

1 Features

- 3-axis accelerometer
- $\pm 500g$, $\pm 250g$, or $\pm 50g$ range
- 14-bit resolution
- User selectable sample rates of 8, 16, 32, 64, 128, 256, and 512
- Internal LiPoly battery charges via USB
- User selectable deadband and trigger
- Accurate (5 PPM) time stamped data using Real Time Clock (RTC)
- Data recorded to a removable microSD card (2GB included)
- Easily readable comma separated text data files
- Data transfer compatible with Windows or Linux via Universal Serial Bus (USB) interface (no special software)
- System appears as USB Mass Storage Device to Windows and Linux OS's.
- Weighs 1.2oz (33g)
- LED indicator lights for system status

2 Applications

The X500-2, X250-2 and X50-2 are applicable to many projects and experiments involving high accelerations:

- Projectile impact studies
- Human trauma monitoring
- Educational purposes

3 Description

The USB Impact Accelerometers provide 14-bit A/D resolution in each of three axes, precise time stamped data logging, microSD memory storage, and easy USB connectivity.

Acceleration is collected in X, Y, and Z axes and stored at a rate of up to 512Hz. When connected via the USB to a personal computer, the data logger appears as a standard mass storage device containing the comma delimited data files and user setup files. The internal lithium-polymer battery charges using the USB power and provides approximately 3 hours of data recording at 512Hz. The data logger is available with 50g, 250g, or 500g sensors.



Figure 1: USB Impact Accelerometer Data Logger

3.1 Operating Instructions

The X500-2, X250-2 and X50-2 are economical solutions for evaluating high g-force events. The system is designed to provide a simple method to gather impact data and quickly deliver the information for analysis. The following instructions outline the steps to begin using the X500-2, X250-2 or X50-2 products. Configuration settings and mounting methods will depend on the particular application.

- Step 1: Ensure the internal lithium-polymer battery is fully charged by plugging the device into a computer USB port. The red LED1 will turn off when the battery is fully charged (see section 3.2.2). In Windows, do not use Notepad as the editor does not terminate new lines properly. GCDC recommends Windows Wordpad to edit the config.txt file.
- Step 2: Configure the device by editing the appropriate tags in the config.txt file. Refer to section 3.2.4 for configuration options.
- Step 3: If necessary, initialize the RTC clock by creating a time.txt file (see section 3.2.6). Setting the RTC ensures that recorded data can be correlated to absolute time.
- Step 4: Unplug the device from the USB port and firmly attach the system to the target object. Depending on the g-force intensity expected, tape, tie-wraps, pipe clamps, or glue are suitable methods of attachment. The 0.75" #6-32 screw can be replaced with a longer screw to firmly attach the enclosure to the target object.
- Step 5: Press the button located at the rear of the enclosure to initiate data recording, (see Figure 2). The red LED1 will blink as the configuration file is accessed. If the time.txt file is present, the RTC is initialized with the time written in the file. Then, the blue LED2 will begin to blink at one second intervals indicating the system is operating. The red LED1 will blink periodically as data is written to the microSD card.
- Step 6: To stop recording, press and hold the button for about 3 seconds. The red LED1 and blue LED2 will blink rapidly for 2 seconds and then turn off. Release the button and the device turns off. Data recording is restarted by pressing the button again (see Step 5).



Figure 2: Starting the Data Logger

3.2 Electrical

3.2.1 Sensor

The X500-2, X250-2, and X50-2 data loggers use analog MEMS accelerometer sensors. The sensors and serial number tags are color coded according to sensor range: 500g – blue; 250g – white (or no color); 50g – red. The logger 15 character serial number starts with CCDC1XXX, where XXX is 500 (500g), or 250 (250g), or 050 (50g). All configurations use a semi-transparent blue plastic enclosure.

The analog sensors commonly exhibit an offset error of 2-3% due to the biased voltage output. Subtract or add the appropriate amount to cancel the offset error and produce an accurate reading throughout the full-scale.

The 250g and 50g versions exhibit a -3db roll off at 400Hz, which means that the signals beyond 400Hz will be attenuated. The 500g sensors have significantly better response capability with a -3db roll off at 32KHz.

