# USB-2401

24-bit 2kS/s USB 2.0-Based Universal Input
DAQ Module

**User's Manual**


**Manual Rev.:** 2.00

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**Part No:** 50-1Z101-1000

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# Revision History

| Revision | Release Date | Description of Change(s) |
|---|---|---|
| 2.00 | Apr 27, 2012 | Initial release |
| | | |

# Preface

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## Conventions

Take note of the following conventions used throughout this manual to make sure that users perform certain tasks and instructions properly.

| | |
|---|---|
| NOTE: | Additional information, aids, and tips that help users perform tasks. |

| | |
|---|---|
| CAUTION: | Information to prevent ***minor*** physical injury, component damage, data loss, and/or program corruption when trying to complete a task. |

| | |
|---|---|
| WARNING: | Information to prevent ***serious*** physical injury, component damage, data loss, and/or program corruption when trying to complete a specific task. |

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# 1 Introduction

## 1.1 Overview

The USB-2401 is a 24-bit, 4-channel simultaneous-sampling universal input USB DAQ module featuring built-in signal conditioning and direct measurement of commonly used sensors, including current output transducers, thermocouple, RTD, load cell, strain gauge, and resistance. Individual channels can be programmed to measure different signal types.

The USB-powered USB-2401 is equipped with removable screw-down terminals for easy device connectivity, and the included multi-functional stand fully supports desktop, rail, or wall mounting.

The USB-2401 is suitable for basic measurement applications requiring high resolution and accuracy, laboratory research and material testing environments, and industrial temperature measurement. U-Test, a free ready-to-use testing program is included to enable operation or testing of all ADLINK USB DAQ series functions with no programming requirements.

## 1.2 Features

- High-speed USB 2.0
- USB powered
- 4-CH simultaneous-sampling analog input
- Built-in signal conditioning for high voltage/current/thermocouple/RTD/strain gauge/load cell/resistance measurement
- Sample rate from 20 S/s to 2 kS/s
- Functional digital I/O
- Removable screw-down terminal
- Lockable USB cable for secure connectivity
- Ready-to-use testing application (U-Test) provided

## 1.3 Applications

- Automotive testing
- Laboratory research
- Biotech measurement
- I/O control

## 1.4 Specifications

### 1.4.1 General Specifications

| Physical, Power, and Operating Environment | |
|---|---|
| Interface | High speed USB 2.0 compatible, mini-USB connector |
| Dimensions | 156 (L) x 114 (W) x 41 (H) mm (6.14 X 4.49 X 1.61 in.) |
| I/O Connector | Two 20-pin removable screw-down terminals |
| Power requirement | USB power (5 V @ 400 mA) |
| Operating environment | **Ambient temperature:** 0 to 55°C<br>**Relative humidity:** 10% to 90%, non-condensing |
| Storage environment | **Ambient temperature:** -20 to 70 °C<br>**Relative humidity:** 5% to 95%, non-condensing |

### 1.4.2 General Analog Input

| General | | |
|---|---|---|
| Number of channels: | 4 differential input (simultaneous-sampling) | |
| Sampling rate (sample/sec) | 20, 40, 80, 160, 320, 500, 1000, 2000 | |
| Resolution | 24-bit | |
| Input coupling | DC | |
| Input mode and range | | |
| | Input range or supporting type | Actual input range |

| | | |
|---|---|---|
| Voltage | ±25V<br>±12.5V<br>±2.5V<br>±312.5mV | ±25V<br>±12.5V<br>±2.5V<br>±312.5mV |
| Current | ±20mA | 2.5V |
| Thermocouple | K, J, N, R, S, B, T, E | 78.125mV |
| RTD (3-wire, 4-wire) | Pt 100, Pt 1000 | 2.5V |
| Half-Bridge (120Ω, 350Ω) | Max. 30mV/V | 78.125mV |
| Full-Bridge (120Ω, 350Ω) | Max. 30mV/V | 78.125mV |
| 2-Wire Resistance | 30kΩ | 2.5V |
| Excitation voltage | 2.5V (for half/full-bridge mode only) | |
| Excitation current | 0.5mA for RTD mode<br>0.05mA for Resistance mode | |
| Cold junction compensation (CJC) accuracy | ± 0.5°C (after 15 minute warmup) | |
| Operational common mode voltage range | Voltage input mode: Vcm+Vpp/2 ≦ input range (25V/12.5V/2.5V/ 0.3125V)<br>Current input mode: Vcm ≦ 24V | |
| Overvoltage protection | Power on:<br>Voltage input mode: 30V<br>Current input mode: 60mA<br>Sensor input mode enable: no protection<br>Sensor input mode disable: 30V<br>Excitation voltage (EX+) and AGND: no protection | |
| FIFO buffer size | 4k samples | |
| Data transfers | Programmed I/O, continuous (bulk transfer mode) | |
| Input impedance | 1.009MΩ for voltage input mode<br>249.5Ω for current input mode | |

### 1.4.3 Analog Input Electrical

**Temperature Draft @20SPS, in ppm/°C**

| Mode | Gain drift | Offset drift |
|---|---|---|
| Voltage (±25V) | 1.389055871 | 0.043023355 |
| Voltage (±12.5V) | 1.37552178 | 0.075556565 |
| Voltage (±2.5V) | 1.662727273 | 0.030882956 |
| Voltage (±312.5mV) | 21.92878977 | 0.110084412 |
| Current (±20mA) | 3.270369091 | 0.282946284 |
| Full-bridge | 28.00370355 | 30.90013157 |
| Half-bridge | 33.48025514 | 1.750342188 |
| Thermocouple | 62.9978196 | 0.164409864 |
| 2-wire RTD | 2.842575758 | 0.522492944 |
| 3-wire RTD | 2.879839489 | 0.258840329 |
| 4-wire RTD | 2.902723485 | 0.018656382 |
| 2-wire resistance | 3.026166667 | 0.03246755 |

**Temperature Draft @160SPS, in ppm/°C**

| Mode | Gain drift | Offset drift |
|---|---|---|
| Voltage (±25V) | 1.533312973 | 0.084457938 |
| Voltage (±12.5V) | 1.520465436 | 0.134715279 |
| Voltage (±2.5V) | 1.732148674 | 0.054557101 |
| Voltage (±312.5mV) | 20.94809375 | 0.130828487 |
| Current (±20mA) | 3.488472439 | 0.305882921 |
| Full-bridge | 26.72626394 | 17.74701205 |
| Half-bridge | 35.27328612 | 1.748929398 |

| Mode | Gain drift | Offset drift |
|---|---|---|
| Thermocouple | 105.3142618 | 0.193622785 |
| 2-wire RTD | 2.965409564 | 0.512440163 |
| 3-wire RTD | 2.996320076 | 0.240909456 |
| 4-wire RTD | 2.854513258 | 0.086721521 |
| 2-wire resistance | 3.40709375 | 0.06209485 |

**Temperature Draft @2000SPS, in ppm/°C**

| Mode | Gain drift | Offset drift |
|---|---|---|
| Voltage (±25V) | 1.620950284 | 0.105635778 |
| Voltage (±12.5V) | 1.584251894 | 0.11027477 |
| Voltage (±2.5V) | 1.701225379 | 0.067356314 |
| Voltage (±312.5mV) | 20.52684091 | 0.113061874 |
| Current (±20mA) | 3.771356399 | 0.338399386 |
| Full-bridge | 30.71138027 | 50.00179464 |
| Half-bridge | 35.58911174 | 1.862124485 |
| Thermocouple | 117.7077884 | 0.435895845 |
| 2-wire RTD | 3.047327178 | 0.452466872 |
| 3-wire RTD | 3.124556345 | 0.189605804 |
| 4-wire RTD | 3.216423295 | 0.088365093 |
| 2-wire resistance | 3.386921402 | 0.04574323 |

## System Noise, in LSB (Typical, 25°C): 20 SPS to 160 SPS

| Mode | Sampling Rate (SPS) | | | |
|---|---|---|---|---|
| | 20 | 40 | 80 | 160 |
| Voltage (±25V) | 9.443641 | 13.58713513 | 22.225423 | 47.06011713 |
| Voltage (±12.5V) | 10.45022375 | 15.55506725 | 23.934448 | 50.668689 |
| Voltage (±2.5V) | 8.941254375 | 12.75718938 | 19.522499 | 46.11391238 |
| Voltage (±312.5mV) | 11.115466 | 15.1842875 | 19.108748 | 39.44412825 |
| Current (±20mA) | 29.50086975 | 33.76906888 | 39.179197 | 53.86180763 |
| Full/Half-bridge | 58.669068 | 33.97045388 | 41.628525 | 67.98029188 |
| Thermocouple | 28.24161013 | 41.73502813 | 51.59679 | 76.21635225 |
| 2-wire RTD | 8.00126525 | 11.64115513 | 16.869046 | 33.30653975 |
| 3-wire RTD | 8.407154625 | 12.01619113 | 16.528028 | 33.69525963 |
| 4-wire RTD | 9.043779125 | 12.47814688 | 16.762287 | 45.44077163 |
| 2-wire resistance | 9.318955625 | 13.208205 | 18.829651 | 43.74764375 |

