

### 1 Features

- 3-axis accelerometer
- $\pm 250g$  range in each axis
- 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 setting
- Accurate (2 PPM) time stamped data using Real Time Clock (RTC)
- Data recorded to a removable microSD card (1GB 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.
- Real-time data acquisition via Human Interface Device (HID) access (Beta)
- LED indicator lights for system status

### 2 Applications

The X250-1 is applicable to:

- Projectile impact studies
- Human trauma monitoring
- Educational purposes

### 3 Description

The USB Impact Accelerometer Model X250-1 uses an 8051 8-bit microcontroller incorporating 14-bit A/D resolution, precise time stamped data logging, microSD memory storage, real-time data access and 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 X250-1 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.

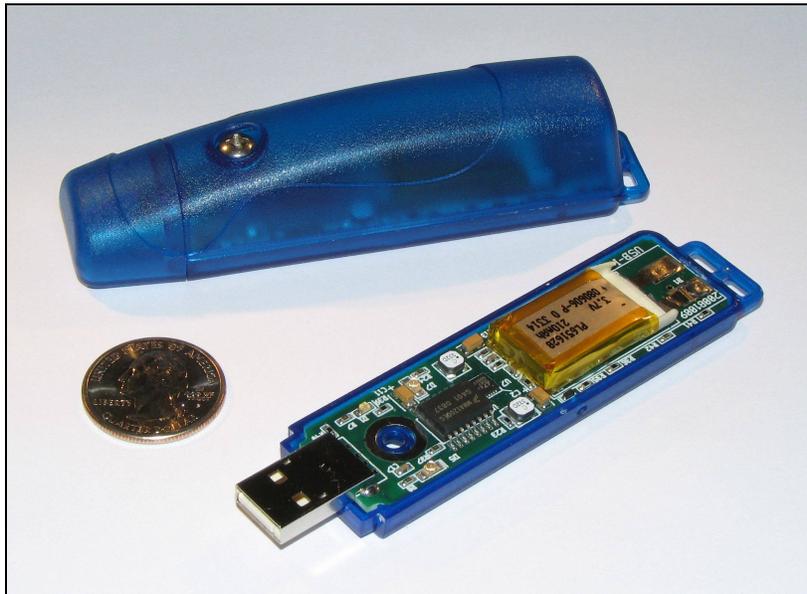


Figure 1: X250-1

## 3.1 Operating Instructions

The X250-1 is an economical solution 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 X250-1. Configuration settings and mounting methods will depend on the particular application.

- Step 1: Ensure the internal Li-Po battery is fully charged by plugging the X250-1 into a computer USB port. The red LED3 will turn off when the battery is fully charged (see section 3.2.3).
- Step 2: Configure the X250-1 by editing the appropriate tags in the config.txt file. Choose faster sample rates to capture fast impact events. Setting the deadband will filter small sensor readings, reduce the number of write operations to the microSD card, and extend the battery life. For example, a deadband of 130 will cause the X250-1 to record g-force changes greater than 5g – other events, such as sitting at rest, will be ignored. 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).
- Step 4: Unplug the X250-1 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 X250-1 enclosure to the target object.
- Step 5: To initiate data recording, use a small stylus to gently press the button located on the side. A ballpoint pen, paper clip, toothpick or similar device will access the button through the 0.090” diameter hole (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 a 2 second interval indicating the system is recording data. The red LED1 will blink periodically as data is written to the microSD card.
- Step 6: To stop recording, use a small stylus to gently press and hold the on/off button for about 3 seconds. The blue LED2 will begin to blink rapidly for 2 seconds then stay on for a brief moment. Release the stylus from the button and the X250-1 turns off. Data recording is restarted by pressing the button again (see Step 5).



