_{FB} can be chosen to cover different ranges.

The CN-0349 Evaluation Software allows the circuit to operate in three modes. In Mode 1 (Position 1 of the switch in Figure 2), the calibration procedure for both the low range and the high range is performed automatically. In Mode 2 (Position 2 of the switch in Figure 2), the temperature measurement of the solution is carried out automatically using an external Pt100 RTD temperature sensor. In Mode 3 (Position 3 of the switch in Figure 2), the actual conductivity of the solution is measured.

Calibration Procedure

For the circuit shown in Figure 1, the calibration procedure uses a three point calibration with three precision resistors, R_{CAL} (R3 = 100 Ω, R4 = 1 kΩ, and R7 = 10 kΩ), minimizing offset and gain errors and linearizing the system within each range. For each range, the calibration procedure is performed at the beginning and at the end of the input range, by using two reference signals (calibration resistors), Y_L and Y_H, as is shown in Figure 3. The values of the reference signals are preloaded in the memory of the microcontroller or they can be input through the keyboard.

For the low range calibration point, the reference signal is Y_L (for example, Y_L = 1/R7 = 1/10 000 Ω = 0.1 mS). When the reference signal Y_L is connected, a code N_L (Magnitude M_L), corresponding to the reference signal Y_L, is obtained. Likewise, for the high range calibration point, the reference is signal Y_H (for example, Y_H = 1/R4 = 1/1000 Ω = 1 mS). When the reference signal Y_H is connected, a code N_H (Magnitude M_H), corresponding to the reference signal Y_H, is obtained.

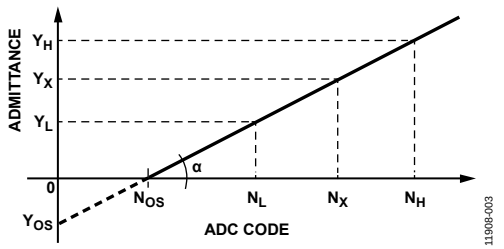

Figure 3. Two Point Calibration for Conductivity Measurement

Then, the gain factor (GF) is calculated by Equation 1

$$GF = \frac{Y_H - Y_L}{N_H - N_L} \quad (1)$$

The offset of the system (N_{OS}) can be determined referring to Figure 3 and calculated by Equation 2.

$$N_{OS} = N_H - Y_H/GF \quad (2)$$

In measurement mode, the unknown input signal (Y_X is converted in code (N_X) and calculated by Equation 3.

$$Y_X = (N_X - N_{OS}) \times GF \quad (3)$$

For the high range, the procedure is the same, but the reference signals are as follows: Y_L = 1/R4 = 1/1000 Ω = 1 mS, and Y_H = 1/R3 = 1/100 Ω = 10 mS.

To achieve a wider measurement range at low conductance ranges (high resistances), a 2 V p-p excitation output voltage is used from the AD5934. To extend the measurement range at high conductance ranges (low resistances), keeping the 2 V p-p excitation output voltage, a precision resistor, R2 = 100 Ω, is connected in series with the unknown conductance, Y_X. Other output voltage ranges can be used to optimize the ADC dynamic range at high conductance ranges (low resistances), as is shown in the Circuit Note CN-0217 and Application Note AN-1252.

Test Data Results

Using the values of the calibration and feedback resistors from Figure 1, as is described in Circuit Design section and the Calibration Procedure section, a series of experiments were conducted.

Table 1, Table 2, and Table 3 show the results in both the low range mode and high range mode. Figure 4, Figure 5, and Figure 6 show the relative errors of each range and the corresponding reading. Precise noninductive resistors with 0.1% or 0.2% tolerances define the input (unknown conductivity Y_X). The symbols used in the tables are defined as follows:

- R_X: reference resistor
- Y_X: calculated reference conductivity
- Y_R : measured (reading) conductivity
- R_R: measured (reading) resistance
- R_R: corrected resistance = R_R – R_R (for R_X = 0)

Low Range Conductivity Measurements

Table 1 shows the results of low range measurements, and Figure 4 shows both the percent relative error of the range and the percent relative error of the reading. In the low range, from 25 µS to 2500 µS, the percent error of the reading does not exceed 0.5%.

