

### 1 Features

- 3-axis accelerometer
- Single gain mode set to +/-16g
- 15-bit resolution
- User selectable sample rate of 12, 25, 50, 100, 200, and 400 Hertz
- Internal Li-Poly battery charges via USB
- Accurate time stamped data using Real Time Clock (RTC)
- User selectable deadband setting
- Convenient on/off button
- 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.
- LED indicator lights for system status
- Weighs 1.3oz (48g)

### 2 Applications

The X16-2 is applicable to:

- Continuous time stamped shock and motion monitoring of critical freight.
- Monitoring human motor activity, or actigraphy, such as exercise intensity or sleeping disorders.
- Vibration monitoring
- Educational purposes

### 3 Description

The USB Accelerometer X16-2 uses a low noise digital 3-axis accelerometer, 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 user selectable rate of up to 400Hz. When connected via the USB to a personal computer, the X16-2 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 36 hours of data recording at 200Hz.



Figure 1: X16-2

### 3.1 Operating Instructions

The X16-2 is a simple, economical solution to capture continuous motion data and quickly deliver the information for analysis. The following instructions outline the steps to begin using the X16-2. 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 X16-2 into a computer USB port. The red LED will turn off when the battery is fully charged (see section 3.2.3).
- Step 2: Configure the X16-2 by editing the appropriate tags in the config.txt file. Choose faster sample rates to capture rapidly changing events. Use high gain 16-bit modes to monitor very small motion or vibration. Refer to section 3.2.4 for a complete list of 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 X16-2 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 X16-2 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 LED 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 1 second interval 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 LED and blue LED will blink rapidly for 2 seconds and then turn off. Release the button and the X16-2 turns off. Data recording is restarted by pressing the button again (see Step 5).

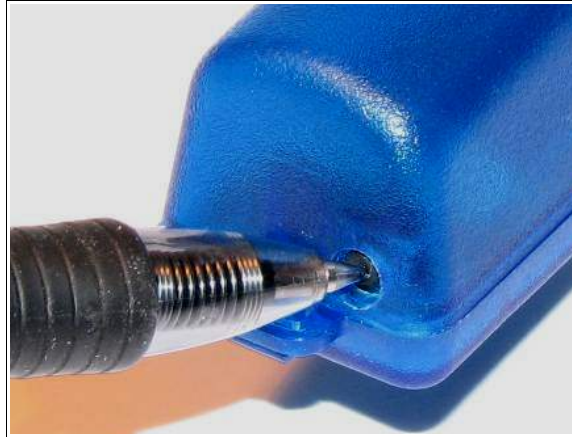


Figure 2: Starting the X16-2

### 3.2 Electrical

#### 3.2.1 Sensor

Table 1: Accelerometer Sensor Characteristics

Parameter	Condition	Min	Typical	Max	Units
Acceleration range			±16.0		g
Resolution			0.001		g/count
Linearity	X, Y, Z axis		±1		%FS
Zero-g Offset Level Accuracy	X, Y axis	-150		+150	mg
	Z axis	-250		+250	mg
Inter-Axis Alignment Error			±0.1		Degrees
Cross-Axis Sensitivity			±1		%

