1 Features

- 16 channel data logger
- 0 – 5v input using basic input module
- 500 mAh lithium-polymer battery
- User defined sample rate between 256Hz and once per 32,768 seconds
- Simple text data files (csv)
- Separate input modules allow for extended flexibility
- Time stamped data sets
- LED indicator lights for system status
- System operates as a USB mass storage device when attached to a computer
- Unique serial number to identify logger
- Logger weighs 2.3oz (65g) excluding input module
- Small Form factor 3"L 2"W 0.8"H (7.6x5.1x2.0 mm)

2 Applications

The ADL16 is applicable to:

- Recording analog signals
- Monitoring multiple sensor channels for industrial systems control
- Recording strain gauge measurements
-

3 Description

The ADL16 is a simple and compact 16-channel analog data logger. The modular design allows for versatile input configurations and the ability to separate the logger from the test setup. The ADL16 is configured using a text file and the USB connectivity allows quick access to the comma separated text data files.

Figure 1: ADL16 Analog Data Logger

NOTE:

This is a preliminary edition of the ADL16 user manual and certain details are subject to change. In particular, the battery charge indication is not yet implemented as described in this document. This manual was draft at firmware version 741.

4 Electrical

4.1 Operating Conditions

The ADL16 is protected from general handling conditions by the plastic enclosure but is not protected from adverse environmental conditions, such as rain, sweat, splashes, and water submersion. The temperature range is limited primarily by the lithium-polymer battery capabilities.

Table 1: Operating Conditions

Parameter	Value
Temperature Range (Operating)	-5°F ~ 130°F (-20°C ~ 55°C)
Temperature Range (Storage)	-5°F ~ 80°F (-20°C ~ 25°C)
Relative Humidity (Operating and Storage)	<90%

4.2 Input Channels

The ADL16 incorporates a 16-channel multiplexed 12-bit analog-to-digital converter with a 0 – 2.5 volt input range. This provides 4096 discrete levels, or counts, to represent the full-scale input range of 2.5 volts. The data file header states 610uV/count sensitivity. Input modules will adjust the signal range to match the capabilities of the logger. For example, the basic 16-channel input module allows for a 0 – 5.0 volt input at 100K ohm impedance (see Appendix A).

Table 2: ADL16 Characteristics

Parameter	Min	Typical	Max	Units
Resolution	—	—	12	Bits
Input Range	0	—	2.5	V
Integral Nonlinearity	—	±1	±1.9	LSB
Differential Nonlinearity	-1	±0.7	1.8	LSB
Signal-to-Noise	62	66	—	dB
Total Harmonic Distortion	—	78	—	dB
Spurious-Free Dynamic Range	—	-79	—	dB

4.3 Indicator LEDs

System status is indicated by two LEDs (see Figure 2). The “Status” LED blinks once per second indicating a properly operating system. The “Status” LED blinks when the ADL16 is recording data, in standby mode, or is connected to a computer via the USB port. The “Data” LED blinks when data is

written or read from the microSD memory card. In data logging mode, the period at which the "Data" LED blinks depends on the sample rate and other configuration settings. The "Data" LED also indicates the lithium-polymer battery charging status when the logger is attached to a USB port. The "statusindicators" tag in the system configuration file turns off or changes the brightness of the status indicators (see section 5.1.9).

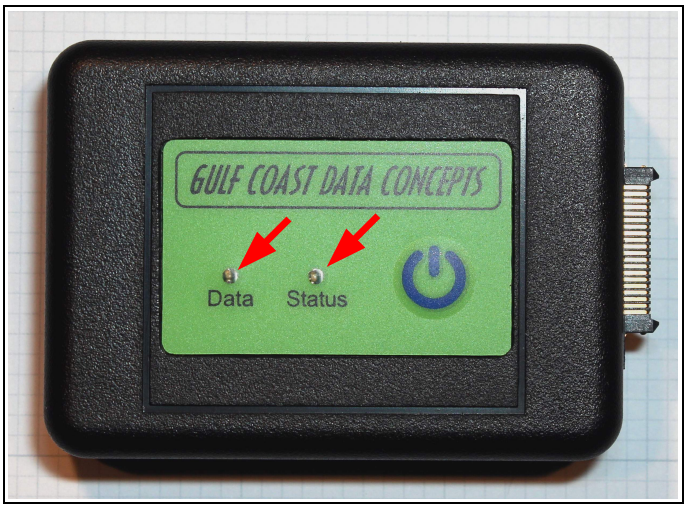

Figure 2: LED Indicators

4.4 Battery

The ADL16 is powered by a internal, hardwired 500mAh lithium-polymer rechargeable battery. The internal battery management system recharges the battery when the ADL16 is plugged into a USB port or attached to a USB 5v power adapter. The battery is not used when the system is connected to a computer USB port. The "Data" LED blinks when the battery is charging according to the sequence illustrated in Figure 3. Note that the "Data" LED will also blink with USB data transfers when connected to a PC, such as a file transfer.