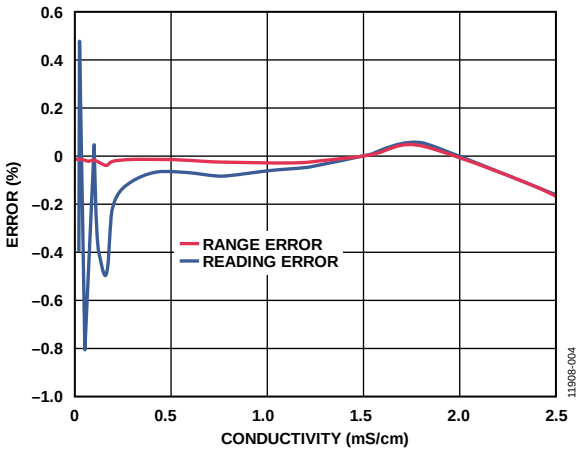

Figure 4. Relative Errors in the Low Range (from 25 µS to 2.5 mS)

Table 1. Low Range, 25 µS to 2.5 mS Measurement Data, R_{FB} = 1 kΩ, R_{CAL1} = 1 kΩ, and R_{CAL2} = 10 kΩ

R_X (Ω)	Y_X (mS/cm)	Y_R (mS/cm)	R_R (Ω)	% Error of Range	% Error of Reading
400	2.5000	2.49600	400.6	−0.1600	−0.160
549	1.8215	1.82240	548.7	+0.0363	+0.050
649	1.5408	1.54100	648.9	+0.0067	+0.011
820	1.2195	1.21900	820.3	−0.0205	−0.042
1000	1.0000	0.99960	1000.4	−0.0160	−0.040
1300	0.7692	0.76860	1301.1	−0.0252	−0.082
2210	0.4525	0.45220	2211.4	−0.0115	−0.064
4700	0.2128	0.21240	4708.1	−0.0146	−0.172
6120	0.1634	0.16380	6105.0	+0.0161	+0.246
9090	0.1100	0.10950	9132.4	−0.0204	−0.465
10100	0.0990	0.09905	10095.9	+0.0016	+0.040
20300	0.0493	0.04908	20374.9	−0.0072	−0.368
29800	0.0336	0.03371	29664.8	+0.0061	+0.456
39700	0.0252	0.02508	39872.4	−0.0044	−0.432

High Range Conductivity Measurements

Table 2 shows the results of the high range measurements, and Figure 5 shows both the percent relative error of the range and the percent relative error of the reading. In the high range, from 0.2 mS to 200 mS, the percent error of the reading does not exeed 3%.

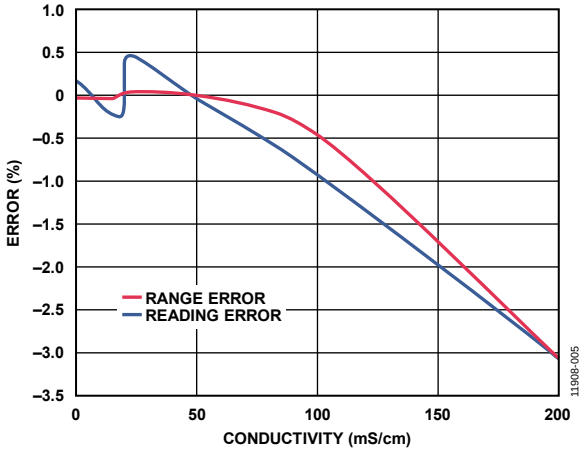

Figure 5. Relative Errors in the High Range (from 0.2 mS to 200 mS)

Table 3 shows the results from Table 2, with the resistive offset of 0.1903 Ω corrected. The R_R column, corrected in Table 3, is obtained by subtracting 0.1903 Ω from the R_R column in Table 2.

The software (CN-0349 Evaluation Software) can make this correction. After correction, the 0.2 mS to 200 mS range has a percent error of less than 1% (see Figure 6).