Table 1: Accelerometer Sensor Characteristics

Parameter	X500-2			X250-2			X50-2			Units
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Acceleration range		±500			±250			±50		g
Resolution		0.0916			0.0381			0.0080		g/count
Linearity		±0.2	±2.0		±0.2	±2.0		±0.2	±2.0	%FS
-3dB Frequency	32K	32K	32K	360	400	440	360	400	440	Hz

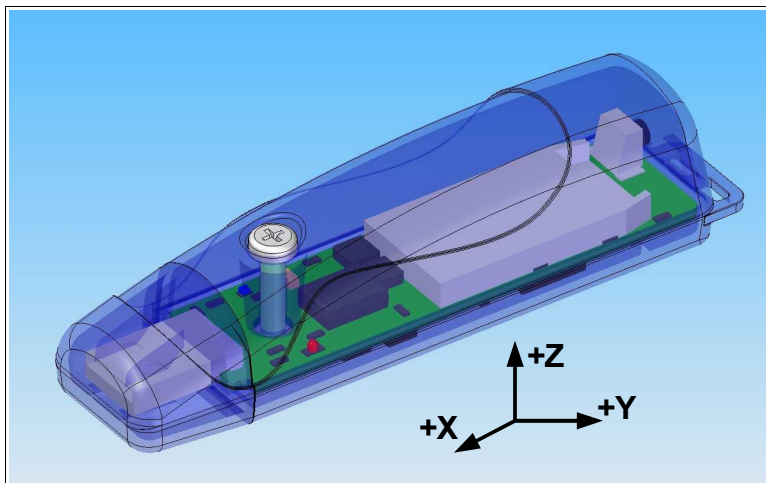


Figure 3: Accelerometer Sensor Orientation

3.2.2 Indicator LEDs

System status is indicated by the two LEDs (see Figure 4). The blue LED2 blinks once per second indicating a properly operating system. The red LED1 will light when the device is connected via the USB and the lithium-polymer battery is charging. The LED charge indicator will turn off when the battery is fully charged. In data logging mode, the red LED1 blinks when data is written or read from the microSD memory card. The period at which the red LED1 blinks depends on the sample rate and other configuration settings. The red LED1 will also blink dimly with USB Human Interface Device (HID) communication activity when connected to a PC. The “statusindicators” tag in the system configuration file turns off or changes the brightness of the LED status indicators (see section 3.2.4.11).

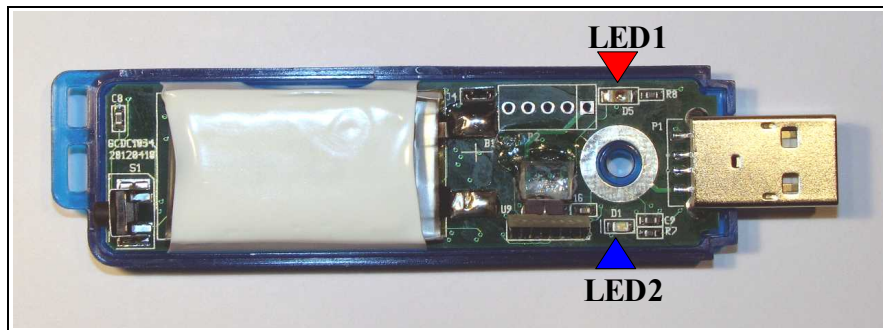


Figure 4: LED Indicators

3.2.3 Battery

The data logger is powered by an internal, hardwired 250mAh lithium-polymer rechargeable battery. The internal battery management system recharges the battery when the device is plugged into a USB port or attached to a USB 5v power adapter. The red LED1 turns on when the battery is charging and off when the battery reaches full charge. The battery provides approximately 3 hours of operation sampling at 512Hz with the deadband set to zero (maximum data recording capability). The battery is not used when the system is connected to a computer USB port. 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. See section 3.2.4.12 for more details.

Remove the two pin connector located near the battery (see Figure 4) to disconnect the battery and reset the device. Resetting the device does not affect data stored on the microSD card.

3.2.4 System Configuration Options

The device 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 2 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 (For Windows systems, *Wordpad* is recommended for editing the config.txt file. *Notepad* does not terminate lines appropriately). 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 2 if the config.txt file is not found.