Battery life depends on the sample rate and sensor current draw. Typical performance is approximately 20 hours of operation sampling at 128 Hz.

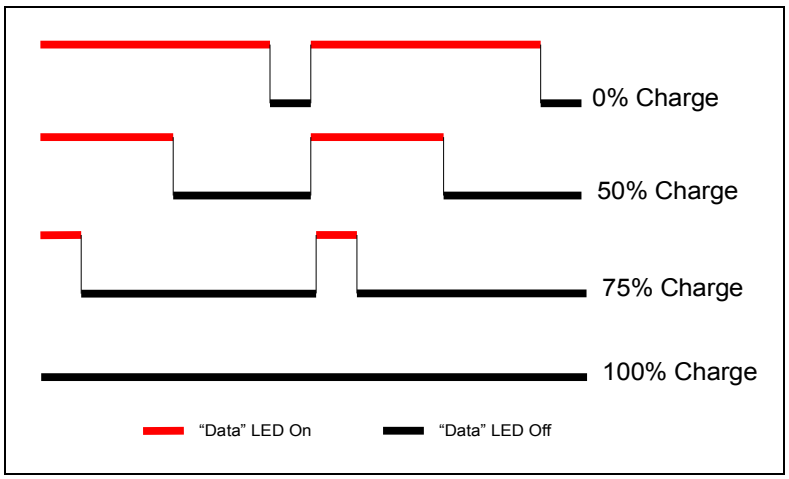

Figure 3: Charge Indication Sequence

A 5v supply via the USB connector provides extended operation of the device independent of the internal battery. Common USB power adapters or USB battery packs for consumer electronics can provide the required 5v supply. The logger does not implement power saving features when connected to an external power supply so power consumption will be higher than when using the internal battery.

The data logger may draw up to 250mA from the USB supply to recharge the battery. Plugging multiple data loggers into a USB hub can exceed the power capacity of the hub. This can cause "brown-outs" of the logger and possibly damage the microSD card.

The logger is always "on" maintaining the real time clock and will eventually discharge the battery completely after several months. The battery must be charged occasionally or remove the battery disconnect jumper to completely deactivate the device for long-term storage (see Figure 4). Keep in a cool (20°C/ 68°F) dry environment to avoid damage of the battery.

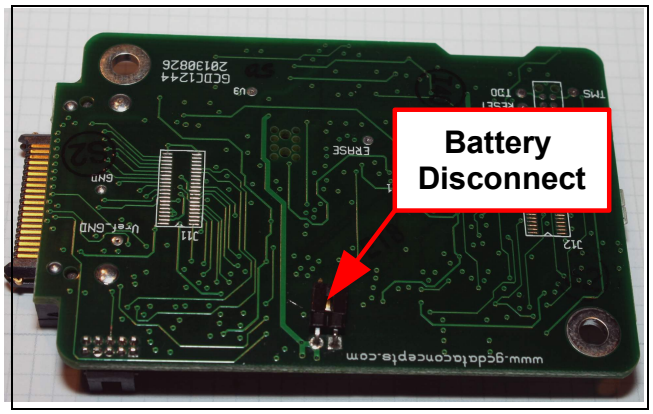

Figure 4: Battery Disconnect

4.4.1 Real Time Clock

A real time clock (RTC) is integrated into the ADL16 and is used to determine time for each line of data recorded. The RTC is set using a text file named "time.txt" located in the root directory of the microSD card. The system looks for the time.txt file upon booting. If the file exists, the time stored in the file is loaded to the RTC and the time.txt file is deleted. The time information in the time.txt file must be in the exact "yyyy-MM-dd HH:mm:ss" 24-hour format, occur on the first line, and end with a newline character. Figure 5 provides an example time.txt file that will initialize the RTC to 2:26:30 pm June 16, 2014.