## System Noise, in LSB (Typical, 25°C): 320 SPS to 2000 SPS

| Mode | Sampling Rate (SPS) | | | |
|---|---|---|---|---|
| | 320 | 640 | 1000 | 2000 |
| Voltage (±25V) | 72.508028 | 142.60307 | 71.11201 | 119.26144 |
| Voltage (±12.5V) | 81.44560913 | 139.01469 | 77.924207 | 128.36732 |
| Voltage (±2.5V) | 66.64280488 | 136.24263 | 71.915341 | 122.92882 |
| Voltage (±312.5mV) | 48.83473638 | 79.888989 | 86.157589 | 128.4315 |
| Current (±20mA) | 77.58907738 | 131.06695 | 80.416917 | 126.239 |
| Full/Half-bridge | 92.8294875 | 144.14509 | 175.67111 | 202.15501 |

| Mode | Sampling Rate (SPS) | | | |
|---|---|---|---|---|
| Thermocouple | 107.9735725 | 143.46202 | 198.49927 | 202.17693 |
| 2-wire RTD | 44.53668125 | 77.870435 | 71.369319 | 127.45831 |
| 3-wire RTD | 42.00570563 | 87.738238 | 72.70806 | 123.21166 |
| 4-wire RTD | 72.2785775 | 155.50389 | 72.168651 | 123.65813 |
| 2-wire resistance | 72.76746238 | 153.9091 | 71.566314 | 122.28421 |

### 1.4.4 Digital Input/Output

| I/O Specifications | |
|---|---|
| Number of channels | 4-CH programmable function digital input (DI)<br>2-CH programmable function digital output (DO) |
| Compatibility | TTL (single-end) (supports 3.3V and 5 V DI but 3.3V DO) |
| Input voltage | Logic low: VIL = 0.8 V max; IIL = 0.2 mA max.<br>Logic high: VIH = 2.0 V min.; IIH = 0.2 mA max. |
| Output voltage | Logic low: VOL = 0.5 V max; IOL = 10 mA max.<br>Logic high: VOH = 2.6V min.; IIH = 10 mA max. |
| Supporting modes (only one can be selected and function at the same time, please see Section 4.6: Programmable Function I/O) | ▶ 4-CH TTL DI and 2-CH TTL DO<br>▶ 1-CH 32-bit general-purpose timer/counters:<br>▷ Clock source: internal or external<br>▷ Max source frequency: internal: 80 MHz; external: 10 MHz<br>▶ 1-CH PWM outputs:<br>▷ Duty cycle:1-99% (please see Section 4.6.3: Mode 10: PWM Output) Modulation frequency: 20 MHz to 0.005Hz |

| I/O Specifications | |
|---|---|
| Data transfers | Programmed I/O |

## 1.5 Software Support

ADLINK provides comprehensive software drivers and packages to suit various user approaches to system building. In addition to programming libraries, such as DLLs, for most Windows-based systems, ADLINK also provides drivers for other application environments such as LabVIEW® and MATLAB®. ADLINK also provides ActiveX component ware for measurement and SCADA/HMI, and breakthrough proprietary software. All software options are included in the ADLINK All-in-One CD.

Be sure to install the driver & utility before using the USB-2401 module.

## 1.6 Driver Support for Windows

### 1.6.1 UD-DASK

UD-DASK is composed of advanced 32/64-bit kernel drivers for customized DAQ application development. USB-DASK enables you to perform detailed operations and achieve superior performance and reliability from your data acquisition system. DASK kernel drivers now support Windows 7/Vista® OS.

### 1.6.2 DAQPilot

DAQPilot is a SDK with a graphics-driven interface for various application development environments. DAQPilot represents ADLINK's commitment to full support of its comprehensive line of data acquisition products and is designed for the novice to the most experienced programmer.

As a task-oriented DAQ driver, SDK and wizard for Windows systems, DAQPilot helps you shorten development time while accelerating the learning curve for data acquisition programming.

You can download and install DAQPilot at:

http://www.adlinktech.com/TM/DAQPilot.html

Please note that only DAQPilot versions 2.3.0.712 and later can support the USB-2401.

## 1.7 Utilities for Windows

### 1.7.1 U-Test

U-Test is a free and ready-to-use utility which can assist instant testing and operation of all ADLINK USB DAQ series functions with no programming. In addition to providing data collection and monitoring functions, U-Test also supports basic FFT analysis and provides direct control of analog output and digital I/O with a user-friendly interface.

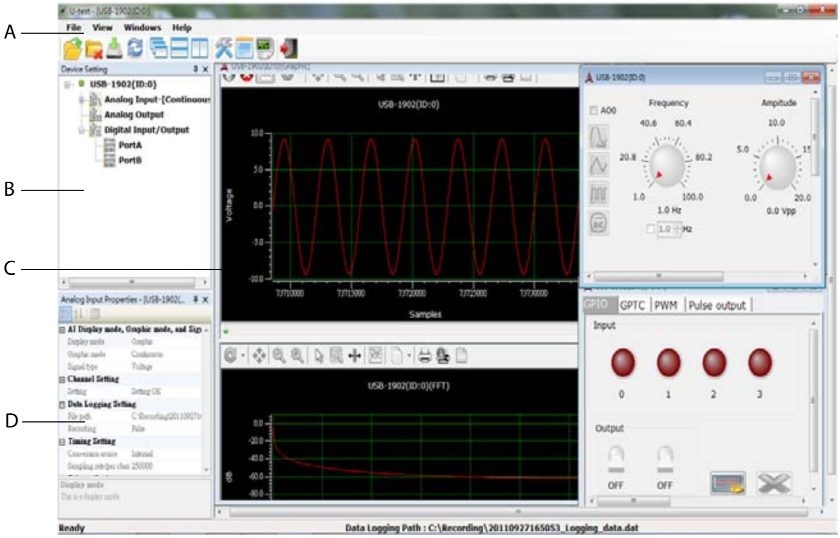


**Figure 1-1: U-Test Interface**

| | |
|---|---|
| A | Main Menu |
| B | Device Viewer |
| C | AI Data View & AO, DIO Control Panel |
| D | Analog Input Configuration |

**Table 1-1: U-Test Interface Legend**

You can download and install U-Test at: http://www.adlink-tech.com/

## 1.8 Overview and Dimensions

NOTE:

All dimensions shown are in millimeters (mm)

### 1.8.1 Module

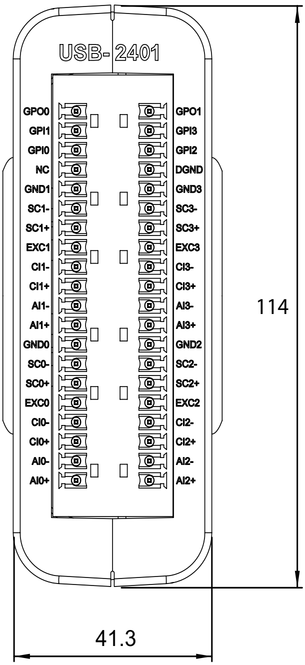


**Figure 1-2: USB-2401 Module Rear View**

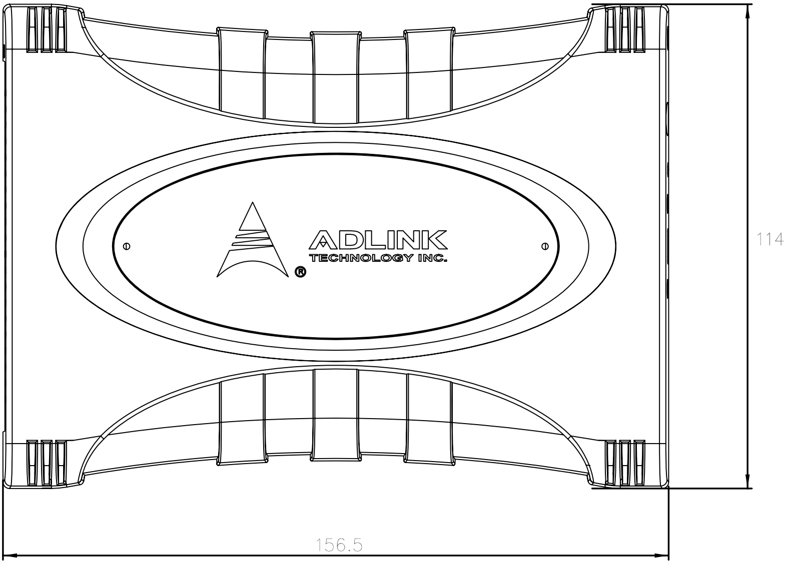


**Figure 1-3: USB-2401 Module Side View**

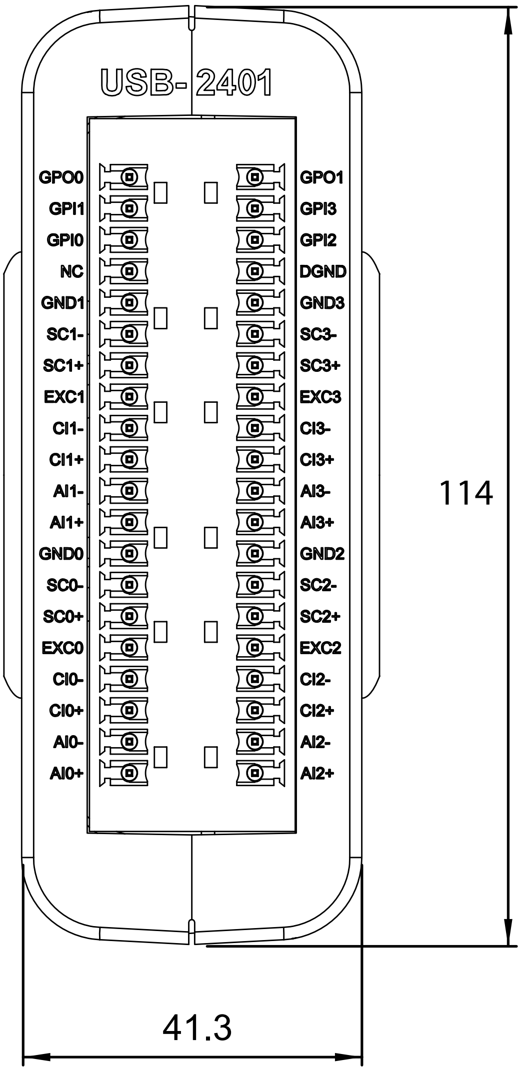


**Figure 1-4: USB-2401 Module Front View**

## 1.8.2 Module Stand

The multi-function USB-2401 stand is compatible with desk, rail, or wall mounting. To fix the module in the stand, slide the module body into the stand until a click is heard. To remove the module from the stand, twist the bottom of the stand in a back-and forth motion and separate from the module.