Table 2: Configuration File Tags and Descriptions

Tag	Valid Settings	Default	Description
deadband	An integer between 0 and 32767	0	Sets the deadband to a range expressed in “counts”. A new sample is recorded if any sensor axis exceeds the previous recorded reading by the deadband value
deadbandtimeout	An integer between 0 and 65535	3	Specifies the period in seconds when a sample is recorded regardless of the deadband setting. This feature ensures periodic data is recorded during very long periods of inactivity.
dwel	An integer between 0 and 65535	1	The number of samples recorded after a deadband threshold triggered event
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.
rtcclocktrim	An integer between -127 and 128	0	Fine adjustment for RTC correction
samplesperfile	An integer greater than 0	28896	The number of lines of data per data file before a new file is created
samplerate	8, 16, 32, 64, 128, 256, 512	256	Sets the rate at which data is collected and recorded to the microSD card.
starttime and stoptime	See section 3.2.4.9	-	Defines when to start and stop recording
stoponusb	-	Off	Stops data logging if 5v USB power is present (see section 3.2.4.10)
statusindicators	“Normal”, “High”, “Off”	Normal	LED status indicators can be activated with normal brightness (Normal), activated with high brightness (High), or completely deactivated (Off).
timeoutonusb	-	Off	Stops USB if no host communications detected (see section 3.2.4.12)

3.2.4.1 deadband

“deadband” defines the minimum difference between recorded sensor readings. A new sample from the accelerometer sensor must exceed the previous recorded reading before the microcontroller records the data. The deadband setting is expressed in "counts" units and is applied to the output of each axis. Table 3 lists the equations necessary to convert a desired g threshold to deadband counts. The deadband value can be set to an integer between 0 and 32767. The deadband function is an effective way to reduce the amount of data collected and extend the system battery life. The deadband functions as a event threshold limit when used in conjunction with the “dwel” feature.

Table 3: Deadband Calculation

Model	Deadband Counts
X500-2	16384*g/1500
X250-2	16384*g/625
X50-2	16384*g/130

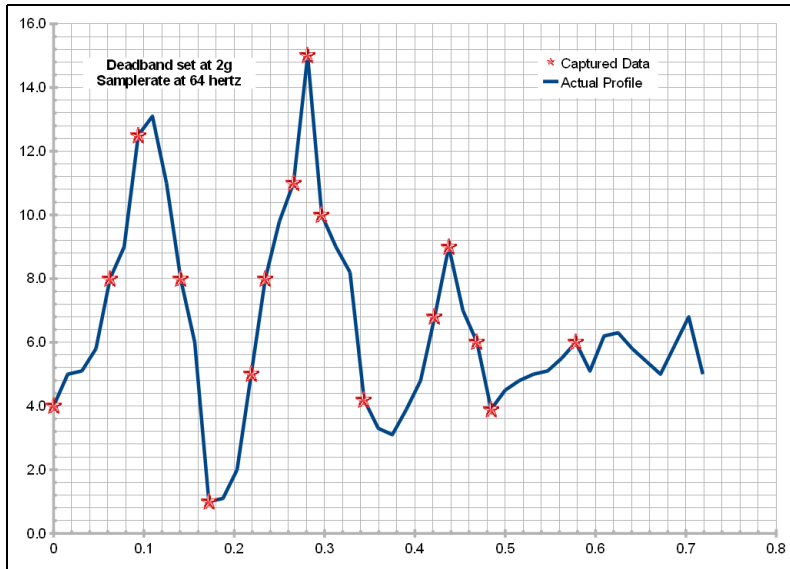


Figure 5: Graphical Illustration of the Deadband Feature

3.2.4.2 deadbandtimeout

“deadbandtimeout” defines the period in seconds when a sample is recorded by the device regardless of the deadband setting. This feature ensures periodic data is recorded during extended periods of inactivity. A valid setting for the deadbandtimeout is an integer between 0 and 65535.

3.2.4.3 dwell

The “dwell” tag defines the number of consecutive samples recorded at the set sample rate after a deadband threshold event. The deadband threshold event occurs when a sensor reading exceeds the last recorded value by the deadband setting. A valid dwell setting is an integer between 0 and 65535.