The time file method of setting the RTC does not require special communication drivers so it can be implemented using a simple text editor. Direct initialization of the RTC is possible but requires specific device drivers and software from Gulf Coast Data Concepts.

The RTC maintains ±5ppm accuracy (-40°C to +85°C), which means that it will drift accuracy about 1 second every 2 days. The RTC is powered by the battery at all times, even when the logger is "off".

```
2014-06-16 14:26:30
```

Figure 5: Example Time Initialization File

Initializing the RTC ensures that the start time and individual time stamps can be correlated to an absolute time – the year, month, day, hour, minute, second, and fractional second. An uninitialized or reset of the RTC will lead to indeterminate time stamps.

After unplugging the logger from the USB port, the logger will load the time.txt file when it is activated either by pressing the on/off button or if the "rebootondisconnect" option is active. Therefore, there is a delay between when the time.txt was created and when the logger actually loads the time information. For most applications, this simple method of initializing the clock results in sufficient accuracy.

4.4.2 Memory Card

The ADL16 stores data to a removable 8GB microSD flash memory card and is compatible with microSD and microSDHC type cards. The ADL16 functions as a Mass Storage Device to computer operating systems when transferring data to and from the microSD memory card. The Mass Storage Device interface is supported by all desktop operating systems and special device drivers are not required. Tablet computers may not recognize the ADL16 due to USB device limitations set by the tablet manufacturer.

The logger needs only the config.txt file to operate. The ADL16 will use default configuration settings if the config.txt is not present. The "config.txt" and "time.txt" files must occur in the root directory (see section 5 and section 4.4.1). The ADL16 will create a folder called "GCDC", if not already present, to place the data files (see section 5.2).

Interrupting the power to the logger can result in corruption of the microSD card. For example, removing the logger from the USB port during file transfers to the PC. Reformat the card if it becomes corrupted (FAT32 file structure). If data transfers to/from the card become slow, consider formatting the card using "SD Card Formatter" software provided by the SD Association (www.sdcard.org).

4.5 Mechanical

The ADL16 logger electronics module is enclosed in a black ABS plastic enclosure and assembled with two Philips head screws. The logger module attaches to the input module via a 40-pin connector. The two modules will "click" together when the connection is fully engaged. The connector will maintain the attachment against moderate handling but an additional locking mechanism is recommended for long term deployments. For example, attaching the module assembly to a backing board as part of the experiment setup. Wrapping the assembly with 2" diameter heat shrink tube (2:1 shrink ratio) provides very good protection.