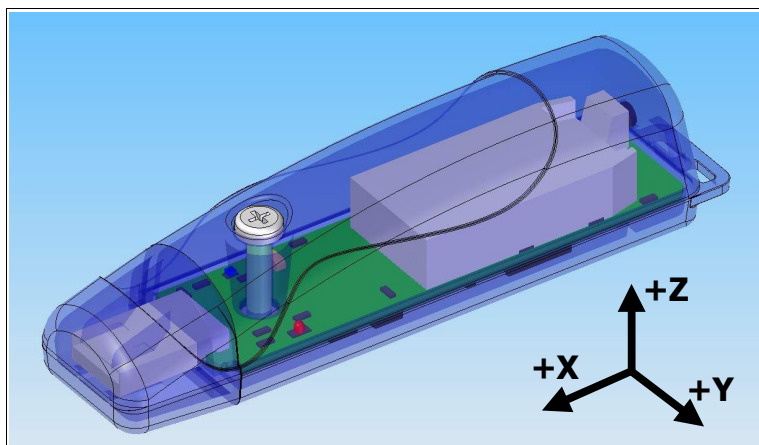
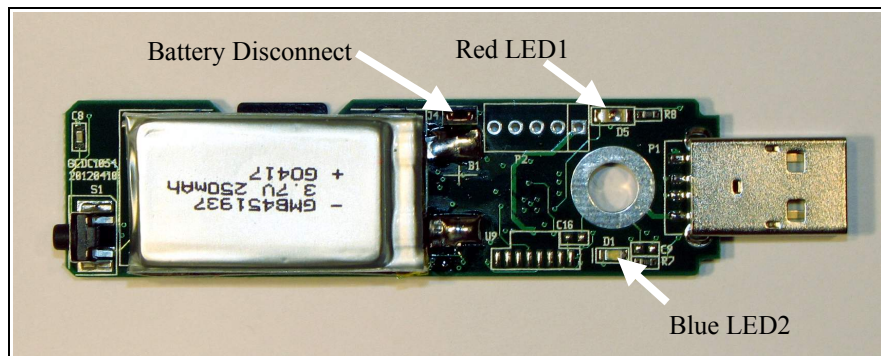


Figure 3: X16-2 Accelerometer Sensor Orientation

### 3.2.2 Indicator LEDs

System status is indicated by the two LEDs (see Figure 4). The blue LED blinks once per second indicating a properly operating system. The red LED blinks when data is written or read from the microSD memory card. In data logging mode, the period at which the red LED blinks depends on the sample rate and other configuration settings. The red LED also functions as the charge indicator and will light when the lithium-polymer battery is charging. The charge indicator status will turn off when the battery is fully charged. Note that the red LED may blink with data transfers after 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 section 3.2.4.11).



**Figure 4: LED Indicators**

### 3.2.3 Battery

The X16-2 is powered by a internal, hardwired 500mAh lithium-polymer rechargeable battery. The internal battery management system recharges the battery when the X16-2 is plugged into a USB port or attached to a USB 5v power adapter. The red LED turns on when the battery is charging and off when the battery reaches full charge. The battery provides approximately 36 hours of operation sampling at 320Hz 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. 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.

### 3.2.4 System Configuration Options

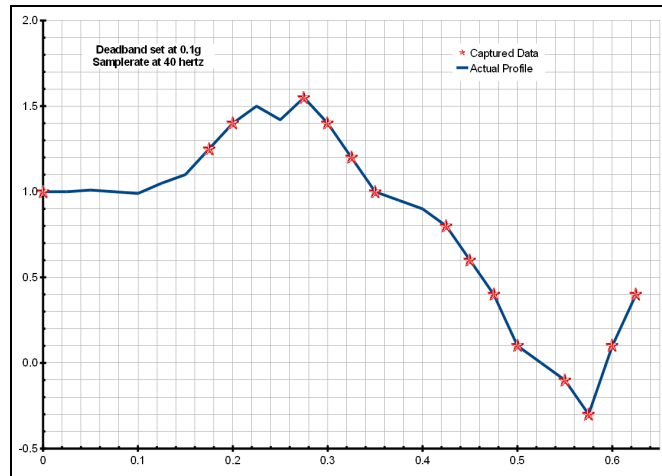
The X16-2 is configured using a set of tags and settings stored in a text file named “config.txt”, which is located in the root directory of the microSD card. The system reads the configuration file at boot time. Table 2 lists the configuration file tags. A tag is followed by an equal sign (“=”) and an applicable tag setting. A line finishes with a newline character (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 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	12, 25, 50, 100, 200, 400	25	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
stoponvusb	-	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. There are 1024 counts per g. 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 “dwell” feature.