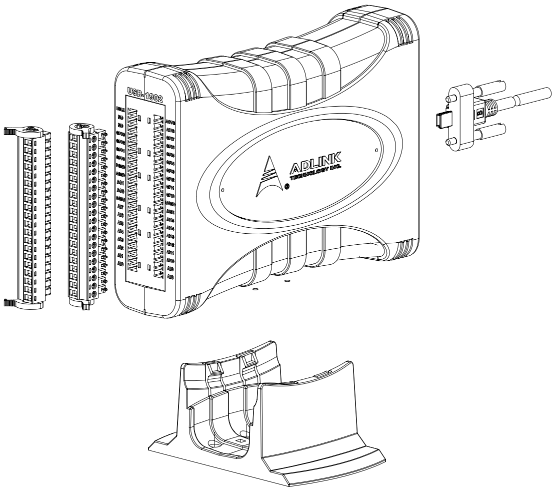


**Figure 1-5: Module, Stand, Connector, and USB Cable**

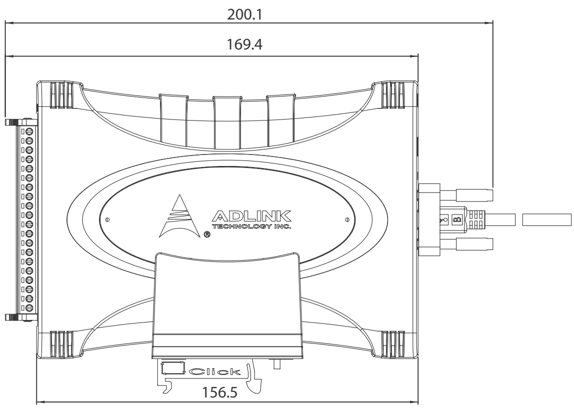


**Figure 1-6: Module, Stand, & Wall Mount Kit Side View (w/ Connections)**

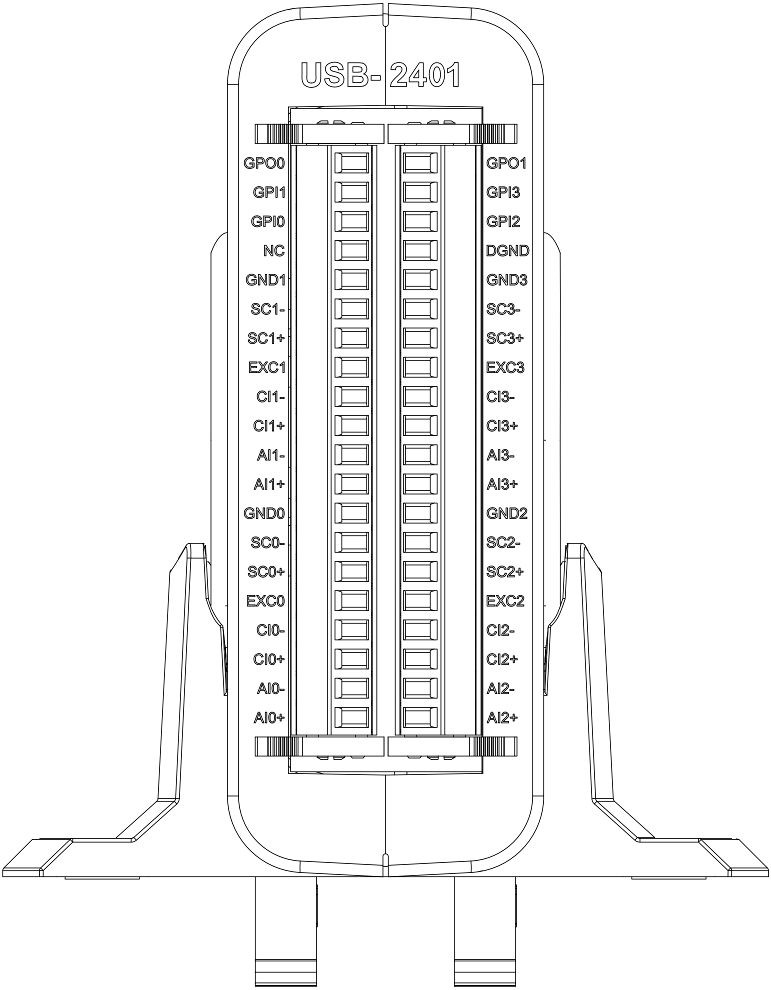


**Figure 1-7: Module In Stand Front View**

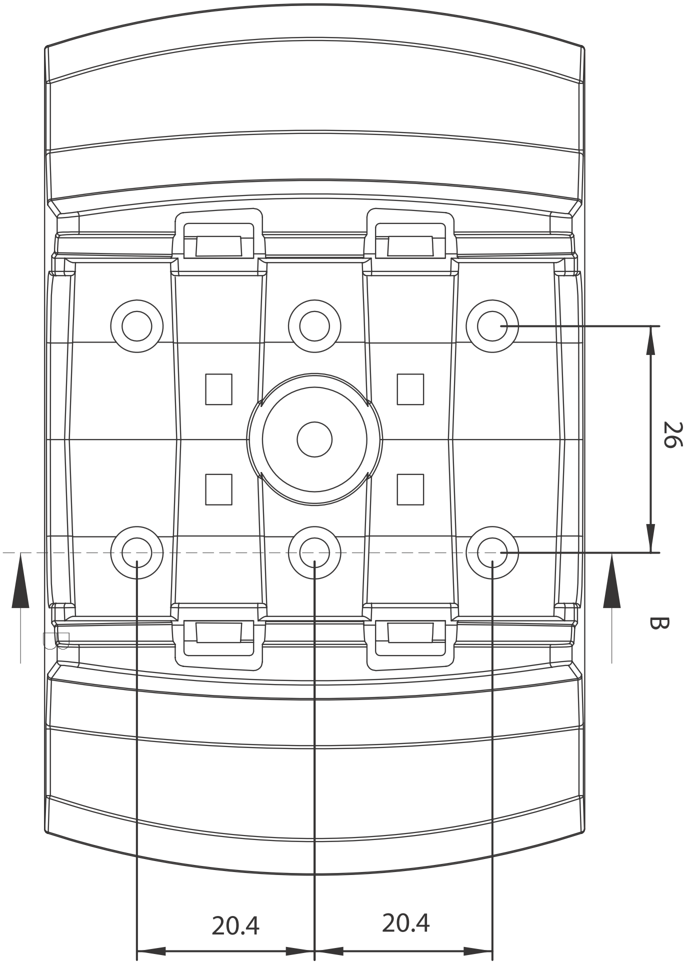


**Figure 1-8: Module Stand Top View**

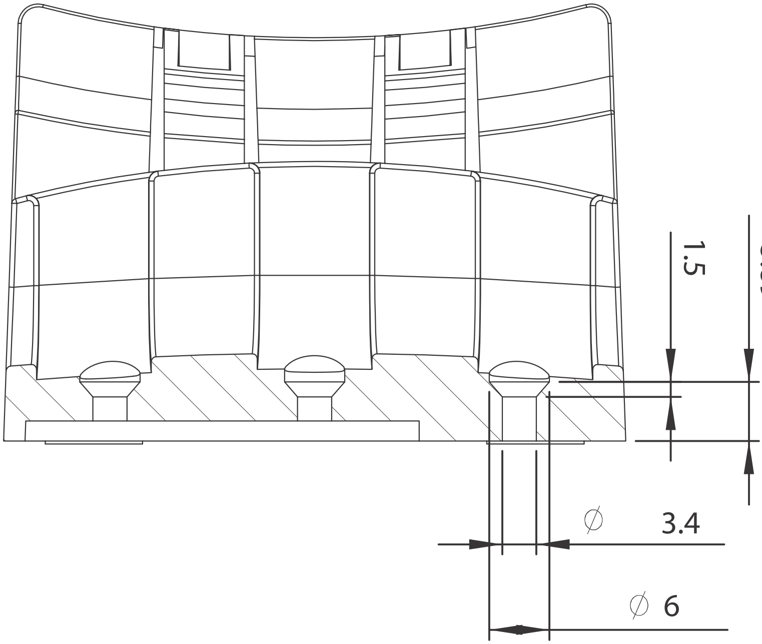


**Figure 1-9: Module Stand Side Cutaway View**

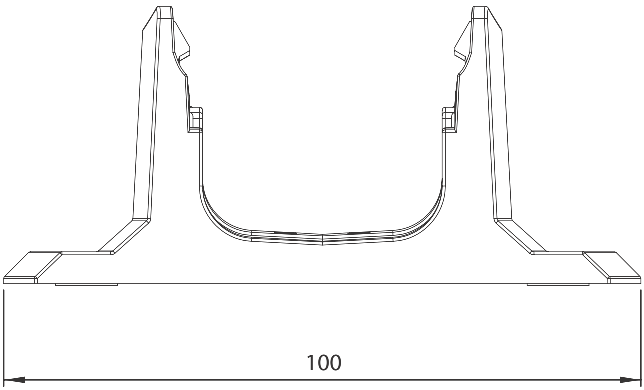


**Figure 1-10: Module Stand Front View**

## 1.9 Connector Information

The USB-2401 module is equipped with 40-pin removable screw-down terminal connectors, with pin assignment and signal description as follows.