4.5.1 Dimensions

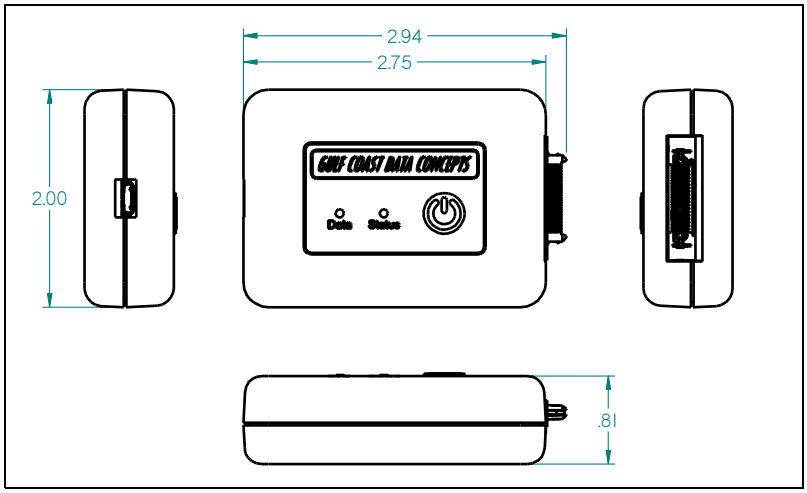

Figure 6: ADL16 Logger Module Dimensions

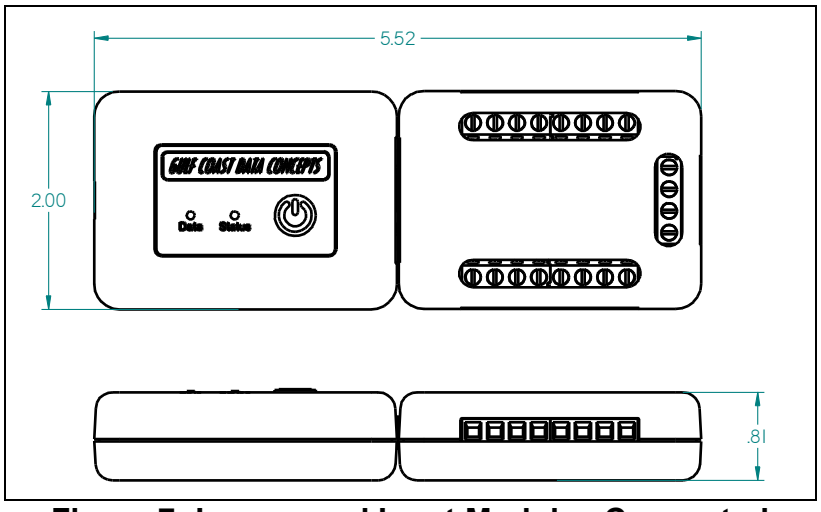

Figure 7: Logger and Input Modules Connected

5 System Operation

5.1 Configuration File

The ADL16 is configured using a set of tags and settings stored in a text file named "config.txt", which is located in the root directory of the microSD card. The system reads the configuration file at boot time. Table 3 lists the configuration file tags. A tag is followed by an equal sign ("=") and an applicable tag setting. A line finishes with a newline character (0x0A). Tags are not case sensitive. Tab and space characters are ignored. Lines starting with a semicolon (";") are treated as comments and ignored by the system. The system will use the default settings listed in Table 3 if the config.txt file is not found.

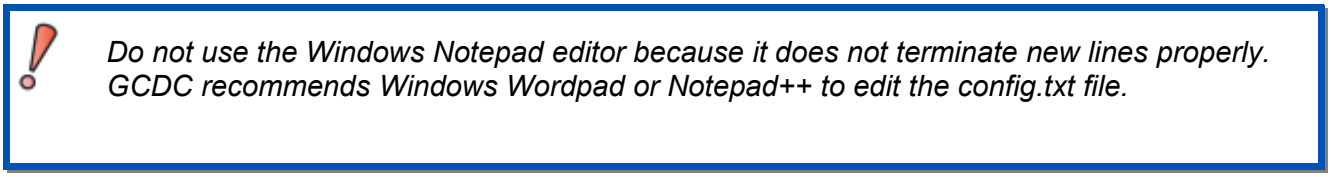

Table 3: Configuration File Tags and Descriptions

Tag	Valid Settings	Default	Description
microRes	-	Off	The presence of this tag sets the device to record time stamps with 0.1ms effective precision.
rebootOnDisconnect	-	off on disconnect	The presence of this tag causes the system to start recording after disconnect from a USB port.
sensorPower	-	Off	The presence of this tag activates the power supply to the input module.
samplePeriod	Integer between 1 and 32768	-	Period between samples expressed in seconds, use sampleperiod when sample rate is less than 1 Hz
samplesPerFile	An integer greater than 0	28896	The number of lines of data per data file before a new file is created
sampleRate	Integer between 1 and 256	128	Sets the rate at which data is collected and recorded to the microSD card.
startTime and stopTtime	See section 5.1.7	-	Defines when to start and stop recording
stopOnVusb	-	Off	Stops data logging if 5v USB power is present (see section 5.1.8)
statusIndicators	"Normal", "High", "Off"	Normal	LED status indicators can be activated with normal brightness (Normal), activated with high brightness (High), or completely deactivated (Off).
Error: Reference source not found	An integer greater than 0	Off	When sensorpower is active, turnondelay defines the number of milliseconds between sensor power and data acquisition

5.1.1 microRes

The "microres" option sets the device to record time stamps with 0.1ms precision. In micro-resolution mode, the time stamps are recorded as XX.YYYYZZ where XX are seconds, YYYY are 0.1 milliseconds, and ZZ are spurious digits that should be ignored. The micro-resolution option should be implemented at sample rates greater than 200 hertz to provide the best timing precision. The power saving features of the ADL16 are disabled in micro-resolution mode and battery life is shortened accordingly.

5.1.2 rebootOnDisconnect

The ADL16 incorporates an on/off button for initiating and terminating the data recording process. Data recording is automatically started upon disconnect from a computer USB port if the tag word "rebootondisconnect" is included in the configuration file.