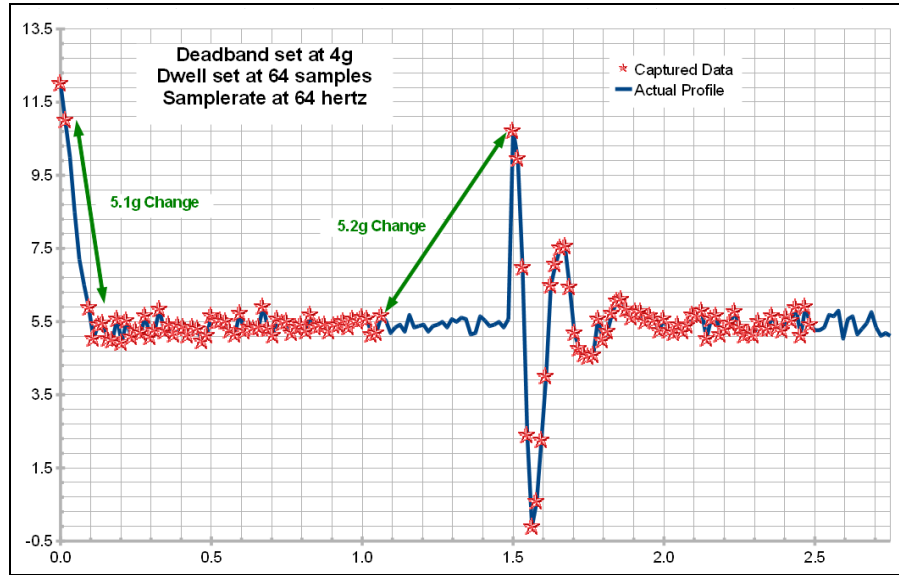


Figure 6: Graphical Illustration of the Dwell Feature

3.2.4.4 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 of 128 hertz or greater to provide the best timing precision.

3.2.4.5 rebootdisconnect

The device incorporates an on/off button for initiating and terminating the data recording process. Data recording automatically starts upon disconnect from a computer USB port if the tag word “rebootdisconnect” is included in the configuration file.

3.2.4.6 rtcclocktrim

The “rtcclocktrim” setting adjusts the RTC oscillator frequency. Positive values increase the oscillation period (lower frequency) and negative values decrease the oscillation period (higher frequency). A valid setting is an integer between -127 and 128. By default, the RTC provides +/- 2ppm (parts per million) precision between 0°C and 40°C. This feature should be used by advanced users only.

3.2.4.7 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. The user should exercise caution before setting large files and test the end-user application for data limitations. Users should limit the maximum file size to no more than 500000 lines.

3.2.4.8 samplerate

The “samplerate” tag defines the interval that data is recorded in Hertz, or samples per second. Valid sample rate settings are 8, 16, 32, 64, 128, 256 and 512 Hz. At 128 Hz or greater, the configuration file should also include the “microres” tag to provide the best timing precision (see section 3.2.4.4).

A short data drop out occurs when a new memory cluster is allocated on the microSD card. The data drop is more likely to occur with sample rates above 128Hz. Periodically remove old data files or reformat the microSD card to help reduce the memory allocation delays (see section 3.2.7).

3.2.4.9 starttime and stoptime

The device 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 device 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 *
```

3.2.4.10 stoponvusb

The “stoponvusb” tag stops data logging operations when a 5v supply is detected on the USB connector. By default, the device switches power from the internal battery to the USB 5v and continues to log data.

3.2.4.11 statusindicators

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

3.2.4.12 timeoutonusb

The “timeoutonusb” tag returns the microprocessor to normal operating speed if no USB communications are detected within 7 seconds after connection to a USB port. This reduces the power requirements when operated from an external 5v USB supply. By default, the microprocessor continues at high-speed mode waiting for USB communications. Utilize the timeoutonusb feature when operating the device from an external 5v USB battery pack.

3.2.4.13 Example Configuration Files

The following example configurations use the X250-2 model to describe the basic features of the data logger. The concepts are also applicable to the X500-2 and X50-2 models but the specific settings reference the X250-2 model.

Example A) The following configuration records data constantly at 256 hertz. The device will initiate data logging with a press of the on/off button. Data files are 50,000 lines long or about 3 minutes each.