| Pin | Function | Pin | Function |
|---|---|---|---|
| 20 | GPO0 | 40 | GPO1 |
| 19 | GPI1 | 39 | GPI3 |
| 18 | GPI0 | 38 | GPI2 |
| 17 | NC | 37 | DGND |
| 16 | GND1 | 36 | GND3 |
| 15 | SC1- | 35 | SC3- |
| 14 | SC1+ | 34 | SC3+ |
| 13 | EXC1 | 33 | EXC3 |
| 12 | CI1- | 32 | CI3- |
| 11 | CI1+ | 31 | CI3+ |
| 10 | AI1- | 30 | AI3- |
| 9 | AI1+ | 29 | AI3+ |
| 8 | GND0 | 28 | GND2 |
| 7 | SC0- | 27 | SC2- |
| 6 | SC0+ | 26 | SC2+ |
| 5 | EXC0 | 25 | EXC2 |
| 4 | CI0- | 24 | CI2- |
| 3 | CI0+ | 23 | CI2+ |
| 2 | AI0- | 22 | AI2- |
| 1 | AI0+ | 21 | AI2+ |

**Table 1-2: USB-2401 Pin Assignment**

| Signal Name | Reference | Direction | Description |
|---|---|---|---|
| GND<0..3> | -------- | | Ground of excitation voltage/current, with GND<0..3> and DGND connected on board |
| DGND | -------- | | Digital ground, DGND and GND<0..3> are connected on board |
| AI<0..4> | GND | I | Differential analog Input channels 0~3 |
| CI<0..4> | GND | I | Current input channel 0~3. |
| EXC<0..3> | GND | O | Excitation output for channel 0~3; can be configured to voltage output (2.5V) or current output (1mA) by software, with corresponding ground pin GND<0..3> |
| SC<0..3> | GND | I | Sensor (small signal) input channel 0~3 |
| GPI<0..3> | DGND | I | Function digital input <0..3> |
| GPO<0..3> | DGND | O | Function digital output <0,1> |
| N/C | N/C | N/C | No connection |

**Table 1-3: I/O Signal Description**

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# 2 Getting Started

WARNING:

The appropriate driver must be installed before you can connect the USB DAQ to the computer system. Refer to Section 1.6: Driver Support for Windows for driver support information.

## 2.1 Connecting the USB-2401 Module

1. Turn on the computer.
2. Connect the USB-2401 module to one USB 2.0 port on the computer using the included USB cable.
3. The first time the USB-2401 module is connected, a New Hardware message appears. It will take around 6 seconds to load the firmware. When loading is complete, the LED indicator on the rear of the USB DAQ module changes from amber to green and the New Hardware message closes.
4. The USB-2401 module can now be located in the hardware Device Manager, as shown.

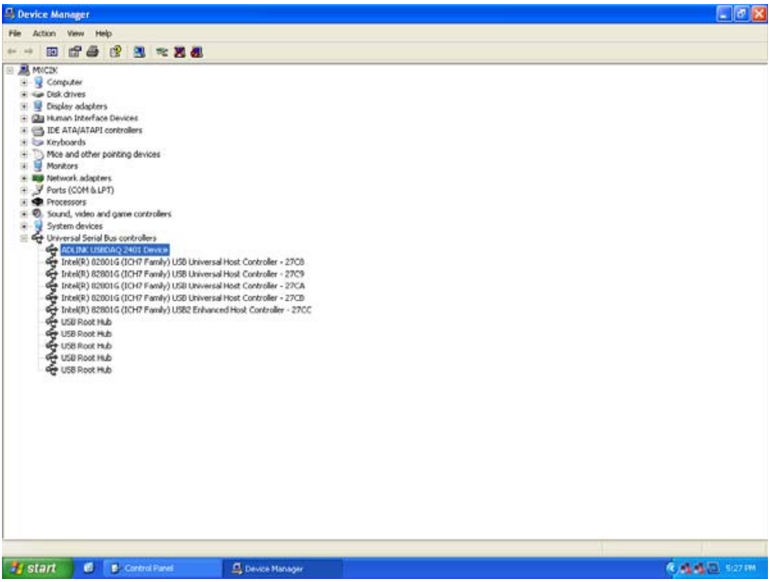


Figure 2-1: USB-2401 Module in Windows Device Manager

If the USB-2401 module cannot be detected, the power provided by the USB port may be insufficient. The USB-2401 module is exclusively powered by the USB port and requires 400 mA @ 5 V.

## 2.2 Device ID

A rotary control on the rear of the module (as shown) controls device ID setting and can be set from 1 to 8. The device ID allows dedicated control of the USB-2401 module irrespective of the connected USB port. When more than one USB module of the same type is connected, each must be set to a different ID to avoid conflicts and errors in operation.

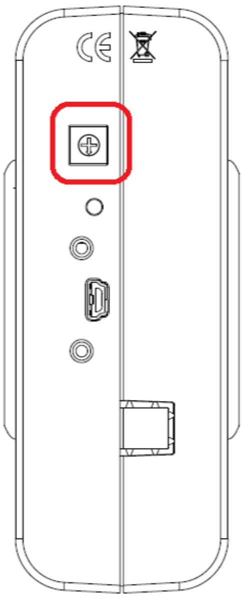

**Figure 2-2: Device ID Selection Control**

## 2.3 Hardware Configuration

All remaining hardware configurations are software programmable, including sampling/update rate, input/output channel, input range, and others. Please see the UD-DASK Function Reference manual for details.

## 2.4 Device Mounting

### 2.4.1 Rail Mounting

The multi-function stand can be mounted on the DIN rail using the rail-mount kit as shown.

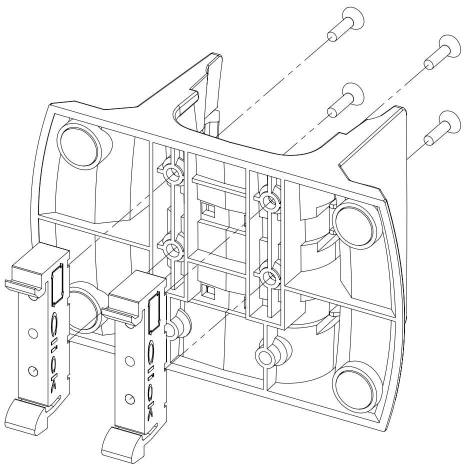

**Figure 2-3: Rail Mount Kit**

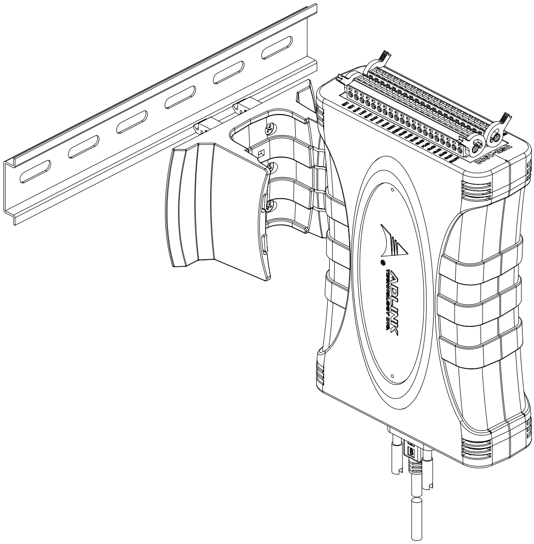

**Figure 2-4: Module Pre-Rail Mounting**

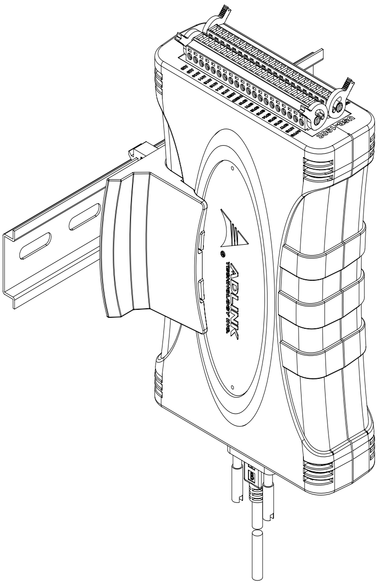

**Figure 2-5: Module Rail-Mounted**

## 2.4.2 Wall Mounting

The multi-function stand can be fixed to a wall using four flush head screws as shown. The four screw holes should be approximately 3.4 mm in diameter.

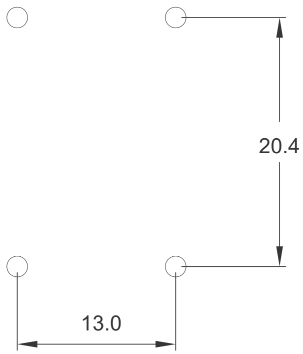


**Figure 2-6: Wall Mount Holes**

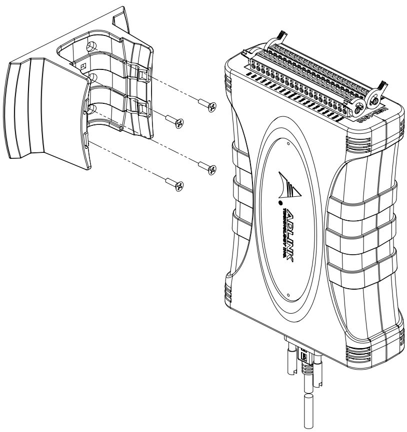

**Figure 2-7: Module with Wall Mount Apparatus**

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# 3 Operation

Operation of the USB-2401 is described here to assist in configuration and programming of the module. Functions described include A/D conversion, programmable function I/O, and others

## 3.1 Functional Layout

The USB-2401 provides 4-channel 24-bit universal analog inputs and supports seven input modes, including voltage input, current input, thermocouple, RTD, full bridge, half bridge, and resistance measurement. The four channels sample simultaneously, and while each can be configured to a different input mode, all active channels must be configured to the same sampling rate. In addition, the USB-2401 also provides 6-channel programmable digital I/O and can be configured to GPIO, GPTC, or PWM mode.