5.1.3 samplesPerFile

"samplesperfile" defines the number of data lines each file can have before a new file is created. This tag controls the size of the data files into easily manageable lengths for later processing. This setting is loaded as a signed 32-bit integer, which can translate into very large data files. The user should exercise caution before setting large files and test the end-user application for data limitations.

5.1.4 samplePeriod

"sampleperiod" defines the number of milliseconds between samples and is used to configure sample rates less than 1 per second. The logger will accept an integer value between than 1 and 32768. Note that "sampleperiod" and "samplerate" are exclusive of each other.

5.1.5 sampleRate

The "samplerate" tag defines the data rate in Hertz, or samples per second. The logger will accept an integer value between 1 and 256.

5.1.6 sensorPower

The ADL16 can support up to 100mA to the input module for sensor power. Add "sensorpower" to the configuration file to activate the logger power supply. The sensor power is deactivated between samples to conserve power when the sample rate is less than 1 Hz. Use "turnOnDelay" to establish a delay after activating the power and before a data sample is collected.

5.1.7 startTime and stopTtime

The ADL16 starts and stops data recording based on the times defined using the "starttime" and "stoptime" tags. The times must be in "MM HH DD" 24-hr format with the three entries separated by a space. Entries marked with "*" operate as a wild card. The ADL16 continues to record after the start time unless defined otherwise by the stoptime tag. Note that the configuration option does not include the month. Example timing configurations:

Example 1: On the 15th day, start recording at 12:30pm and stop recording at 6:00pm.

starttime = 30 12 15
stoptime = 00 18 15

Example 2: Start recording at the beginning of every hour and stop recording 45 minutes later.

starttime = 00 *
stoptime = 45 *

5.1.8 stopOnVusb

The "stoponvusb" tag stops data logging operations when a 5v supply is detected on the USB connector. Add the "rebootondisconnect" option so the logger will resume recording when removed from the 5v supply. This configuration is convenient for halting data logging while charging the battery from a USB power supply. Without the stoponvusb option (default), the device switches power from the internal battery to the USB 5v and continues to log data.

5.1.9 statusIndicators

The brightness intensity of the LED status indicators is defined using the "statusindicators" tag and valid settings of "normal", "high", and "off".

5.1.10 turnOnDelay

When the logger is supplying power to the input module, the logger will activate the power first and wait for a period of time before sampling the channels. This allows the sensors to stabilize before a sample is taken. The "turnondelay" defines the number of milliseconds to wait between power activation and data acquisition.

5.1.11 Example Configuration Files

Example A) The configuration file in Figure 2 will set the logger to record at 5 Hz and each data file will include 1 hour of data. The standard time stamp precision is sufficient for such slow data rates.

```
; example config file for
; analog data logger product
; set sample rate
SampleRate = 5
; file size to one hr
samplesperfile = 18000
; turn on LEDs
statusindicators = Normal
; no need for microresolution
;microResolution
; no need to power sensors
;sensorPower
```

Figure 8: Example A Configuration

Example B) Figure 23 shows a configuration file that records one sample every 5 seconds. In this case, the sensor power is activated for 10 milliseconds before a sample is collected. The 10 millisecond delay allows the sensors to stabilize before a measurement is taken. The power is deactivated after the input channels are sampled.

```
; example config file for
; analog data logger product
; sample every 5 seconds
samplePeriod = 5
; file size to one day
samplesPerFile = 17280
; turn on LEDs
statusIndicators = Normal
; no need for microresolution
;microResolution
; activate power for sensors
sensorPower
; turn on power 10 msec before
; taking a sample
turnOnDelay = 10
```

Figure 9: Example B Configuration

5.2 Data Files

5.2.1 File Creation

The ADL16 creates a new data file when the system is booted or when the maximum number of data lines is reached in the previous data file. A system boot condition occurs when the on/off button is pressed, 5v power is restored to the system via the USB connector, or when the ADL16 is removed from a computer USB port with the "rebootondisconnect" feature enabled. Data files are placed in a folder named "GCDC" and are named data-XXX.csv, where XXX is a sequential number starting with 001. The system will create up to 999 files. At the beginning of each file, a header is written describing the system configuration and the current time when the file was created.

5.2.2 Data Format

Data is written to files in comma separated text format starting with the file header information and followed by event data entries. Table 4 lists the valid header tags, although not all tags may occur in the header, depending on the system configuration. Each data line contains a time entry followed by the raw counts from the 12-bit analog-to-digital converter for each channel. The time entry is seconds elapsed from the start time recorded in the header. Add the elapsed time to the start time to determine the complete time record of the sample. Figure 10 represents an example data file.

