PLC and DCS Universal Analog Input Using Either 4-Pin or 6-Pin Terminal Block

**EVALUATION AND DESIGN SUPPORT**

Circuit Evaluation Boards  
CN-0325 Evaluation Board (EVAL-CN0325-SDPZ)  
System Demonstration Platform (EVAL-SDP-CB1Z)

Design and Integration Files  
Schematics, Layout Files, Bill of Materials

**CIRCUIT FUNCTION AND BENEFITS**

The circuit shown in Figure 1 provides two, 16-bit, fully isolated, universal analog input channels suitable for programmable logic controllers (PLCs) and distributed control system (DCS) modules. Both channels are software programmable and support a number of voltage, current ranges, thermocouple, and RTD types, as shown in Figure 1.

![Figure 1. Universal Analog Input Overview](image)

For the 4-terminal block channel (CH2), the voltage, current, thermocouple, and RTD inputs all share the same 4 terminals, thus minimizing the number of terminal pins required. For the 6-pin terminal block channel (CH1), the voltage and current inputs share a set of 3 terminals, and the thermocouple and RTD inputs share another set of 3 terminals; this configuration requires more terminals but has a lower part count and component cost. Figure 2 shows a photo of the printed circuit board (PCB), and Figure 3 shows a more detailed schematic of the circuit.

![Figure 2. Universal Analog Input Board](image)
CIRCUIT DESCRIPTION

The AD7795 low noise, 16-bit, Σ-Δ ADC with on-chip in-amp and reference is used for the data conversion. The on-chip in-amp and current sources provide a complete solution for RTD and thermocouple measurement. For the voltage and current inputs, the AD8226 instrumentation amplifier with >90 dB CMRR is used to provide a high input impedance and reject any common-mode interference. The voltage and current signals are scaled to the range of the ADC using a precision resistor divider.

The ADG441, an ultralow noise, low dropout XFET 2.5 V voltage reference is used as the reference for the ADC.

For the 4-pin terminal block channel (CH2), the ADG442, low R<sub>ON</sub>, latch-up proof switch is used to switch between voltage, current, thermocouple, and RTD input modes.

Digital and power isolation is achieved using ADuM3471, a PWM controller and transformer driver with quad-channel isolator which is used to generate an isolated ±15 V supply using an external transformer. The ADuM1311, triple-channel digital isolator is also used in the 4-pin terminal block circuit to isolate the control lines for the ADG442 switches.

The ADP2441, 36 V step-down dc-to-dc regulator has a wide tolerance on its input supply making it ideal for accepting a 24 V industrial supply. It accepts up to 36 V, thereby making reliable transient protection of the supply input more easily achievable. It steps the input voltage down to 5 V to power the ADuM3471 as well as all other controller-side circuitry. The circuit also includes standard external protection on the 24 V supply terminals.

Figure 3. Functional Block Diagram (Simplified Schematic: All Connections and Decoupling Not Shown)
The ADP2441 also features a number of other safety and reliability functions, such as undervoltage lockout (UVLO), a precision enable, a power good pin, and overcurrent-limit protection. It also can achieve up to 90% efficiency in the 24 V input, 5 V output configuration.

**HARDWARE**

Figure 4 shows the location of the channel containing the 4-pin terminal block and the channel with the 6-pin terminal block. It also shows the location of the 24 V supply input.

![Figure 4. Channel Locations](image)

**Channel Selection**

Jumpers need to be inserted and switched to configure both supply and SPI signals between CH1 and CH2, as shown in Table 1.

<table>
<thead>
<tr>
<th>Link No.</th>
<th>Digital Function</th>
<th>Link Position to Select CH1, 6-Pin Terminal Block</th>
<th>Link Position to Select CH2, 4-Pin Terminal Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>JK0</td>
<td>5 V supply</td>
<td>CH1</td>
<td>CH2</td>
</tr>
<tr>
<td>JK1</td>
<td>SCLK</td>
<td>CH1</td>
<td>CH2</td>
</tr>
<tr>
<td>JK2</td>
<td>CS</td>
<td>CH1</td>
<td>CH2</td>
</tr>
<tr>
<td>JK3</td>
<td>DN</td>
<td>CH1</td>
<td>CH2</td>
</tr>
<tr>
<td>JK4</td>
<td>DOUT</td>
<td>CH1</td>
<td>CH2</td>
</tr>
<tr>
<td>JK11</td>
<td>TEMP_CS</td>
<td>Not inserted</td>
<td>Inserted</td>
</tr>
</tbody>
</table>

**Power Configurations**

A 24 V supply powers the controller side of the board. Alternately, a 5 V supply can be used, bypassing the ADP2441 circuitry. This 5 V input has no overvoltage protection and must not exceed 6 V. The supply used must be configured using the J4 link option as described in Table 2.