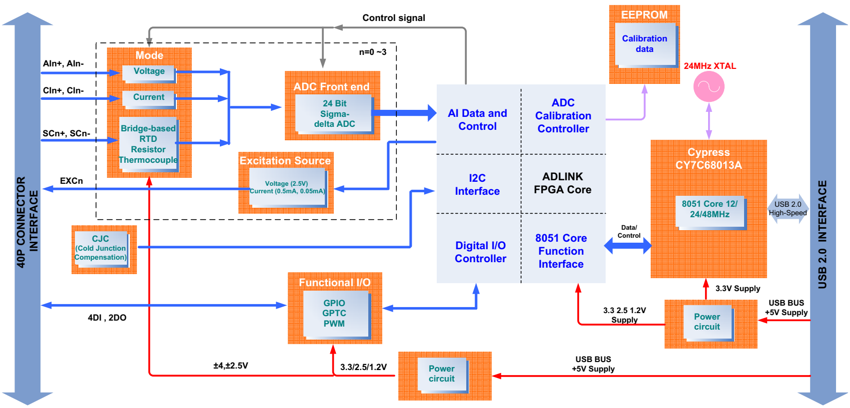


**Figure 3-1: USB-2401 Functional Block Diagram**

## 3.2 Signal Sources

### 3.2.1 Floating Signal Source

Not connected in any way to the existing ground system. Devices with isolated output are floating signal sources, such as optical isolator outputs, transformer outputs, and thermocouples.

### 3.2.2 Ground-Referenced Signal Source

Connected in some way to the existing ground system, to a common ground point with respect to the USB DAQ, when the computer is connected to the same power system. Non-isolated output of instruments and devices connected to the existing power systems are ground-referenced signal sources.

## 3.3 Signal Connection

Each analog input channel can be configured to different input modes by the software API. Details of signal connection in different input modes follow.

### 3.3.1 Voltage Input Mode

The properties of the signal to be measured must be considered. The differential input mode provides two inputs that respond to signal voltage difference between them. If the signal source is ground-referenced, the differential mode can be used for the common-mode noise rejection.

Connection of ground-referenced signal sources under differential input mode is as shown.

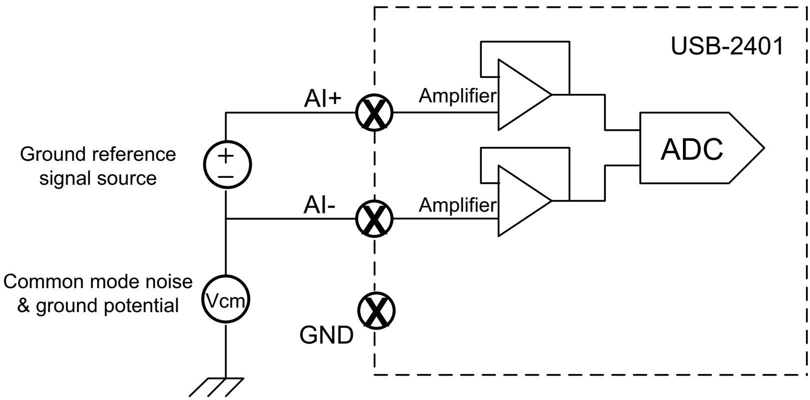


**Figure 3-2: Ground-Referenced Source and Differential Input**

For floating signal sources, addition of a resistor at each channel provides a bias return path. The resistor value should be about

100 times the equivalent source impedance, such that if the source impedance is less than 100Ω, the negative side of the signal needs only be connected to GND as well as the negative input of the Instrumentation Amplifier without any resistors. Connection of a floating signal source to the USB-2401 in differential input mode is as shown.

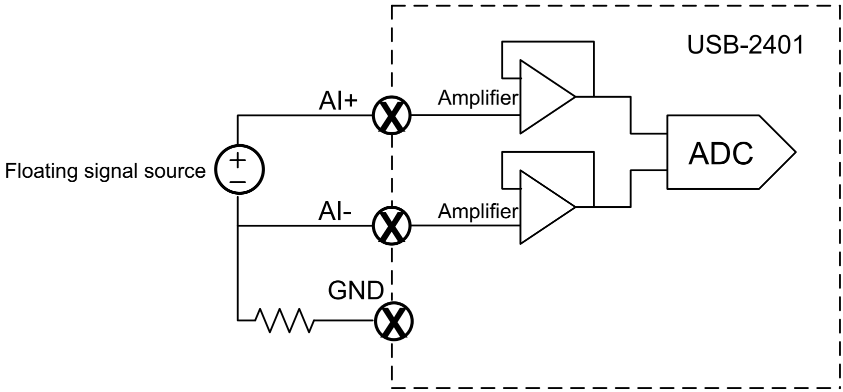


**Figure 3-3: Floating Source and Differential Input**

### 3.3.2 Current Input Mode

Current signal source can be floating or grounded reference, converted to voltage through a precision 249.5Ω resistor. Cross-voltage on the precision resistor is considered differential signal. The differential signal pair passes through differential amplifier buffers and is measured by the analog-to-digital converter chip (ADC) with ±2.5 V input range.

The formula to calculate voltage-to-current conversion is:

$$Current(mA) = \frac{V(volt)}{18.6701527}$$

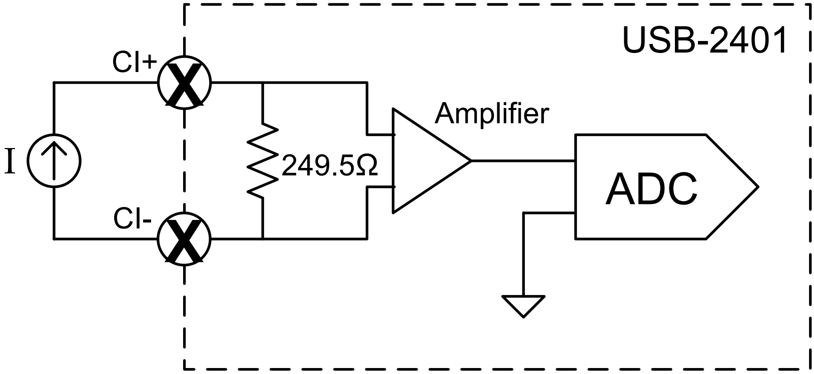


**Figure 3-4: Current Source Connection**

### 3.3.3 Full Bridge and Half Bridge Input Mode

A bridge-based transducer is a passive device, requiring voltage excitation to convert the resistive change to an electrical signal. The USB-2401 provides a steady 2.5V excitation voltage for each analog input channel in full bridge and half bridge modes. For half-bridge transducer, USB-2401 has built-in precision 20kΩ resistors to compensate the circuit as a full-bridge transducer measurement.

Also provided is a moving average function, a common and useful digital filtering method of smoothing fluctuation caused by noise. The averaging number for data can be set to 0, 2, 4, 8, or 16, where 0 represents disabling the moving average function.

A typical four-wire connection is shown.

NOTE:

A dotted line represents the connection and circuit of full-bridge mode.

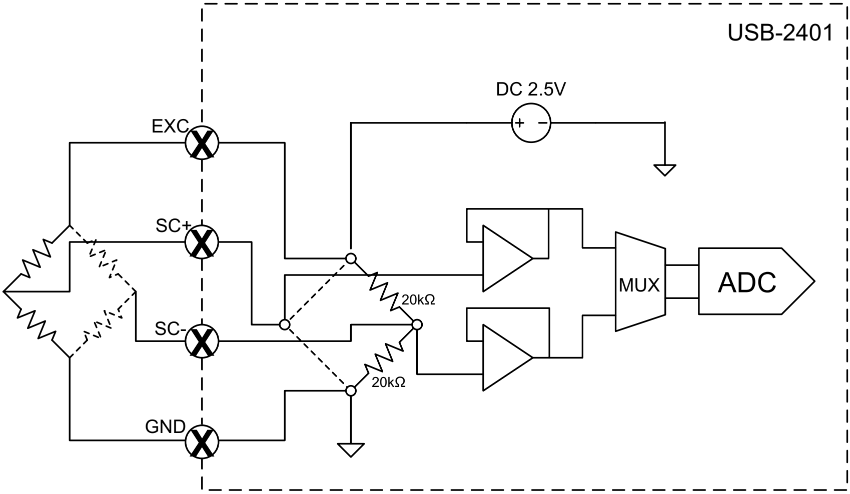


**Figure 3-5: Full Bridge and Half Bridge Connection**

### 3.3.4 Thermocouple Input Mode

A thermocouple consists of two different conductors that produce a voltage proportional to a temperature difference between either end of the pair of conductors. The USB-2401 uses 78.125mV input range to acquire the thermocouple signal, and provides a precision built-in digital temperature sensor for cold junction compensation (CJC). CJC reading is available by software API with data in °C. The CJC is in the USB-2401 module.


NOTE:

The CJC temperature sensor is housed in the USB-2401 and requires 15 minutes' warmup to stabilize.