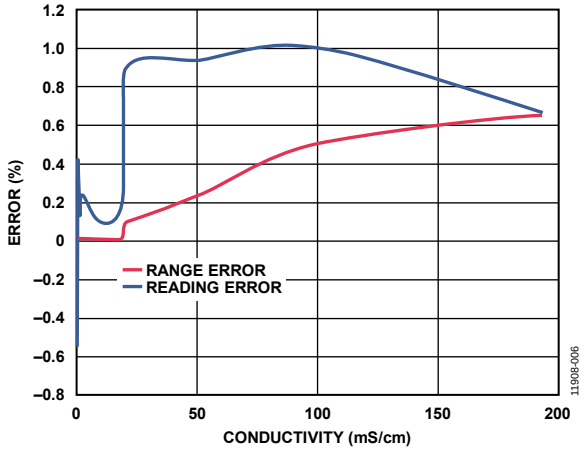

Figure 6. Relative Errors in the High Range 0.2 mS to 200 mS Measurements After Correction of the Resistive Offset (0.1903 Ω)

Table 2. High Range,0.2 mS to 200 mS Measurement Data, R_{FB} = 100 Ω, R_{CAL1} = 100 Ω, and R_{CAL2} = 1 kΩ

R_X (Ω)	Y_X (mS/cm)	Y_R (mS/cm)	R_R (Ω)	% Error of Range	% Error of Reading
0	∞	5255	0.1903	Not applicable	Not applicable
1	1000.0000	809.4	1.2355	−95.3000	−19.06
5	200.0000	193.9	5.1573	−3.0500	−3.05
10	100.0000	99.1	10.09	−0.4500	−0.90
20	50.0000	49.99	20.00	−0.0050	−0.02
50	20.0000	20.1	49.75	+0.0500	+0.50
100	10.0000	9.99	100.10	−0.0050	−0.10
200	5.0000	5.004	199.84	+0.0020	+0.08
500	2.0000	2.004	499.00	+0.0020	+0.20
1000	1.0000	1.001	999.00	+0.0005	+0.10
1300	0.7692	0.7681	1301.91	−0.0006	−0.15
2210	0.4525	0.4533	2206.04	+0.0004	+0.18
4700	0.2128	0.2116	4725.90	−0.0006	−0.55
6120	0.1634	0.1641	6093.85	+0.0004	+0.43

Table 3. High Range from 0.2 mS to 200 mS with Correction for the Resistive Offset (0.1903 Ω), R_{FB} = 100 Ω, R_{CAL1} = 100 Ω, and R_{CAL2} = 1 kΩ

R_X (Ω)	Y_X (mS/cm)	Y_R (mS/cm)	R_R (Ω)	R_R (Ω) Corrected	Y_R (mS/cm)	% Error of Range	% Error of Reading
0	∞	5255	0.1903	0.00	Not applicable	Not applicable	Not applicable
1	1000.00	809.4	1.2355	1.045	956.77	−21.6149	−4.323
5	200.00	193.9	5.1573	4.967	201.33	+0.6644	+0.664
10	100.00	99.1	10.09	9.901	101.00	+0.5024	1.005
20	50.00	49.99	20.00	19.81	50.47	+0.2351	+0.940
50	20.00	20.1	49.75	49.56	20.18	+0.0886	+0.886
100	10.00	9.99	100.10	99.91	10.01	+0.0045	+0.090
200	5.00	5.004	199.84	199.65	5.01	+0.0044	+0.175
500	2.00	2.004	499.00	498.81	2.00	+0.0024	+0.238
1000	1.00	1.001	999.00	998.81	1.00	+0.0006	+0.119
1300	0.7692	0.7681	1301.91	1301.72	0.77	−0.0005	−0.132
2210	0.4525	0.4533	2206.04	2205.85	0.45	+0.0004	+0.188
4700	0.2128	0.2116	4725.90	4725.71	0.21	−0.0006	−0.544
6120	0.1634	0.1641	6093.85	6093.65	0.16	+0.0004	+0.432

Table 4. Test Results of Measurements on Conductivity of Standard Potassium Chloride (KCl) Solutions Using Circuit Shown in Figure 1

Measurement	Standard Cell Conductivity						Unit
Standard KCl Solution (Conductivity Values)	0.1469	0.2916	0.7182	1.408	12.85	111.3	mS/cm
Conductivity Reading	0.1471	0.2923	0.7215	1.415	12.93	109.8	mS/cm
Error of Reading	0.14	0.22	0.46	0.5	0.62	1.35	%

Conductivity Measurements using Conductivity Cells

Table 4 shows the results of conductivity measurements on six 0.1% accurate standard KCl solutions: 0.1469 mS/cm, 0.2916 mS/cm, 0.7182 mS/cm, 1.408 mS/cm, 12.85 mS/cm, and 111.3 mS/cm.

The conductivity cell used is a Sensorex CS200TC-PT1 with a cell constant equal to 1/cm and a built-in Pt100 RTD temperature sensor.