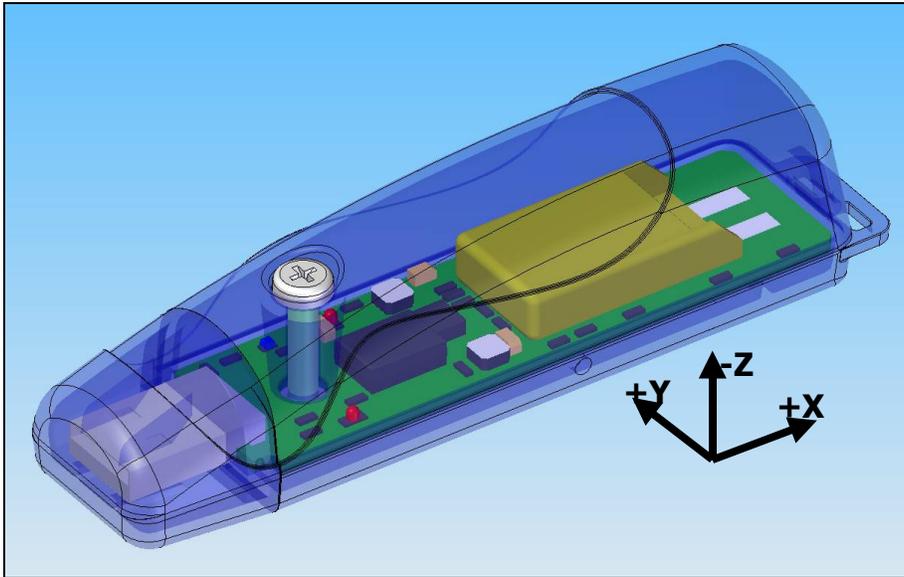
Figure 2: Starting the X250-1

## 3.2 Electrical

### 3.2.1 Sensor

Table 1: Accelerometer Sensor Characteristics

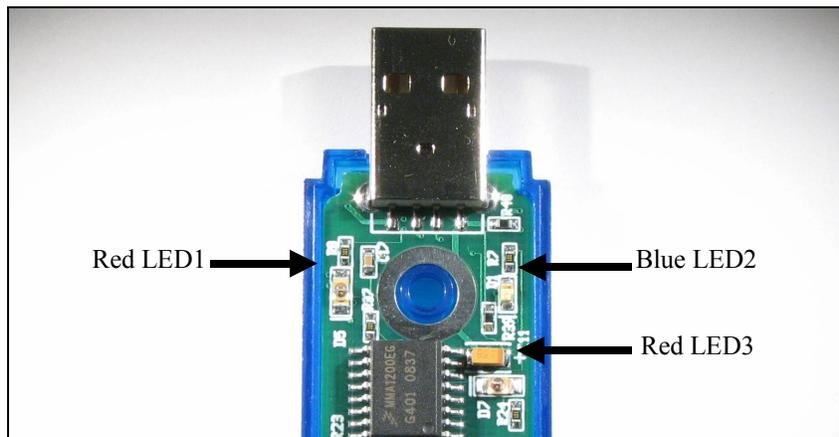
Parameter	Condition	Min	Typical	Max	Units
Acceleration range			±250		g
Resolution	Counts output		0.0381		g/count
Linearity	X, Y axis		±0.2	±2.0	%
	Z axis	-2.0		+2.0	%FS
Sensing Element Resonant Frequency	X, Y axis		24		KHz
	Z axis		10		KHz



**Figure 3: Accelerometer Sensor Orientation**

### 3.2.2 Indicator LEDs

System status is indicated by the three LEDs located near the USB connector (see Figure 4). The red LED1 blinks when data is written or read from the microSD memory card or when HID communications occur. In data logging mode, the period at which the red LED1 blinks depends on the deadband setting. The blue LED2 indicates system operation. A steady blinking blue LED2, approximately once per two seconds, indicates a properly operating system. The blue LED2 blinks once per second when the USB Impact Accelerometer is connected to a computer via the USB port. The red LED3 is the charge indicator and will light when the X250-1 is connected via the USB and the lithium-polymer battery is charging. The charge indicator will turn off when the battery is fully charged. The “statusindicators” tag in the system configuration file turns off or changes the brightness of the LED status indicators (see Table 2).



**Figure 4: LED Indicators**

## 3.2.3 Battery

The X250-1 is powered by a internal, hardwired 210mAh lithium-polymer rechargeable battery. The internal battery management system recharges the battery when the X250-1 is plugged into a USB port. The red LED3 turns on when the battery is charging and off when the battery reaches full charge (see Figure 4). The battery provides approximately 3 hours of operation sampling at 512Hz with the deadband set to zero (maximum data recording capability). Greater operating times are achieved with slower sample rates and appropriate use of the deadband limit. The battery is not used when the system is connected to a computer USB port. USB communication activity halts the data recording. Therefore, extended operation is achieved by connecting a 5V supply via the USB connector (such as a personal electronics USB charger).