The last line of the final data file records the reason for the termination, such as “shutdown: switched off”, “shutdown: low battery”, “shutdown: max files exceeded”, “shutdown: vbus disconnect”, or “connected to computer”. The line is designated as a comment with a semicolon (“;”).

Table 4: Data File Header Tags

Tag	Description
Attached to:	Describes the type of input module attached to the logger, followed by the module unique serial number
Fullscale	Provides the fullscale sensitivity, for example 610 uV/count
SampleRate	Rate at which data is recorded to the microSD card
SamplePeriod	Number of seconds between samples
Start_Time	The current time when the data file was created
Temperature	Temperature of sensor in °C when data file was created
Title	The name of the USB Accelerometer ADL16 unit and sensor type
Vbat	Battery voltage (mV) measured at the file start time
Version	The version control information of the firmware, including unique serial number

```
;Title, http://www.gcdataconcepts.com, Datalogger
;Version, 741, Build date, Jun 25 2014,  SN:CCDC40021316C32
;Start_time, 2014-07-10, 10:47:33.000
;Temperature, 32.00, deg C,  Vbat, 3792, mv
;Attached to: Unknown,  SN: Unknown
;Fullscale 4096counts => 2.500V, 610uV/count
;SampleRate, 20,Hz
;Time, Ch1, Ch2, Ch3, Ch4, Ch5, Ch6, Ch7, Ch8, Ch9, Ch10, Ch11, Ch12, Ch13, Ch14, Ch15, Ch16
0.020,3523,3629,3985,3672,166,3930,1491,2146,3492,630,3080,3535,324,1995,1965,794
0.070,1853,2236,3861,1501,3340,493,1257,3148,3455,698,980,1085,3487,2158,1743,3126
0.119,2944,966,666,2310,1927,3900,3297,605,2181,1179,1407,2299,843,2134,3698,216
0.169,1559,2351,1779,477,122,2716,1589,2466,2066,2176,2637,183,703,2718,1992,3565
0.219,1715,1636,3675,2611,2288,1389,3914,3951,2731,3930,2542,1254,3612,3433,2791,943
0.269,813,1625,626,1443,1180,2324,3692,2398,1534,1186,3191,3527,2855,993,209,3997
0.319,2437,2956,1604,2957,3034,258,975,3923,2271,2137,3175,3166,1360,57,1389,1662
0.368,486,2561,2115,284,3501,1195,2959,1403,3403,2310,2211,1145,4015,3500,2443,3681
0.418,160,324,1096,834,447,399,4017,1609,2665,3516,1658,1711,1794,2683,1251,2208
0.468,2092,1642,1430,182,2660,1333,2593,3192,1668,18,930,2651,944,499,2071,3032
0.518,2860,3600,2263,1021,1687,1835,1714,3340,2322,1577,2104,1957,3016,1637,3757,3571
0.567,3688,1626,3613,3422,1019,776,1313,337,3248,3241,2244,378,1283,2860,278,3614
```

Figure 10: Example Data File

5.2.3 Data Conversion

The ADL16 records the raw digital data from the analog-to-digital converter. Converting the data to engineering units will depend on the sensor and the signal conditioning included with input module. Input modules built by GCDC will include instructions for converting the raw data.

6 Software

The ADL16 records data to comma delimited text files and uses text based files for configuration settings. Therefore, no special software is required to access or utilize the ADL16. For data analysis, Gulf Coast Data Concepts recommends using a commercial or open source mathematics package, such as MatLab, Microsoft Excel, OpenOffice Calc, Octave, R, or similar applications.

7 Troubleshooting

Problem	Resolution
I press the on/off button but the logger does not appear to activate and no LEDs blink.	Make sure the battery is charged.
	Check the battery disconnect jumper is set properly.
	The logger could be operating correctly but the status indicators are turned off. Check the "statusindicator" option in the config.txt file.
I press the on/off button, the blue LED blinks once per second but the red LED does not indicate logging.	The logger is in standby mode waiting for a start time to occur. Check the config.txt file for the start/stop settings.
The blue LED blinks slowly.	The microSD card is not present or is corrupted. Check that the card is inserted properly and the card is not corrupted.
I plug the logger into a USB port but the PC does not indicate an external drive present.	The microSD card is not present in the logger or is not inserted properly. Check that the card is fully inserted into the logger.
	The microSD card is corrupted or damaged. Reformat the card or replace the card.