The standard KCl solutions were made in a specialized Bulgarian laboratory, and they were used as data points to check the system. When the cell constant of the conductivity cell is unknown, standard solutions can also be used as calibration points instead of calibration resistors.

More information about conductivity measurement and standard solutions can be found in Shreiner, R.H., and Pratt, K.W., Primary *Standards and Standard Reference Materials for Electrolytic Conductivity (2004)*, NIST Special Publication 260-142.

PCB Layout Considerations

In any circuit where accuracy is crucial, it is important to consider the power supply and ground return layout on the board. The PCB must isolate the digital and analog sections as much as possible. The PCB for this system is constructed in a simple, 2-layer stack up, but 4-layer stack up gives better electromagnetic interference/radio frequency interference (EMI/RFI) performance. See the MT-031 Tutorial for more discussion on layout and grounding, and the MT-101 Tutorial for information on decoupling techniques. Decouple the power supply of the AD8606 with a 10 µF capacitor and a 0.1 µF capacitor to properly suppress noise and reduce ripple. Place the capacitors as close to the device as possible, with the 0.1 µF capacitor having a low effective series resistance (ESR) value. Ceramic capacitors are advised for all high frequency decoupling. Power supply lines must have as large a trace width as possible to provide low impedance path and to reduce glitch effects on the supply line. The ADuM5000 and the ADuM1250 *iso*Power devices require power supply bypassing at the input and the output supply pins. Note that low ESR bypass capacitors are required as close to the chip pads as possible. A parallel combination of at least two capacitors is required to suppress noise and reduce ripple. The recommended capacitor values are 0.1 µF and 10 µF for V_{DD1} and V_{ISO}, which applies for both the ADuM5000 and the ADuM1250. The smaller capacitor must have a low ESR; for example, a ceramic capacitor. The total lead length between the ends of the low ESR capacitor and the input power supply pin must not exceed 2 mm. Installing the bypass capacitor with traces more than 2 mm in length may result in data corruption.

For more information, see the ADuM5000 data sheet and the ADuM1250 data sheet.

A complete documentation package including schematics, board layout, and bill of materials (BOM) can be found at www.analog.com/CN0349-DesignSupport.

Setting Up and Programming

The EVAL-CN0349-PMDZ uses the CN-0349 Evaluation Software to perform calibration procedures and to capture data from conductivity cells. Figure 7 shows the calibration window of the software. Click **Calibrate** to initialize the calibration procedure. The software performs the three point calibration procedure automatically by controlling the ADG715 octal switch. To perform the calibration procedure properly, the three calibration resistance indicators must be previously filled in with the correct values. During the automatic calibration procedure, the software makes measurements in the three calibration points and stores the calibration coefficients (Gain Factor G and System Offset N_{OS}) in the software memory, as described in the Calibration Procedure section. For the two measurement ranges, two different calibration coefficients are calculated and stored in the memory (G1 and G2, N_{OS1} and N_{OS2}). When making a measurement, the corresponding gain factor and system offset is selected according to the chosen range.

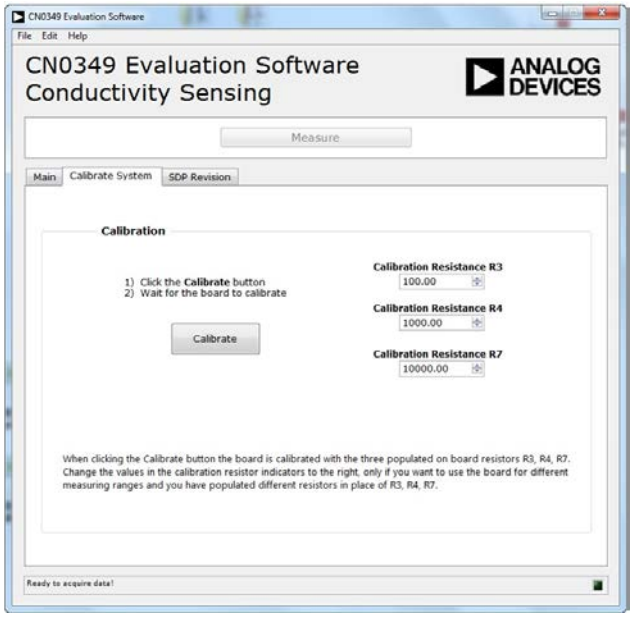

Figure 7. CN-0349 Software Calibration Window

Figure 8 shows the main window of the software, where different measurement results are presented. According to the chosen range, a measurement can be performed and values for the input impedance, conductivity, temperature, and conductivity temperature compensated are obtained. To display the results properly, data for the probe corrections must be properly selected.