## 3.2.4 System Configuration Options

The X250-1 is configured using a set of tags and settings stored in a file named “config.txt”, which is located in the root directory of the microSD card. The system reads the configuration file each at boot time. Table 2 lists the configuration file keywords. Lines starting with a semicolon (“;”) are treated as comments and ignored by the system. Figure 5 illustrates an example configuration file. The system will use the default settings listed in Table 2 if the config.txt file is not found.

### 3.2.4.1 Deadband

“deadband” defines the difference between g-forces that must be present before the unit records another piece of data. This is used to reduce the number of data samples. Input numbers for the “deadband” command are in counts. To convert desired g-force deadband setting into counts, use the following formula:

$$8192+(16384\times G\text{-force})/625=\text{Counts}$$

### 3.2.4.2 Deadband Timeout

“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 very long periods of inactivity.

### 3.2.4.3 Reboot on Disconnect

The X250-1 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. Note that the system must first be turned on and the configuration file read before the rebootOnDisconnect option is implemented by the system. Subsequent disconnects will then cause a reboot and immediate data recording.

### 3.2.4.4 Samples Per File

“samplesPerFile” defines the number of lines each data 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.

### 3.2.4.5 Sample Rate

The “sampleRate” tag defines the interval in Hertz that a data sample is recorded. For example, a sample period of 128 means data is recorded 128 times a second.

**Table 2: Configuration File Tags and Descriptions**

Tag	Valid Settings	Default	Description
deadband	An integer between 0 and 8192	80	Sets the deadband to a range expressed in “counts”. Full scale (500g) is 16384 counts. A new sample is recorded if any sensor axis exceeds the previous reading by the deadband value
deadbandtimeout	An integer between 0 and 60	0	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.
rebootOnDisconnect		Turn off on disconnect	The presence of this tag causes the system to start recording after disconnect from a USB port.
samplesperfile	An integer between 100 and 200,000	76,800	The number of lines of data per data file before a new file is created
samplerate	8, 16, 32, 64, 128, 256, or 512	256	Sets the rate at which data is collected and recorded to the microSD card
startTime	See section 3.2.4.6	-	Defines when to start recording
stopTime	See section 3.2.4.6	-	Defines when to stop recording
Statusindicators	“Normal”, “High”, “Off”	Normal	LED status indicators can be activated with normal brightness (Normal), activated with high brightness (High), or completely deactivated (Off).

### 3.2.4.6 Start Time and Stop Time

The X250-1 starts and stops data recording based on the times defined using the “starttime” and “stoptime” tags. The times must be in “MM HH” 24-hr format. Entries marked with “\*” are ignored, or operate as a wild card. Example timing configurations:

**Example 1:** Start recording at 12:30pm and stop recording at 6:00pm.

```
startTime = 30 12  
stopTime = 00 18
```

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

```
startTime = 00 *  
stopTime = 45 *
```

### 3.2.4.7 Status Indicators

The brightness intensity of the LED status indicators is defined using the “statusIndicators” tag and valid settings of “Normal”, “High”, and “Off”.

```
;PRODUCT_ID = X250-1  
; this is an example config file  
; deadband of 130 ingores changes less than 5g  
deadband = 130  
DeadBandTimeout = 5  
samplesperfile = 50000  
statusindicators = Normal  
SampleRate = 512
```

**Figure 5: Example Configuration File**

### 3.2.5 Data Files

A new data file is created 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 system reset switch is pressed. 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. Table 3 lists the valid header tags, although not all tags may occur in the header.