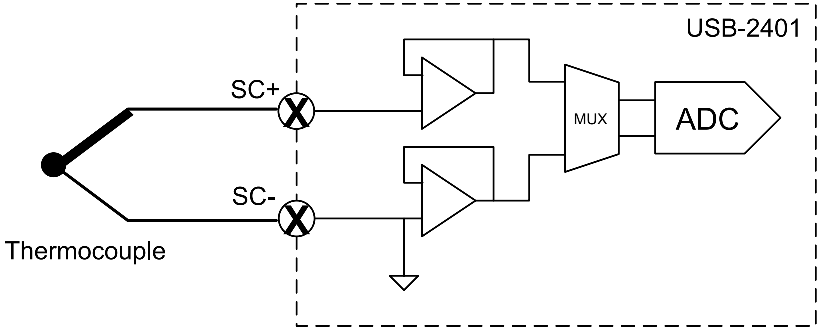


**Figure 3-6: Thermocouple Connection**

### 3.3.5 RTD Input Mode

The resistance temperature detector (RTD) measures temperature by correlating the resistance of the RTD element with temperature. The USB-2401 can generate a steady 0.5 mA excitation current source to each channel in RTD input mode to measure cross-voltage on the RTD. The actual input range is ±2.5V with a formula of voltage to RTD resistance conversion of:

$$RTD(\Omega) = \frac{\mathrm{V(volt)}}{0.0005}$$

Since the excitation current can only drive cross-voltage up to 1.5V with good linearity, the maximum equivalent value of the RTD resistor is limited to 3kΩ.

The USB-2401 can support two, three, and four-wire RTD measurement. Adopting three- and four-wire connections rather than two-wire can eliminate connection lead resistance effects from measurement. Three-wire connection is sufficient for most purposes and most universal industrial applications. Four-wire connections are used for the most precise application requirements.

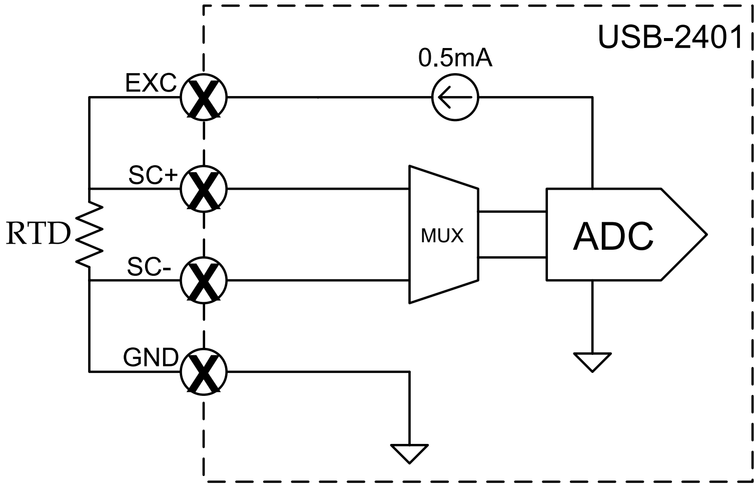


**Figure 3-7: 4-Wire RTD Connection**

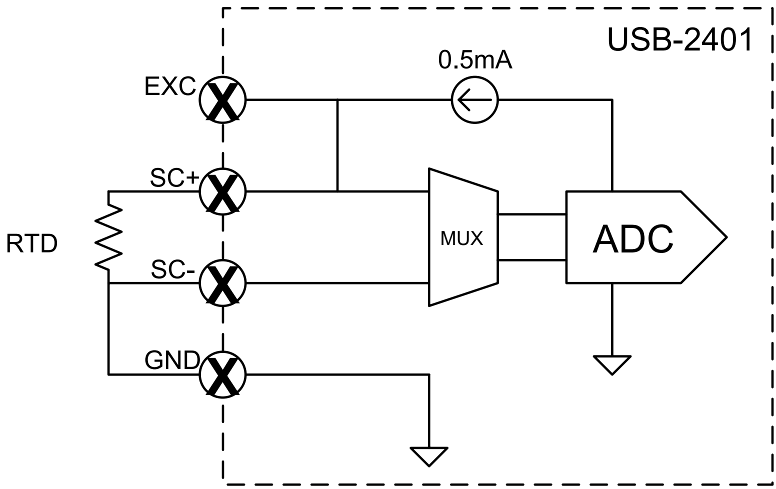


**Figure 3-8: 3-Wire RTD Connection**

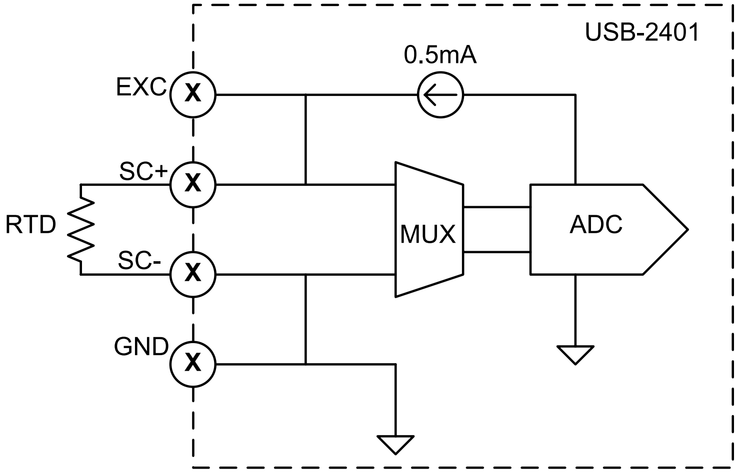


**Figure 3-9: 2-wire RTD Connection**

### 3.3.6 Wire Resistance Mode

The USB-2401 can source precision 0.05 mA excitation current to the resistor to be measured and use a 2.5V input range to acquire cross-voltage on the resistor. The formula of voltage to resistance conversion is:

$$R(\Omega) = \frac{\mathrm{V(volt)}}{0.00005}$$

Since the excitation current can only drive the cross-voltage up to 1.5V with good linearity, the maximum equivalent value of the resistor is limited to 30kΩ.

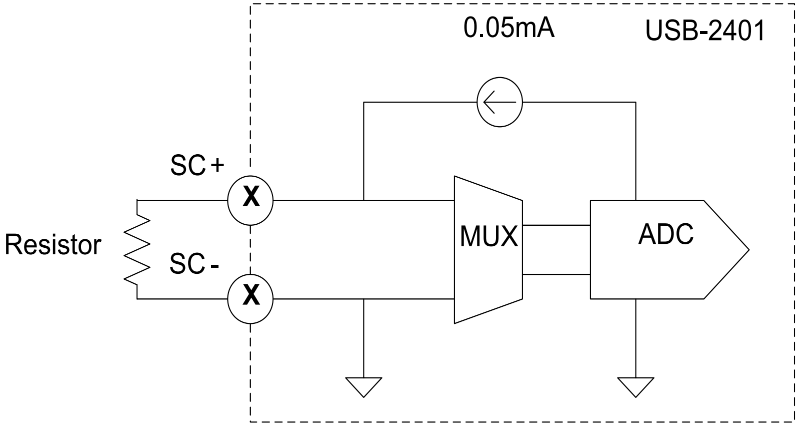


**Figure 3-10: 2-Wire Resistance Connection**

## 3.4 AI Data Format

The acquired 24-bit A/D data is 2's complement coded data format. Valid input ranges and optimum transfer characteristics are as shown.

| **Description** | **Bipolar Analog Input Range** | | | | **Digital Code** |
|---|---|---|---|---|---|
| Full-scale range | ±25 V | ±12.5 V | ±2.5 V | ±0.3125V | N/A |
| Least significant bit | 2.98uV | 1.49uV | 0.298uV | 0.037uV | N/A |
| FSR-1LSB | 24.999997 V | 12.4999985 V | 2.4999997 V | 0.3124999V | 7FFFFF |
| Midscale +1LSB | 2.98uV | 1.49uV | 0.298uV | 0.037 uV | 000001 |
| Midscale | 0 V | 0 V | 0 V | 0 V | 000000 |
| Midscale -1LSB | -2.98uV | -1.49uV | -0.298uV | -0.3124999uV | FFFFFF |
| -FSR | -25 V | -12.5 V | -2.5 V | -0.3125V | 800000 |

**Table 3-1: Analog Input Range and Output Digital Code**

| Description | Bipolar Analog Input Range | Digital Code |
|---|---|---|
| Full-scale range | ±78.125 mV | N/A |
| Least significant bit | 9.313nV | N/A |
| FSR-1LSB | 78.1249907 mV | 7FFFFF |
| Midscale +1LSB | 9.313nV | 000001 |
| Midscale | 0 V | 000000 |
| Midscale -1LSB | -9.313nV | FFFFFF |
| -FSR | -78.125mV | 800000 |

**Table 3-2: Analog Input Range and Output Digital Code (cont'd)**

## 3.5 ADC Sampling Rate

Sampling Rate refers to ADC internal conversion speed as set by the user. When programming through a software API, the desired ADC sampling rate must be set, whether for single value, using a software polling command, or block data in continuous buffer mode. Available sampling rates are 20SPS, 40SPS, 80SPS, 160SPS, 320SPS, 500SPS, 1000SPS, and 2000SPS.

NOTE: Accuracy frequently deteriorates with increased ADC sampling rate.

### 3.5.1 Software Polling Data Transfer (Non-Buffering Programmed I/O)

Polling mode benefits flexible timing and is suitable for retrieving the latest data without FIFO buffering latency. The USB-2401 continuously updates the latest acquired data onto a data port for specific channels. Data not retrieved in time is overwritten with new data without notice. As the software polling rate (here equaling data rate) of a PC may exceed the ADC sampling rate, it is possible to receive multiple identical data before a new conversion has completed. Please refer to UD-DASK function reference for the details of corresponding software API instruction.