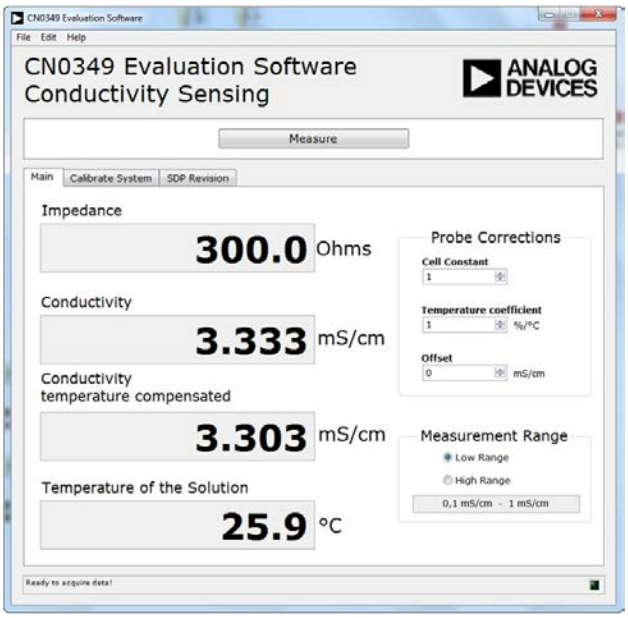

Figure 8. CN-0349 Evaluation Software Window

The cell constant has to be the same as the one used for the measurements. For standard cells, this constant is usually between 0.01/cm and 10/cm.

The offset indicator is used for offset correction to alter the measurement by an offset value expressed in mS/cm.

The temperature coefficient must be chosen depending on the measured solution. When the value of this coefficient is set to 0%/°C, no temperature compensation is performed.

COMMON VARIATIONS

This circuit was proven to work with good stability and accuracy with the component values shown. Other precision op amps can be used in place of a dual version AD8606. Two single version AD8605 op amps can be used instead of the AD8606 to facilitate the PCB layout. The AD8608 is a quad version of the AD8605 and can be used as a substitute for the AD8606, if additional precision op amps are needed. The AD8601, the AD8602 and the AD8604 are single, dual, and quad rail-to-rail, input and output, single-supply amplifiers, featuring very low offset voltage and wide signal bandwidth, which can be used in place of the AD8605, the AD8606, and the AD8608.

The AD5933 impedance converter is similar to the AD5934 and combines an on-board frequency generator with a 12-bit, 1 MSPS ADC.

The ADM3260 is a hot swappable, dual channel I^2C isolator with an integrated dc-to-dc converter that can be used in place of the ADuM5000 and ADuM1250 combination.

If galvanic isolation is not required, the power and the I^2C lines can be connected directly to the microprocessor.

CIRCUIT EVALUATION AND TEST

This circuit uses the EVAL-CN0349-PMDZ circuit board, the SDP-PMD-IB1Z, and the EVAL-SDP-CB1Z system demonstration platform (SDP) evaluation board. The SDP-PMD-IB1Z interposer board and the EVAL-SDP-CB1Z SDP board have 120-pin mating connectors. The SDP-PMD-IB1Z interposer board and the EVAL-CN0349-PMDZ board have 8-pin IMOD matching connectors, allowing quick setup and evaluation of the performance of the circuit. The EVAL-CN0349-PMDZ board contains the circuit to be evaluated, and the SDP evaluation board is used with the CN-0349 Evaluation Software to capture the data from the EVAL-CN0349-PMDZ circuit board.

Equipment Needed

The following equipment is needed:

- A PC with a USB port, Windows® XP or Windows Vista® (32-bit), or Windows®7 or Windows 8 (64-bit or 32-bit)
- The EVAL-CN0349-PMDZ circuit evaluation board
- The EVAL-SDP-CB1Z SDP evaluation board
- The SDP-PMD-IB1Z interposer board
- A 6 V power supply or wall wart (EVAL-CFTL-6V-PWRZ)
- The CN-0349 Evaluation Software
- A conductivity cell with integrated Pt100 sensor (for example, Sensorex CS200TC-PT1)

Getting Started

Load the evaluation software by placing the CN-0349 Evaluation Software CD into the PC. The user can also download the most up to date copy of the evaluation software from CN-0349 Evaluation Software. Using **My Computer**, locate the drive that contains the evaluation software CD and open the **setup.exe**. Follow the on-screen prompts to finish the installation. It is recommended to install all software components to the default locations.