Data is written to the file in comma separated text format starting with the time entry. Each line represents a data event and ends with a newline character. The time entry is in seconds elapsed since the start time recorded in the header. The digital count reading from the X, Y, and Z axes are recorded after the time. Figure 6 represents an example data file. Equation 1 converts the raw data into g-force using the nominal characteristics of the sensor system.

$$Gforce = (counts - 8192) * 625 / 16384 \qquad \text{Equation 1}$$

**Table 3: 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
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
TEMPERATURE	Temperature of sensor in °C when data file was created
TITLE	The name of the USB Impact Accelerometer X250-1 unit
VERSION	The version control information of the USB Impact Accelerometer firmware

```

;Title, http://www.gcdataconcepts.com, X250-1
;Version, 276:402M, Build num, 0x15D, Build date, 20090114 11:15:58, SN:CCDC120100843
;Start_time, 2009-01-14, 20:22:35.000
;Temperature, 23.50, deg C
;SampleRate, 512,Hz
;Deadband, 165
;Headers, time,Ax,Ay,Az
0.000,4007,3997,3873
0.117,3943,4187,3961
0.121,4051,3989,3879
6.757,3882,3984,3873
6.825,4065,3972,3921
6.926,3900,3967,3882
6.996,4066,3956,3938
7.096,3892,3964,3863
7.165,4074,3956,3926
7.261,3903,3955,3873
7.333,4084,3964,3925
7.362,4254,4034,3949
7.387,4082,4019,3938
    
```

**Figure 6: Example Data File**

**3.2.6 Real Time Clock**

A real time clock (RTC) is integrated into X250-1 system and is used to determine time for each line of data recorded. The RTC maintains  $\pm 2$ ppm accuracy (0°C to +40°C).

The RTC is set using a text file named “time.txt” located in the root directory of the microSD card. The X250-1 system looks for the time.txt file during the boot sequence. If the file exists, the time written 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 any special communication drivers to the device so it can be implemented using any text editor. Direct initialization of the RTC is possible but requires specific device drivers from Gulf Coast Data Concepts.

## 3.2.7 Memory Card

The X250-1 stores data to a removable microSD flash memory card. If a new memory card is used, it must be formatted to FAT16 for proper operation of the X250-1. Under Windows XP, the card must be formatted using the “FAT” file system and the default allocation size. Do not select “Quick Format” or “FAT32”. The X250-1 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 X250-1 functions as a Mass Storage Device to computer operating systems when transferring data to and from the microSD memory card.

## 3.3 Mechanical

The electronics are enclosed in a three-part plastic enclosure. The semi-transparent blue colored ABS plastic allows attenuated sight of the three indicator LEDs. 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 X250-1 to other structures. A slip-on cap protects the USB connector.