### 3.5.2 Continuous Acquisition Mode

Differs from software polling mode only in the generation of block data in continuous acquisition mode without the need to consider data overwriting or acquiring repeat data in software polling mode. This mode is suitable for when continuous data is to be acquired in a fixed and precise time interval. Please note the data buffer size must be a multiple of 128 in continuous acquisition mode. Please refer to UD-DASK function reference for details of corresponding software API instruction.

## 3.6 Programmable Function I/O

The USB-2401 supports powerful programmable I/O function provided by an FPGA chip, configurable as TTL DI/DO, 32-bit timer/counters, and PWM output. These signals are single-ended and 5V TTL-compliant.

### 3.6.1 TTL DI/DO

Programmable function I/O can be used as static TTL-compliant 4-CH digital input and 2-CH digital output. The I/O lines can be updated by software polling, with sample and update rate fully controlled by software timing.

| Pin | Function | Pin | Function |
|---|---|---|---|
| 20 | GPO0 | 40 | GPO1 |
| 19 | GPI1 | 39 | GPI3 |
| 18 | GPI0 | 38 | GPI2 |
| 17 | NC | 37 | DGND |

**Table 3-3: TTL Digital I/O Pin Definition**

### 3.6.2 General Purpose Timer/Counter

The USB-2401 is equipped with one general purpose timer/counter featuring:

- Count up/down controllable by hardware or software
- Programmable counter clock source (internal clock up to 80MHz, external clock up to 10 MHz)
- Programmable gate selection (hardware or software control)
- Programmable input and output signal polarities (high active or low active)
- Initial Count loaded from a software API
- Current count value readable by software without affecting circuit operation.

| Pin | Function | Pin | Function |
|---|---|---|---|
| 20 | GPTC_OUT0 (GPO0) | 40 | GPTC_OUT1 (GPO1) |
| 19 | GPTC_UD (GPI1) | 39 | GPTC_AUX (GPI3) |
| 18 | GPTC_CLK (GPI0) | 38 | GPTC_GATE (GPI2) |
| 17 | NC | 37 | DGND |

**Table 3-4: Timer/Counter Pin Definition**

The timer/counter has three inputs that can be controlled via hardware or software, clock input (GPTC_CLK), gate input (GPTC_GATE), and up/down control input (GPTC_UD). The GPTC_CLK input provides a clock source input to the timer/counter. Active edges on the GPTC_CLK input increment or decrement the counter. The GPTC_UD input directs the counter to count up or down (high: count up; low: count down), while the GPTC_GATE input is a control signal acting as a counter enable or counter trigger signal in different applications. The GPTC_OUT then generates a pulse signal based on the timer/counter mode set.

All input/output signal polarities can be programmed by software application. For brevity, all GPTC_CLK, GPTC_GATE, and GPTC_OUT in the following illustrations are assumed to be active high or rising-edge triggered.

### 3.6.3 General Purpose Timer/Counter Modes

Ten programmable timer/counter modes are available. All initialize following a software-start signal set by the software. The GPTC software reset initializes the status of the counter and reloads the initial value to the counter. The operation remains halted until software start is executed again. Operations under different modes are as follows.

**Mode 1: Simple Gated-Event Counting**

In this mode, the counter calculates the number of pulses on the GPTC_CLK after a software start. Initial count can be loaded from the software application. Current count value can be read back by software any time with no influence on calculation. GPTC_GATE enables/disables calculation. When GPTC_GATE is inactive, the counter halts the current count value. Operation in which initial count = 5, countdown mode is shown.

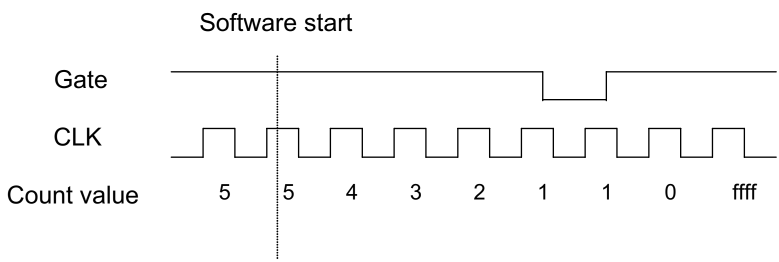


**Figure 3-11: Mode 1-Simple Gated-Event Calculation**

**Mode 2: Single Period Measurement**

The counter calculates the period of the signal on GPTC_GATE in terms of GPTC_CLK. The initial count can be loaded from the software application. After software start, the counter calculates the number of active edges on GPTC_CLK between two active edges of GPTC_GATE. After the completion of the period interval on GPTC_GATE, GPTC_OUT outputs high and then current count value can be read by the software application. Operation in which initial count = 0, count-up mode is shown.

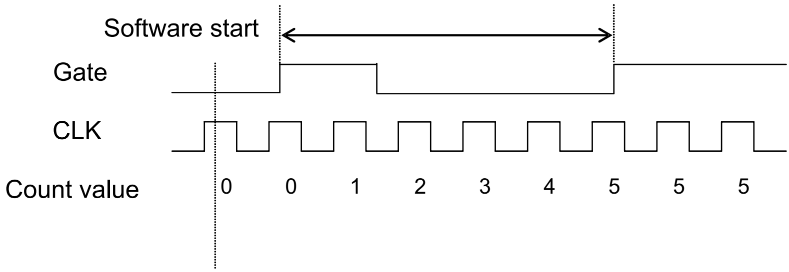


**Figure 3-12: Mode 2-Single Period Measurement**

### Mode 3: Single Pulse-Width Measurement

The counter calculates the pulse-width of the signal on GPTC_GATE in terms of GPTC_CLK. Initial count can be loaded from the software application. After software start, the counter calculates the number of active edges on GPTC_CLK when GPTC_GATE is in its active state.

After the completion of the pulse-width interval on GPTC_GATE, GPTC_OUT outputs high and current count value can be read by the software application. Operation in which initial count = 0, count-up mode is shown.

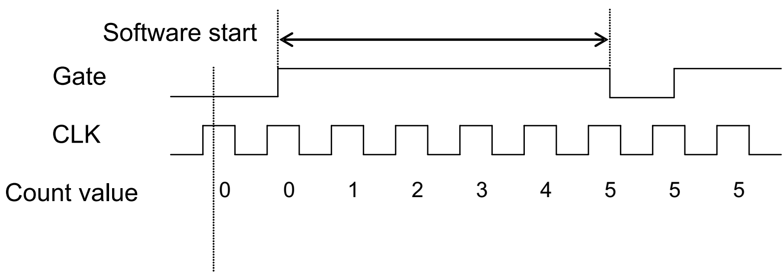


**Figure 3-13: Mode 3-Single Pulse-Width Measurement**

### Mode 4: Single-Gated Pulse Generation

This mode generates a single pulse with programmable delay and programmable pulse-width following software start. The two programmable parameters can be specified in terms of periods of the GPTC_CLK input by the software application. GPTC_GATE enables/disables calculation. When GPTC_GATE is inactive, the counter halts the current count value. Generation of a single pulse with a pulse delay of two and a pulse-width of four is shown.

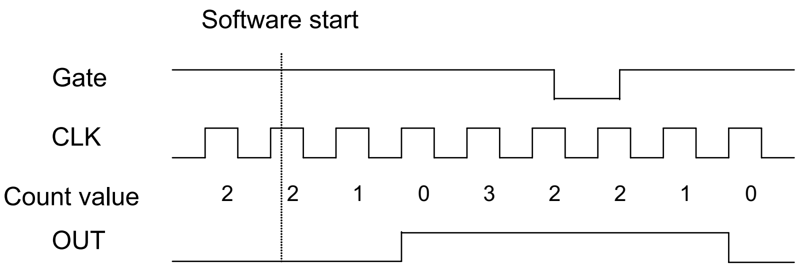


**Figure 3-14: Mode 4-Single-Gated Pulse**

### Mode 5: Single-Triggered Pulse

This mode generates a single pulse with programmable delay and programmable pulse-width following an active GPTC_GATE edge. These programmable parameters can be specified in terms of periods of the GPTC_CLK input. When the first GPTC_GATE edge triggers the single pulse, GPTC_GATE has no effect until software start is executed again. Generation of a single pulse with a pulse delay of two and a pulse-width of four is shown.

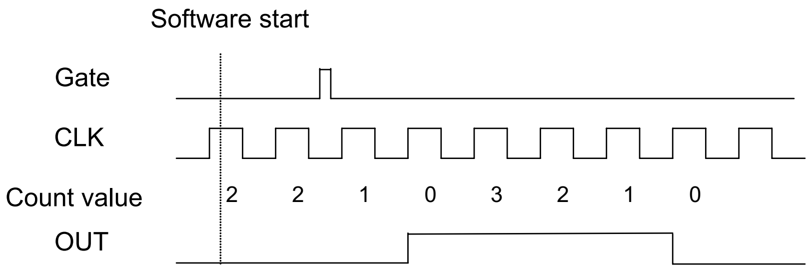


**Figure 3-15: Mode 5-Single-Triggered Pulse**

### Mode 6: Re-Triggered Single Pulse Generation

This mode is similar to Mode 5 except that the counter generates a pulse following every active edge of GPTC_GATE. After software start, every active GPTC_GATE edge triggers a single pulse with programmable delay and pulse width. Any GPTC_GATE triggers that occur when the prior pulse is not completed are ignored. Generation of two pulses with a pulse delay of two and a pulse width of four is shown.