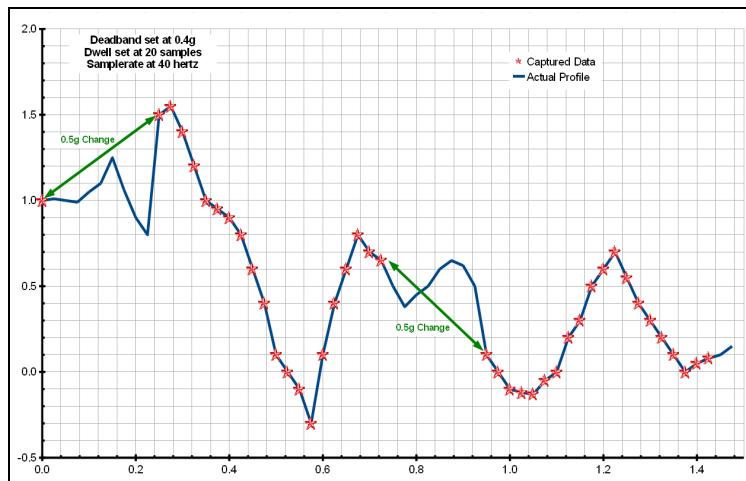
**Figure 5: Graphical Illustration of the Deadband Feature**

### 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 micros

The “micros” option sets the device to record time stamps with 0.1ms precision. In micro-resolution mode, the time stamps are recorded as XX.YYYYYZZ 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 80 hertz or greater to provide the best timing precision. The power saving features of the X16-2 are disabled in micro-resolution mode and battery life is shortened accordingly.

### 3.2.4.5 rebootondisconnect

The X16-2 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.

### 3.2.4.6 rtclocktrim

The “rtcclcocktrim” 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. 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.

### 3.2.4.8 samplerate

The “samplerate” tag defines the data rate in Hertz, or samples per second. Valid sample rate settings are 12, 25, 50, 100, 200, and 400 Hz. At 100 Hz or greater, the configuration file should also include the “microres” tag to provide the best timing precision (see section 3.2.4.4).

### 3.2.4.9 starttime and stoptime

The X16-2 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 X16-2 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 15<sup>th</sup> 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

Example A) The following configuration records data constantly at 25 hertz. The device will boot and begin logging data once removed from a computer USB port. Each data file is 37,500 lines long, which is 25 minutes.

```
; Example X16-2 Config file
; set to record constantly at 25Hz
samplerate = 25
deadband = 0
; set file length
samplesperfile = 37500
; make device start upon USB disconnect
rebootondisconnect
```

**Figure 7: Configuration File Example A**

Example B) Setting the deadband to 50 counts at high gain causes the device to record only changes greater than 0.05g. The deadbandtimeout setting forces a sample write every 60 seconds. Status indicators will turn off about 10 seconds after the device turns on.

```
; Example X16-2 Config file
; set to record constantly at 50Hz
samplerate = 50
; record motion >0.05g
deadband = 50
; force a write operation every minute
deadbandtimeout = 60
; set file length 30min
samplesperfile = 90000
; turn off LEDs
statusindicators = off
```

**Figure 8: Configuration File Example B**



Example C) The micro-resolution is activated to provide the best timing precision at the 100 Hz sample rate. If motion exceeds 0.1g (100 counts), the device captures continuous data 100 times a second for 2 seconds or until the change in acceleration falls below 0.1g. The `timeoutonusb` option reduces the system power requirements while connected an external 5v USB battery pack.

```
; Example X16-2 Config file
; set to record constantly at 100Hz
samplerate = 100
; turn on micro-resolution
microres
; set threshold >0.1g
; record 2 seconds of data
deadband = 100
dwell = 200
; force write every 5 minutes
deadbandtimeout = 300
; set file length
samplesperfile = 30000
; use external 5v USB battery
timeoutonusb
```

**Figure 9: Configuration File Example C**

### 3.2.5 Data Files

The X16-2 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 X16-2 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. Figure 9 represents an example data file.

#### 3.2.5.1 Format and Data Conversion

Data is written to files in comma separated text format starting with the file header information and followed by event data entries. Each data line contains a time entry and the raw accelerometer sensor readings from the X, Y, and Z axes. The time entry is in seconds past the start time recorded in the header. The raw sensor data format is signed digital “counts”. The raw counts are converted to “g” by dividing the value by 1024. Table 3 lists the valid header tags, although not all tags may occur in the header.