<table>
<thead>
<tr>
<th>Link No.</th>
<th>Link Position to Select 24 V Input (Default)</th>
<th>Link Position to Select 5 V Input (Default)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J4</td>
<td>VCC1</td>
<td>VCC2</td>
</tr>
</tbody>
</table>

For the analog input side of the isolation barrier, there are two options for powering a regulated 5 V for the analog circuitry. Either the ADP1720 linear regulator can be used to step the 15 V down to 5 V, or else the internal 5 V regulator of the ADuM3471 can be used. The link configurations for each is shown in Table 3.

<table>
<thead>
<tr>
<th>Link No.</th>
<th>Link Position for ADP1720, 5 V Regulator (Default)</th>
<th>Link Position for ADuM3471 5 V Regulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>J3</td>
<td>Vreg</td>
<td>Vaum</td>
</tr>
<tr>
<td>J9</td>
<td>Vreg</td>
<td>Vaum</td>
</tr>
</tbody>
</table>

**CH2: 4-PIN TERMINAL BLOCK CHANNEL**

**Input Connectors**

The P12 connector is used for voltage and current input connections. Figure 11 and Figure 12 show simplified schematics for this input connection and configuration. This configuration allows differential inputs in the ranges of 0 V to 5 V, 0 V to 10 V, ±5 V, ±10 V, 0 mA to 20 mA, 4 mA to 20 mA, and ±20 mA. Connect voltage or current inputs between V1+ and V1−, because current inputs also short the V1+ and I1 pins together. Shorting V1+ to I1 allows the 249 Ω, 0.1%, 0.25 W to be used as a current sensing resistor.
**Thermocouple**

The P12 connector is also used for thermocouple inputs. Various thermocouple types can be connected including J, K, T, and S types. The thermocouple is connected between the V1+ and V1– inputs (see Figure 5). Figure 6 shows how to connect a thermocouple (Type T, in this example) to the universal analog input board. See Figure 13 for a simplified schematic of the thermocouple input.

![Figure 6. CH2 Thermocouple Connector](image)

**RTD**

The P12, P13 connectors are used for RTD inputs. The hardware can support both 1000 Ω and 100 Ω platinum RTD inputs. For 3-wire mode, the two common wires are connected to V1+ and V1–, and the return is connected to Vm (see Figure 5). Figure 7 shows how to connect a 3-wire RTD sensor to the universal analog input board. See Figure 14 for a simplified schematic of the RTD input.

![Figure 7. CH2 RTD Connector](image)

**CH1: 6-PIN TERMINAL BLOCK CHANNEL**

**Input Connectors**

<table>
<thead>
<tr>
<th>P11</th>
<th>P10</th>
</tr>
</thead>
<tbody>
<tr>
<td>V+</td>
<td>V+</td>
</tr>
<tr>
<td>V–</td>
<td>V–</td>
</tr>
<tr>
<td>Vm</td>
<td>V1+</td>
</tr>
<tr>
<td>V1–</td>
<td>I1</td>
</tr>
</tbody>
</table>

*Figure 8. CH1 Channel Input Connectors; See Figure 13 for a Simplified Input Diagram*

**Voltage and Current**

The P10 connector is used for voltage and current input connections. This allows differential inputs in the ranges of 0 V to 5 V, 0 V to 10 V, ±5 V, ±10 V, 0 mA to 20 mA, 4 mA to 20 mA, and ±20 mA. Connect voltage or current inputs between V1+ and V1– (see Figure 13). For current inputs, also short V1+ and I1 pins together, thereby connecting a 249 Ω precision current sensing resistor with 0.1% accuracy and 0.25 W rating.

**Thermocouple**

The P11 connector is used for thermocouple inputs. Various thermocouple types can be connected including J, K, T, and S types. The thermocouple is connected between the V+ and V– inputs (see Figure 8). Figure 9 shows how to connect a thermocouple (Type T in this example) to the universal analog input board.