```
; example X250-2 config file
; set to record constantly at 256Hz
samplerate = 256
deadband = 0
deadbandtimeout = 0
; set file length
samplesperfile = 50000
; status LEDs
statusindicators = normal
```

Figure 7: Configuration File Example A

Example B) The device will record 3 seconds of data at 512hz if motion above 20g is detected on any axis. A data sample is recorded every 5 minutes. The X250-2 boots and begins operation once disconnected from a host USB port.

```
; example X250-2 config file
; set sample rate to 512Hz
samplerate = 512
; maximum timing resolution
microres
; set threshold > 20g
; record 3 seconds of data
deadband = 320
dwell = 1536
; force a write every 5 minutes
deadbandtimeout = 300
; set file length
samplesperfile = 30000
; make device start upon USB disconnect
rebootondisconnect
```

Figure 8: Configuration File Example B

3.2.5 Data Files

Data is written to files in comma separated text format starting with the file header information and followed by data entries. The header describes the system configuration, firmware version, and the precise time when the file was created. Each header line is preceded with a semicolon (“;”). Table 5 lists the valid header tags. Data entries include a time stamp and the raw accelerometer sensor readings from the X, Y, and Z axes. The time stamp is seconds elapsed from the start time recorded in the header. The raw sensor data format is signed digital “counts” from the A/D converter. Table 4 lists the equations for converting the counts data into g (standard acceleration of gravity).

The device 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 device 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. Figure 9 represents an example data file.

USB Impact Accelerometer Models X500-2, X250-2, X50-2

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 (“;”).