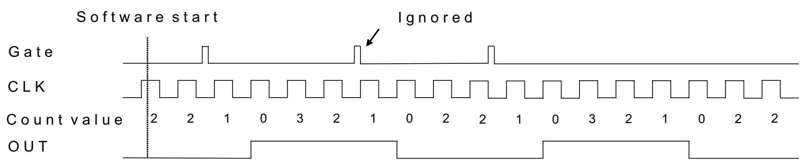


**Figure 3-16: Mode 6-Re-Triggered Single Pulse**

### Mode 7: Single-Triggered Continuous Pulse Generation

This mode is similar to Mode 5 except that the counter generates continuous periodic pulses with programmable pulse interval and pulse-width following the first active edge of GPTC_GATE. When the first GPTC_GATE edge triggers the counter, GPTC_GATE has no effect until software start is executed again. Generation of two pulses with a pulse delay of four and a pulse-width of three is shown.

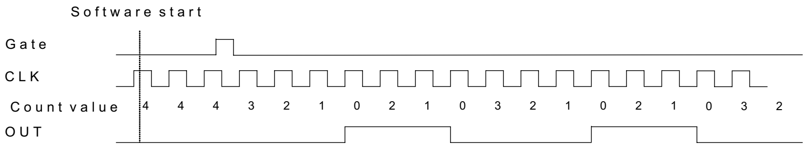


**Figure 3-17: Mode 7-Single-Triggered Continuous Pulse**

### Mode 8: Continuous Gated Pulse Generation

This mode generates periodic pulses with programmable pulse interval and pulse-width following software start. GPTC_GATE enables/disables calculation. When GPTC_GATE is inactive, the counter halts the current count value. Generation of two pulses with a pulse delay of four and a pulse-width of three is shown.

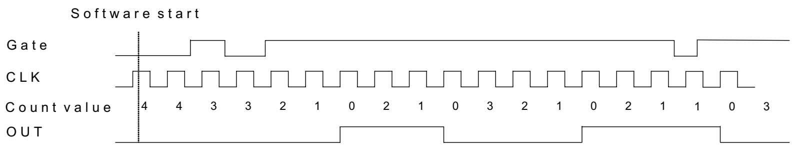


**Figure 3-18: Mode 8-Continuous Gated Pulse**

### Mode 9: Edge Separation Measurement

Measures the time differentiation between two different pulse signals. The first pulse signal is connected to GPTC_GATE and the second signal is connected to GPTC_AUX. Clocks that pass between the rising edge signal of two different pulses through the 40 MHz internal clock or external clock are calculated. You can calculate the time period via the known clock frequency. The maximum counting width is 32-bit. Decrease of the counter value in Edge Separation Measurement mode is shown.

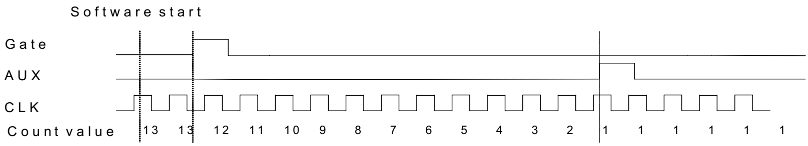


**Figure 3-19: Mode 9-Edge Separation Measurement**

## Mode 10: PWM Output

The USB-1900 Series timer/counter can also simulate a PWM (Pulse Width Modulation) output. By setting a varying amount of Pulse_initial_cnt and Pulse_length_cnt, varying pulse frequencies (Fpwm) and duty cycles (Dutypwm) can be obtained. PWM output is shown.

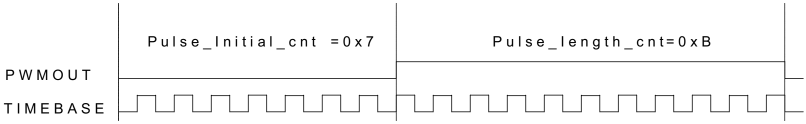


**Figure 3-20: Mode 10-PWM Output**

Calculation of the PWM frequency and duty cycle is as follows.

$$F_{PWM} = \frac{F_{Timebase}}{Pulse\_initial\_cnt + Pulse\_length\_cnt}$$

$$Duty_{PWM} = \frac{Pulse\_length\_cnt}{Pulse\_initial\_cnt + Pulse\_length\_cnt}$$

# 4 Calibration

The USB-2401 is factory-calibrated before shipment. The associated calibration constants of the TrimDACs firmware are written to the onboard EEPROM. TrimDACs firmware is the algorithm in the FPGA. Loading calibration constants entails loading the values of TrimDACs firmware stored in the onboard EEPROM.

The recommended re-calibration interval is one year. Please contact your local dealer to request calibration service.

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# Important Safety Instructions

For user safety, please read and follow all **instructions**, **WARNINGS**, **CAUTIONS,** and **NOTES** marked in this manual and on the associated equipment before handling/operating the equipment.

- Read these safety instructions carefully.
- Keep this user's manual for future reference.
- Read the specifications section of this manual for detailed information on the operating environment of this equipment.
- When installing/mounting or uninstalling/removing equipment:
  - Turn off power and unplug any power cords/cables.
- To avoid electrical shock and/or damage to equipment:
  - Keep equipment away from water or liquid sources;
  - Keep equipment away from high heat or high humidity;
  - Keep equipment properly ventilated (do not block or cover ventilation openings);
  - Make sure to use recommended voltage and power source settings;
  - Always install and operate equipment near an easily accessible electrical socket-outlet;
  - Secure the power cord (do not place any object on/over the power cord);
  - Only install/attach and operate equipment on stable surfaces and/or recommended mountings; and,
  - If the equipment will not be used for long periods of time, turn off and unplug the equipment from its power source.

- Never attempt to fix the equipment. Equipment should only be serviced by qualified personnel.

A Lithium-type battery may be provided for uninterrupted, backup or emergency power.

---

WARNING:

Risk of explosion if battery is replaced with an incorrect type; please dispose of used batteries appropriately.

---

- Equipment must be serviced by authorized technicians when:
  - The power cord or plug is damaged;
  - Liquid has penetrated the equipment;
  - It has been exposed to high humidity/moisture;
  - It is not functioning or does not function according to the user's manual;
  - It has been dropped and/or damaged; and/or,
  - It has an obvious sign of breakage.

# Getting Service

Contact us should you require any service or assistance.

**ADLINK Technology, Inc.**
Address: 9F, No.166 Jian Yi Road, Zhonghe District
New Taipei City 235, Taiwan
新北市中和區建一路 166 號 9 樓
Tel: +886-2-8226-5877
Fax: +886-2-8226-5717
Email: service@adlinktech.com

**Ampro ADLINK Technology, Inc.**
Address: 5215 Hellyer Avenue, #110, San Jose, CA 95138, USA
Tel: +1-408-360-0200
Toll Free: +1-800-966-5200 (USA only)
Fax: +1-408-360-0222
Email: info@adlinktech.com

**ADLINK Technology (China) Co., Ltd.**
Address: 上海市浦东新区张江高科技园区芳春路 300 号 (201203)
300 Fang Chun Rd., Zhangjiang Hi-Tech Park,
Pudong New Area, Shanghai, 201203 China
Tel: +86-21-5132-8988
Fax: +86-21-5132-3588
Email: market@adlinktech.com

**ADLINK Technology Beijing**
Address: 北京市海淀区上地东路 1 号盈创动力大厦 E 座 801 室(100085)
Rm. 801, Power Creative E, No. 1, B/D
Shang Di East Rd., Beijing, 100085 China
Tel: +86-10-5885-8666
Fax: +86-10-5885-8625
Email: market@adlinktech.com

**ADLINK Technology Shenzhen**
Address: 深圳市南山区科技园南区高新南七道 数字技术园
A1 栋 2 楼 C 区 (518057)
2F, C Block, Bldg. A1, Cyber-Tech Zone, Gao Xin Ave. Sec. 7,
High-Tech Industrial Park S., Shenzhen, 518054 China
Tel: +86-755-2643-4858
Fax: +86-755-2664-6353
Email: market@adlinktech.com

**ADLINK Technology, Inc. (French Liaison Office)**
Address: 15 rue Emile Baudot, 91300 Massy CEDEX, France
Tel: +33 (0) 1 60 12 35 66
Fax: +33 (0) 1 60 12 35 66
Email: france@adlinktech.com

**ADLINK Technology Japan Corporation**
Address: 〒101-0045 東京都千代田区神田鍛冶町 3-7-4
神田 374 ビル 4F
KANDA374 Bldg. 4F, 3-7-4 Kanda Kajicho,
Chiyoda-ku, Tokyo 101-0045, Japan
Tel: +81-3-4455-3722
Fax: +81-3-5209-6013
Email: japan@adlinktech.com

**ADLINK Technology, Inc. (Korean Liaison Office)**
Address: 서울시 서초구 서초동 1675-12 모인터빌딩 8 층
8F Mointer B/D,1675-12, Seocho-Dong, Seocho-Gu,
Seoul 137-070, Korea
Tel: +82-2-2057-0565
Fax: +82-2-2057-0563
Email: korea@adlinktech.com

**ADLINK Technology Singapore Pte. Ltd.**
Address: 84 Genting Lane #07-02A, Cityneon Design Centre,
Singapore 349584
Tel: +65-6844-2261
Fax: +65-6844-2263
Email: singapore@adlinktech.com

**ADLINK Technology Singapore Pte. Ltd. (Indian Liaison Office)**
Address: 1st Floor, #50-56 (Between 16th/17th Cross) Margosa Plaza,
Margosa Main Road, Malleswaram, Bangalore-560055, India
Tel: +91-80-65605817, +91-80-42246107
Fax: +91-80-23464606
Email: india@adlinktech.com

**ADLINK Technology, Inc. (Israeli Liaison Office)**
Address: 6 Hasadna St., Kfar Saba 44424, Israel
Tel: +972-9-7446541
Fax: +972-9-7446542
Email: israel@adlinktech.com