![Figure 9. CH1 Thermocouple Connector](image)

**RTD**

The P11 connector is also used for RTD input. The hardware can support both 1000 Ω and 100 Ω platinum RTD inputs. For 3-wire mode, the two common wires are connected to V+ and V–, and the return is connected to Vm (see Figure 8). Figure 10 shows how to connect a 3-wire RTD sensor to the universal analog input board.

![Figure 10. RTD Connector](image)

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System Resolution for 4-Pin Terminal Block Channel

With chop enable or disable selected and the data update rate selected, Table 4 shows the 4-pin terminal block channel system resolution measured with effective resolution and peak-to-peak resolutions for each input type. Note that all resolution measurements are based on the full-scale ranges as follows:

- ±10 V: full-scale range referred to 20 V
- 0 V to 5 V: full-scale range referred to 5 V
- Type K: full-scale range referred to 1520°C
- Type J: full-scale range referred to 900°C
- Type T: full-scale range referred to 550°C
- Type S: full-scale range referred to 1765°C
- PT100: full-scale range referred to 850°C
- PT1000: full-scale range referred to 850°C

<table>
<thead>
<tr>
<th>Range</th>
<th>Data Update Rate (Hz)</th>
<th>Chop</th>
<th>Samples</th>
<th>RMS Noise (V/°C)</th>
<th>Peak-to-Peak Noise (V/°C)</th>
<th>RMS Resolution (Bits)</th>
<th>Peak-to-Peak Resolution (Bits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>−10 V to +10 V</td>
<td>470</td>
<td>Disable</td>
<td>2700</td>
<td>1.14E-04</td>
<td>6.72E-04</td>
<td>16.0</td>
<td>15.2</td>
</tr>
<tr>
<td></td>
<td>470</td>
<td>Enable</td>
<td>1759</td>
<td>8.17E-05</td>
<td>6.72E-04</td>
<td>16.0</td>
<td>15.2</td>
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<td>16.7</td>
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<td>16.0</td>
<td>16.0</td>
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<tr>
<td>0 V to 5 V</td>
<td>470</td>
<td>Disable</td>
<td>1660</td>
<td>1.08E-04</td>
<td>5.04E-04</td>
<td>15.8</td>
<td>13.6</td>
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<td>470</td>
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<td>2263</td>
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<td>0.00E+00</td>
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<td>16.0</td>
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<td>16.7</td>
<td>Disable</td>
<td>1010</td>
<td>1.14E-02</td>
<td>5.17E-02</td>
<td>16.0</td>
<td>15.1</td>
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<td></td>
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<td>Enable</td>
<td>1032</td>
<td>3.23E-03</td>
<td>5.17E-02</td>
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<td>Type J (°C)</td>
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<td>4.01E-02</td>
<td>16.0</td>
<td>14.7</td>
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<td>1858</td>
<td>2.17E-03</td>
<td>4.01E-02</td>
<td>16.0</td>
<td>14.7</td>
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<td>Type T (°C)</td>
<td>16.7</td>
<td>Disable</td>
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<td>6.44E-03</td>
<td>2.95E-02</td>
<td>16.0</td>
<td>14.5</td>
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<td>Type S (°C)</td>
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<td>Disable</td>
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<td>13.3</td>
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<td>PT100 (°C)</td>
<td>16.7</td>
<td>Disable</td>
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<td>PT1000 (°C)</td>
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<td>0.00E+00</td>
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<td>16.0</td>
</tr>
</tbody>
</table>
System Resolution for 6-Pin Terminal Block Channel

With chop enable or disable selected and the data update rate selected, Table 5 shows the 6-pin terminal block channel system resolution measured with effective resolution and peak-to-peak resolutions for each input type. Note that all resolution measurements are based on the full scale ranges as follows:

- ±10 V: full-scale range referred to 20 V
- 0 V to 5 V: full-scale range referred to 5 V
- Type K: full-scale range referred to 1520°C
- Type J: full-scale range referred to 900°C
- Type T: full-scale range referred to 550°C
- Type S: full-scale range referred to 1765°C
- PT100: full-scale range referred to 850°C
- PT1000: full-scale range referred to 850°C

Table 5. Measured RMS Noise, Peak-to-Peak Noise, RMS Resolution, and Peak-to-Peak Resolution