```
;Title, http://www.gcdataconcepts.com, x50-2, AD22280
;version, 1540, Build num, 0x41F, Build date, 20130219 12:38:11, SN:CCDC10501206041
;start_time, 2013-02-20, 09:39:40.294
;Switch, unknown
;Temperature, 25.25, deg c, vbat, 3973, mv
;SampleRate, 128, Hz
;Deadband, 0, counts
;DeadbandTimeout, 0, sec
;Headers, time, Ax, Ay, Az
0.968, -9, -4, -121
0.975, -25, -13, -109
0.983, -17, -15, -106
0.991, -18, -15, -113
0.998, -18, -23, -112
1.005, -15, -24, -117
1.012, -24, -24, -108
1.020, -12, -20, -105
1.027, -22, -13, -108
1.035, -9, -7, -121
1.042, -4, -5, -127
1.050, 2, 2, -130
1.058, -18, -11, -108
1.065, -31, -17, -107
```

Figure 9: Example Data File

Table 4: Converting Raw Counts Data to g Units

Model	g
X500-2	(counts) * 1500 / 16384
X250-2	(counts) * 625 / 16384
X50-2	(counts) * 130 / 16384

Table 5: Data File Header Tags

Tag	Description
Deadband	A new sample from the sensor must exceed the last reading by the deadband value
DeadbandTimeout	The period in seconds when a sample is recorded regardless of the deadband setting
Decimate	See section 5
Dwell	The number of samples recorded after a threshold event
Headers	The names of each column of data in the file
SampleRate	Rate at which data is recorded to the microSD card
Start Time	The current time when the data file was created
Switch	Auxiliary digital input (not used)
Temperature	Temperature of sensor in °C when data file was created
Title	The name of the USB Accelerometer unit
Vbat	Battery voltage measured at the start time
Version	The version control information of the firmware, including unique serial number

3.2.6 Real Time Clock

A real time clock (RTC) is used to determine time for each line of data recorded. Initializing the RTC ensures that the start time and individual time stamps can be correlated to an absolute time. An uninitialized or reset RTC defaults to the first day of the year 1900.

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

The RTC maintains ± 5 ppm accuracy (0°C to +40°C) and is powered by the lithium-polymer battery or the USB power when available. The RTC also provides the system temperature (°C) recorded to the header of each data file.

3.2.7 Memory Card

The device stores data to a removable microSD flash memory card. The system is compatible with microSD and microSDHC cards up to 2GB in size. The device will create a folder called “GCDC”, if not already present, to place the data files (see section 3.2.5). The “config.txt” and “time.txt” files must occur in the root directory (see section 3.2.4 and section 3.2.6). The data logger functions as a Mass Storage Device to computer operating systems when transferring data to and from the microSD memory card.

The microSD card included with the data logger performs as a Class 4 card. Faster cards (high class rating) will improve performance slightly but the overall logging rate is limited to the micro-controller and data bus to the microSD card. Occasional write delays are caused by new memory allocations on the card, which can cause data drops. Best performance is maintained by periodically clearing old data files, defragmenting the card, or reformatting the card.

The memory card must be formatted to FAT16 for proper operation of the data logger, which limits the maximum memory space to 2GB. Using Windows, the card must be formatted using the “FAT” file system and the default allocation size.

3.3 Mechanical

The electronics are enclosed in a three-part semi-transparent blue plastic enclosure. The top and bottom enclosure components and the printed circuit board are secured together with a 0.75" long #6-32 screw and nut. Longer screw lengths can facilitate attachment of the data logger to other structures. A slip-on cap protects the USB connector. The device weighs 1.2oz (33g).