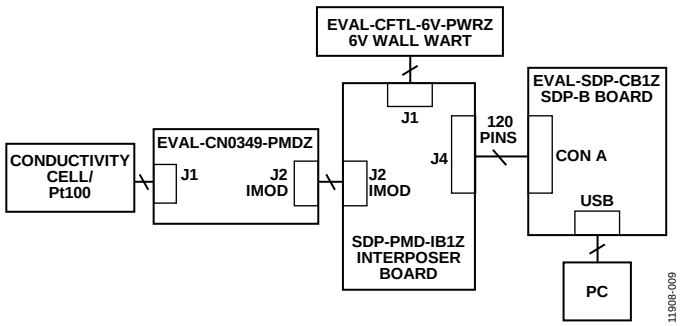

Figure 9. Test Setup Functional Block Diagram

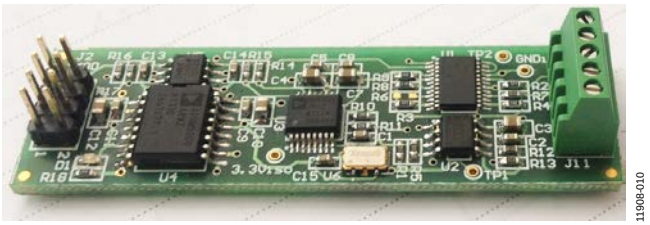

Figure 10. Photo of EVAL-CN0349-PMDZ Evaluation Board

Functional Block Diagram

See Figure 1 for the circuit block diagram and see the **EVAL-CN0349-PMDZ-Altium DesignerSchematic.pdf** file for the circuit schematics. This pdf file is located in the CN-0349 Design Support Package. A block diagram of the test setup is shown in Figure 9.

Setup

For proper setup, take the following steps:

1. Connect the EVAL-CFTL-6V-PWRZ (6 V dc power supply) to the SDP-PMD-IB1Z interposer board via the dc barrel jack.
2. Connect the SDP-PMD-IB1Z interposer board to the EVAL-SDP-CB1Z SDP board via the 120-pin Connector A.
3. Connect the EVAL-SDP-CB1Z SDP board to the PC via the USB cable.
4. Connect the EVAL-CN0349-PMDZ evaluation board to the SDP-PMD-IB1Z interposer board via the 8-pin header IMOD connector cable supplied with the CN-0349 board (4-pin MTE cable, Digilent, Inc.).

Connect the conductivity cell to the EVAL-CN0349-PMDZ evaluation board via the J1 terminal block. A photo of the EVAL-CN0349-PMDZ board is shown in Figure 10.

Test

Launch the CN-0349 Evaluation Software. The software will be able to communicate with the SDP board if the Analog Devices SDP drivers are listed in the **Device Manager**. When USB communications are established, the SDP board is used to send, receive, and capture serial data from the EVAL-CN0349-PMDZ board. Data, information, and details regarding how to use the evaluation software for data capturing can be found in the CN-0349 Software User Guide.

LEARN MORE

CN-0349 Design Support Package: http://www.analog.com/CN0349-DesignSupport.

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Riordan, Liam, AN-1053 Application Note, *AN5933 Evaluation Board Example Measurement*, Analog Devices.

Usach, Miguel, AN-1252 Application Note, *How to Configure the AD5933/AD5934*, Analog Devices.

Wayne, Scott. *iCoupler Digital Isolators Protect RS-232, RS-485, and CAN Buses in Industrial, Instrumentation, and Computer Apps*, Analog Dialogue, Volume 39, Number 4, 2005.

Data Sheets and Evaluation Boards

CN-0349 Circuit Evaluation Board (EVAL-CN0349-PMDZ)

SDP/PMD Interposer Board (SDP-PMD-IB1Z)

System Demonstration Platform (EVAL-SDP-CB1Z)

AD8606 Data Sheet

ADG715 Data Sheet

ADuM1250 Data Sheet

ADuM5000 Data Sheet

REVISION HISTORY

9/14—Revision 0: Initial Version

I²C refers to a communications protocol originally developed by Philips Semiconductors (now NXP Semiconductors).

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