Problem	Resolution
	The USB connection could be faulty or the extender cable (if present) could be faulty. Remove the extender cable and plug the logger into another USB port.
I press the on/off button but the logger records only for a short period of time.	Check that the battery is fully charged.
	The microSD card is full and data files must be deleted.
The logger seems to ignore the config.txt file and use default settings.	Check that the config.txt file is properly formatted and not corrupted. Each setting should occur on a separate line.
	Some IT organizations implement an automatic encryption of all removable media devices. This will encrypt the config.txt file and the logger will not be able to access the file. Do not allow encryption of the device.
The start time in the data file header is incorrect.	Initialize the RTC.
The logger is exhibiting inconsistent behavior, the LEDs stay on or blink slowly, or the logger does not mount to a PC.	Remove the battery disconnect jumper (see Figure 2), wait 10 seconds, and then replace the jumper. Disconnecting the battery resets the logger but does not affect the files on the microSD card. The RTC will require initialization.
The ADL16 does not start consistently and the data files include invalid time stamps.	The attached sensors are drawing more current than ADL16 can provide, which is causing a "brown-out" of the data acquisition cpu. Try powering the sensors using a separate power supply system.

8 Appendix A: Basic 16-Channel Input Module

The basic 16-channel input module provides convenient screw post terminals for attaching sensors to the ADL16 data logger. This input module does not provide any signal conditioning but includes a simple voltage divider network to adjust the input range to 0 – 5 volts with 100K ohm impedance. Activate the logger "sensorPower" feature and the input module will provide a 5v regulated power source (50mA maximum total current draw).

The input module contains a unique serial number that is read by the logger and stored to the data file header. This maintains traceability of the data file to the specific input module.

The voltage divider network increases the input range to 5 volts and changes the ADL16 sensitivity factor. When converting data, remember to multiply the sensitivity factor by 2. For example, a raw channel value of 1743 counts converts as: 1743 counts * 610uV/count * 2 = 2.126460 volts. Another way to approach the conversion is to divide the range by the resolution: 5 volts / 4096 counts = 1220uV/count. Then, 1743 counts * 1220 uV/count = 2.126460 volts.

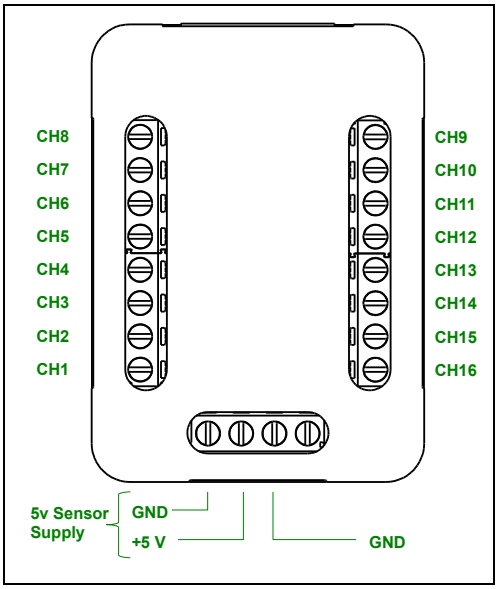

Figure 11: Input Module Channel Layout

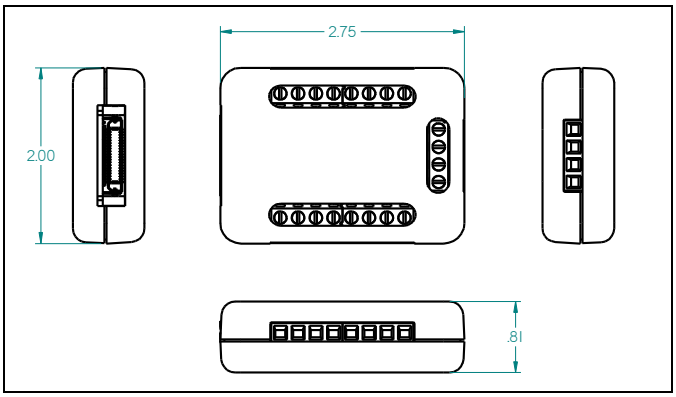

Figure 12: General 16-Channel Input Module Dimensions