<table>
<thead>
<tr>
<th>Range</th>
<th>Data Update Rate (Hz)</th>
<th>Chop</th>
<th>Samples</th>
<th>RMS Noise (V/°C)</th>
<th>Peak-to-Peak Noise (V/°C)</th>
<th>RMS Resolution (Bits)</th>
<th>Peak-to-Peak Resolution (Bits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>−10 V to +10 V</td>
<td>470</td>
<td>Disable</td>
<td>2229</td>
<td>1.44E-04</td>
<td>6.72E-04</td>
<td>16.0</td>
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<td></td>
<td>470</td>
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<td>0 V to 5 V</td>
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</table>
SIMPLIFIED INPUT CIRCUIT DIAGRAMS

Figure 11. CH2 Simplified Voltage Input Diagram

Figure 12. CH2 Simplified Current Input Diagram
Figure 13. CH2 Simplified Thermocouple Input Diagram

Figure 14. CH2 Simplified RTD Input Diagram

Figure 15. CH1 Simplified Input Diagram
SOFTWARE DESCRIPTION

The universal analog input board is shipped with a CD-ROM containing the CN0325 Evaluation Software designed using LabVIEW®. This evaluation software can be installed onto a standard PC with Windows® XP (SP2), Windows Vista (32-bit and 64-bit), or Windows 7 (32-bit and 64-bit). To use the evaluation software, the Analog Devices, Inc., System Demonstration Platform—Blackfin® (SDP-B) board is required.

When the evaluation software runs, the optimized default configurations as well as the calibrated parameters from the onboard EEPROM are loaded into the software. The evaluation software allows the user to acquire data from the universal analog input board, which can be analyzed or saved to a file. The analysis results are displayed on the screen in plots and in digital format. The user can set up their own configuration and calibration values and save these into the on-board EEPROM; the software records the configuration and uploads it automatically the next time the software runs.

Software Installation

To install the evaluation software, do the following:

1. Insert the CD-ROM into the PC, or download the software installation package from the following location: ftp://ftp.analog.com/pub/cftl/CN0325/.
2. Locate the setup.exe file. Double-click the setup.exe file to start the installation procedure.
3. Follow the on-screen instructions to complete the installation.

Install the evaluation software before connecting the evaluation board and SDP-B board to the USB port of the PC to ensure that the evaluation system and SDP-B board are correctly recognized when connected to the PC.

After the evaluation software is installed, do the following:

1. Connect the SDP-B board to the USB port of the PC using the supplied cable.
2. Connect the EVAL-CN0325-SDPZ evaluation board to either of the SDP connectors (CON A or CON B).
3. Power up the evaluation board. Ensure that the jumpers are set up correctly, as described in the Hardware section.
4. Start the CN-0325 evaluation software (CN0325.exe) and proceed through any dialog boxes that appear. This step completes the installation.

USING THE SOFTWARE

The main window of the software is shown in Figure 16. The hardware is configured via the Configuration tab, which is divided into three separate subtabs: Hardware Configuration, AD7795 Configuration, and ADT7310 Configuration. The Acquisition Result tab shows all the data from the ADC and converts results to the relevant units. The Calibration tab allows the user to calibrate any of the ranges. Details about the connected SDP-B board and evaluation software can be found in the S/W Version Info tab.

Main Window Buttons

The main window contains several buttons. Their functions are as follows:

- Connect to SDP: click to set up the connection between the SDP-B board and the evaluation board.
- Disconnect to SDP: click to stop the connection between the SDP-B board and the evaluation board.
- Capture Mode: select Single Capture for single capture, or Continuous Capture for continuous capture.
- Start Acquisition/Stop Acquisition: click to start or stop data capture.
- Save Data: save the data shown from the software into a file for further analysis.
- QUIT: quit the application.
**Configuration Tab**

### Hardware Configuration Tab

The screenshot of the Configuration tab (see Figure 17) shows the correct jumper settings and wire connections based on the input selection. To ensure correct results, the jumper settings on the hardware must be the same as the settings in the software. The different input selection options are as follows:

- **Circuit Type**: there are two, fully isolated, universal analog input circuits to choose from. The 6-terminal block is the lowest cost solution with six terminals for sensor and signal connection. The 4-terminal block is a more compact solution with 4-pin terminals for sensor and signal connections.

- **Input Signal Type**: the evaluation board can convert multiple types of signals including voltage, current, thermocouple, and RTD. After the input signal type is selected, the desired range of the thermocouple/RTD type must also be chosen.