### 3.3.1 Dimensions

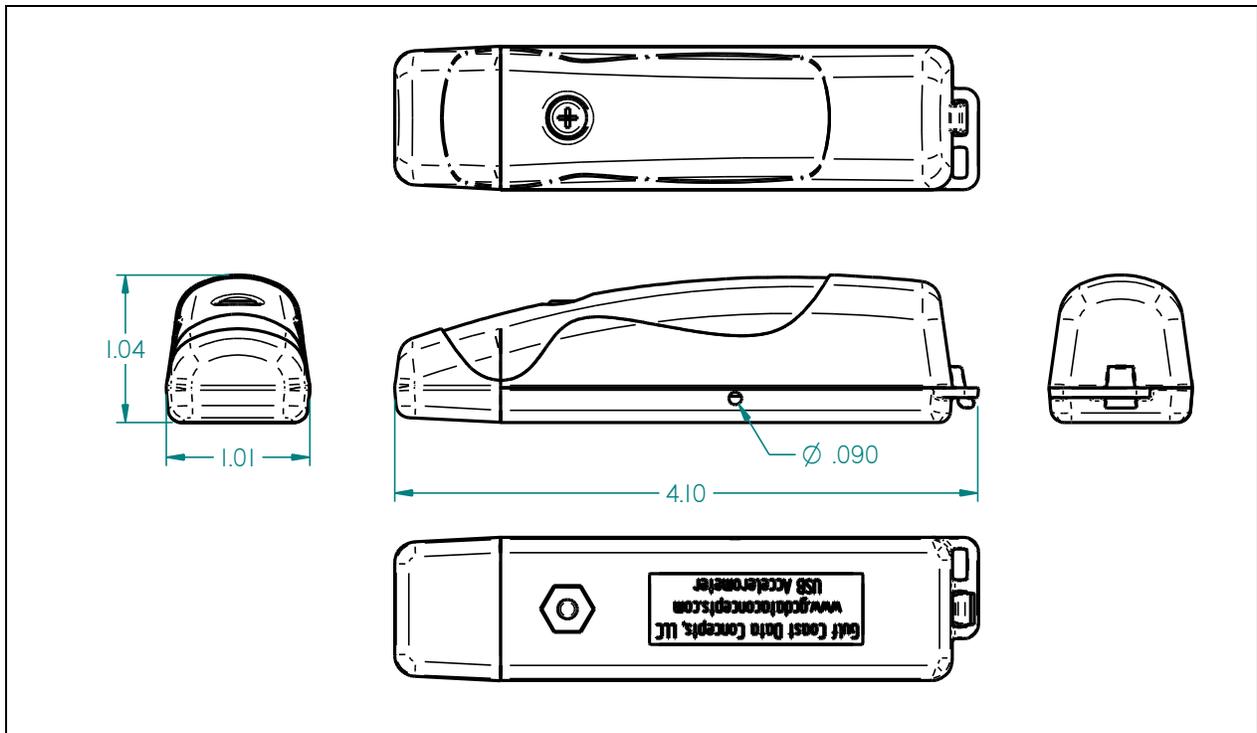
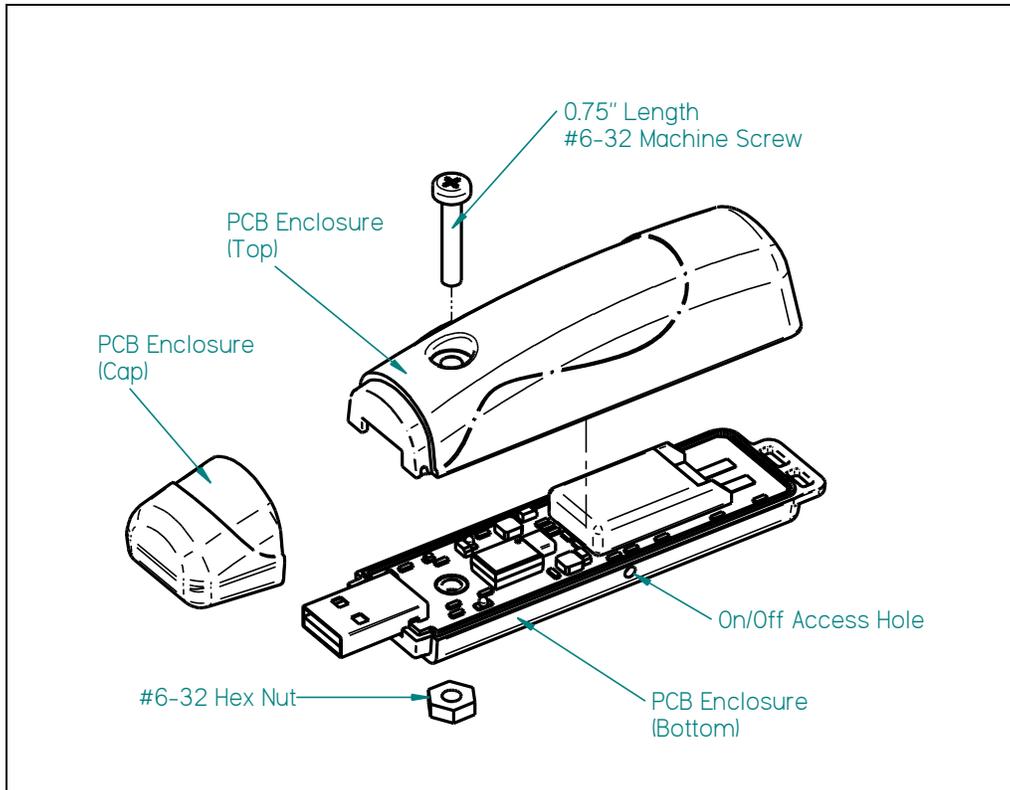


Figure 7: Enclosure Dimensions

## 3.3.2 Assembly



**Figure 8: Exploded View of USB Impact Accelerometer**

## 4 Software

The USB Impact Accelerometer X250-1 records data to comma delimited text files and uses text based files for configuration settings. Therefore, no special software is required to utilize the X250-1. 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 X250-1 unit or can be downloaded from the website at [www.gcdadataconcepts.com](http://www.gcdadataconcepts.com). For data analysis, Gulf Coast Data Concepts recommends using a commercial or open source mathematics package, such as MathCAD, Microsoft Excel, Octave, R, S, or similar applications.