3.3.1 Dimensions

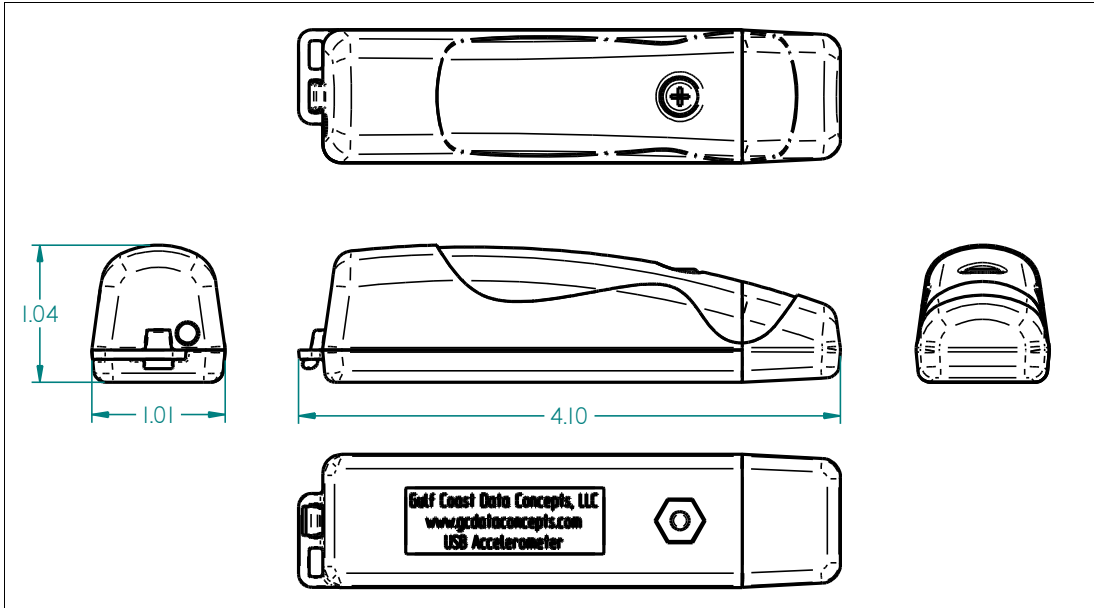


Figure 10: Enclosure Dimensions

3.3.2 Assembly

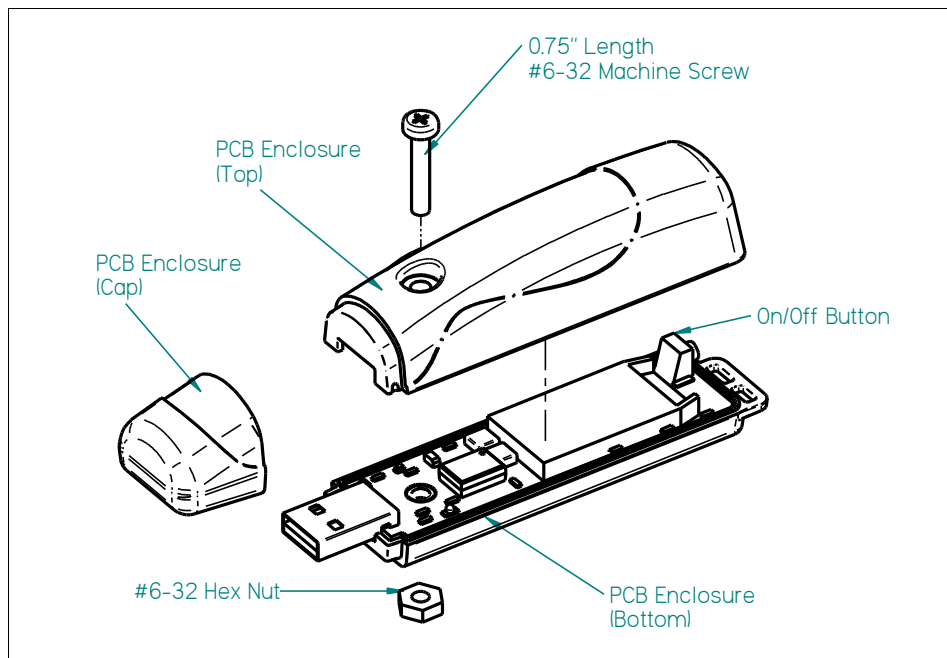


Figure 11: Exploded View of USB Impact Accelerometer

4 Software

The device records data to comma delimited text files and uses text based files for configuration settings. Therefore, no special software is required to utilize the data loggers. However, Gulf Coast Data Concepts provides the Java based software program *XLR8R* that allows easy visual presentation of the data, copy-paste export of data segments, as well as configuration file and time file creation utilities. *XLR8R* is included on the microSD card of each unit or can be downloaded from the website at www.gcdataconcepts.com. 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.

5 Special Experimental Features

The microprocessor samples the accelerometer sensors at 16 times the requested rate using a 10-bit AD converter. For example, at 512Hz the sensor is actually sampled at 8192Hz. The data is summed and decimated by a factor of 16. This increases the sample resolution to 14-bit. The data logger can be configured with a smaller decimation factor. This effectively increases the recorded sample rate at the cost of resolution. The decimation rate is controlled by adding "decimate = X" in the configuration file, where "X" is a value of 16, 8, 4, or 2. For example, a decimate factor of 8 reduces the resolution to 13-bit but doubles the sample rate to 1024 hertz. Note that the data file will show "SampleRate, 512, Hz" and "Decimation, 8" (the timing values will be 1024 hertz). Since the decimation factor affects the resolution, the conversion equations also change.

Table 6: Decimation Factors

Decimate Factor	Selected Sample Rate	Effective Sample Rate	Bit Resolution	g
16	512	512	14	(counts) * FS / 16384
8	512	1024	13	(counts) * FS / 8192
4	512	2048	12	(counts) * FS / 4096
2	512	4096	11	(counts) * FS / 2048

FS=1500 for X500-2, FS=625 for X250-2, FS=130 for X50-2

The microprocessor is limited by the small memory cache so the data will not stream continuously at these high rates. The data will burst with about 16 samples. However, the decimate feature will allow the data logger to function as a peak recorder with up to a 4K sample rate. Decimation factors of 8 and 4 usually work well depending on the quality of the microSD card. However, at decimation of 2 the microSD card will fault on most units and the data logger will not operate. The decimate feature is considered an experimental configuration option.

```
; example X500-1 config file
; implementing the decimate feature
; set sample rate to 512 Hz
samplerate = 512
; change the decimate factor
; effective sample rate is 2048
decimate = 4
; set threshold to >20g
; note that resolution is 13bit
; so deadband calculated with 4096
deadband = 55
; record 32 samples
dwell = 32
; force a write every 5 minutes
DeadBandTimeout = 300
; set file size
samplesperfile = 20000
; activate LEDs
statusindicators = Normal
```

Figure 12: Example Configuration Using Decimate Feature

The X500-2 configuration in Figure 12 will record 32 samples at 2048Hz once a 20g threshold is detected on any axis. The micro-resolution is not activated so fewer characters are written to the microSD card. Furthermore, the 0.1ms precision micro-resolution is not adequate to measure a 2048Hz sample rate (0.48ms period). In the case of such fast data rates, it is better to reduce the character stream and assume the recorded sample rate is accurate.