- **Capture Mode**: the user must set the method for capturing the data. In single capture mode, only the specified number of samples are captured. In continues capture mode, data is continuously captured until the user stops the acquisition.

### AD7795 Configuration Tab

For each type of input signal range selected in the Hardware Configuration tab, there is a default configuration loaded to the universal analog input board. The AD7795 Configuration tab (see Figure 17) allows more advanced configurations and provides the flexibility to evaluate the board with a different configuration than the default value.

Using this tab requires specific knowledge of the AD7795 registers, functions, and hardware structure. An incorrect configuration can cause acquisition and operation error. Click **Recover All range to Default** to recover the default configurations for the range(s).

### ADT7310 Configuration Tab

An on-board temperature sensor chip, the ADT7310, is placed close to the terminal blocks for cold-junction compensation during thermocouple measurements. In a typical measurement setup, a default configuration is loaded to the universal analog input board. The ADT7310 Configuration tab (see Figure 18) allows more advanced configuration and provides the flexibility to evaluate the board with a different configurations than the default value. Using this tab requires specific knowledge of the ADT7310 registers, functions, and hardware structure.

### Acquisition Result Tab

### Converted Result Tab

A result is converted to the relevant units based on the raw data from the data converter along with the channel configuration and calibration values. The data is shown in a waveform chart in the Converted Result tab (see Figure 19). The data is also analyzed to provide the number of samples, the mean, the minimum and maximum values, the RMS and peak-to-peak noise, as well as the RMS and peak-to-peak resolution.
ADC RAWData Tab

The acquisition data read directly from ADC is shown in the waveform chart in the ADC RAWData tab. The data is also analyzed to provide the number of samples, the mean, the minimum and maximum values, the RMS and peak-to-peak noise, as well as the RMS and peak-to-peak resolution.

Histogram Tab

The Histogram tab (see Figure 20) shows the distribution of the raw ADC data that has been captured. This histogram graph can be used to evaluate the noise and acquisition stability.

Calibration Tab

The evaluation software also provides independent calibrated parameters for each input signal and sensor type, which allows the user to accurately calibrate the offset and gain of the system to achieve a high level of dc precision for the system (see Figure 21). The calibrated parameters can be stored into the on-board EEPROM for later reuse. A complete calibration requires both a zero-scale calibration and a full-scale calibration.

![Figure 20. Histogram Tab](image)

To ensure a proper calibration, take the following steps:

1. From the Range for Calibration drop-down box, select the desired input range.
2. Apply the correct input signal specified in Zeroscale Value and click Zeroscale Calibrate. Follow the prompt to complete the zero-scale calibration.
3. Apply the correct input signal specified in Fullscale Value and click Fullscale Calibrate. Follow the prompt to complete the full-scale calibration.
4. Click Save into EEPROM.

The calibrated parameters are placed into the internal calibration register of ADC. When the user clicks Save into EEPROM, the new calibration values are permanently saved to the EEPROM, and these values are loaded the next time this range is selected.

Copies of the factory default calibrated values are stored in the on-board EEPROM. Click Recover to Default to return all the calibrated values to their factory default values.
S/W Version Info Tab

Figure 22 shows the S/W Version Info tab. This tab provides information about the connected SDP-B board.

Clicking Flash LED flashes the LED on the SDP-B board, which indicates that the connection between the SDP-B and evaluation boards is successfully set up.

Clicking Read Firmware reads the information about the current code on the SDP-B board.

The fields in the S/W Version Info tab are as follows:

- **Major Rev**: the major code revision number
- **Minor Rev**: the minor code revision number
- **Host Code Rev**: the version of the host code with which the firmware was developed
- **BF Code Rev**: the Blackfin code revision number of the firmware
- **Date**: the date the code was compiled
- **Time**: the time the code was compiled
LEARN MORE

CN-0325 Design Support Package:
www.analog.com/CN0325-DesignSupport

AD779x Instrumentation Converters—Frequently Asked Questions


MT-031 Tutorial. Grounding Data Converters and Solving the Mystery of "AGND" and "DGND". Analog Devices.


Data Sheets and Evaluation Boards

AD7795 Data Sheet
AD8226 Data Sheet
ADT7310 Data Sheet
ADP2441 Data Sheet
ADR441 Data Sheet
ADP1720 Data Sheet
ADuM3471 Data Sheet

System Demonstration Platform (EVAL-SDP-CB1Z)

REVISION HISTORY

11/15—Revision 0: Initial Version