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, X6-2
;Version, 1000, Build num, 0x97C, Build date, 20101019 12:15:20, SN:CCDC22010123767
;Start_time, 2010-11-02, 20:10:41.004
;Switch, Unknown
;Temperature, 26.75, deg C, Vbat, 3945, mv
;Gain, high
;SampleRate, 40,Hz
;Deadband, 50, counts
;DeadbandTimeout, 60,sec
;Headers, time,Ax,Ay,Az
1.739,59,29,-636
1.765,151,305,-1838
1.790,-61,221,-1651
1.816,108,388,-1520
1.841,101,330,-311
1.867,387,203,-484
1.892,178,214,-461
1.918,75,18,-1137
1.943,90,343,-1887
1.969,19,236,-1642
2.002,75,485,-919
    
```

**Figure 10: Example Data File**

**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
Dwell	The number of samples recorded after a threshold event
Gain	Specifies sensor sensitivity of 16g
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 Accelerometer X16-2 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 integrated into the X16-2 and 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 any text editor. Direct initialization of the RTC is possible but requires specific device drivers from Gulf Coast Data Concepts.

The RTC maintains  $\pm 5$ ppm accuracy ( $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ ) and is powered by the lithium-polymer battery or the USB power when available. The RTC also provides the system temperature ( $^{\circ}\text{C}$ ) recorded to the header of each data file.

### 3.2.7 Memory Card

The X16-2 stores data to a removable 2GB microSD flash memory card. The device operates using FAT16 file structure, which limits the maximum microSD card capacity to 2GB. The “config.txt” and “time.txt” files must occur in the root directory (see section 3.2.4 and section 3.2.6). The X16-2 functions as a Mass Storage Device to computer operating systems when transferring data to and from the microSD memory card.

The X16-2 is compatible with microSD and microSDHC type cards but the card must be formatted to FAT16 for proper operation of the X16-2. 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 X16-2 will create a folder called “GCDC”, if not already present, to place the data files (see section 3.2.5).

### 3.3 Mechanical

The X16-2 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 X16-2 to other structures. A slip-on cap protects the USB connector. The X16-2 weighs 1.3oz (48g).

#### 3.3.1 Dimensions

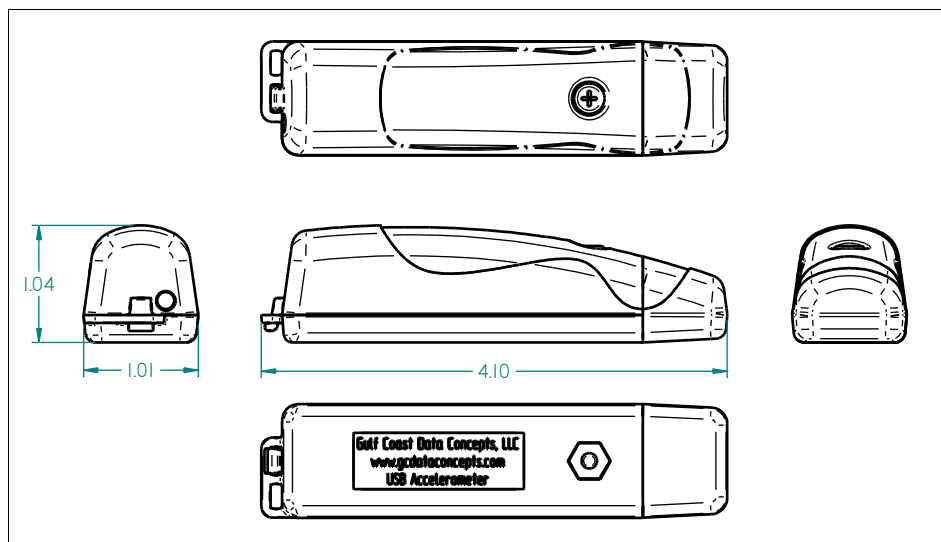


Figure 11: Enclosure Dimensions

## 3.3.2 Assembly

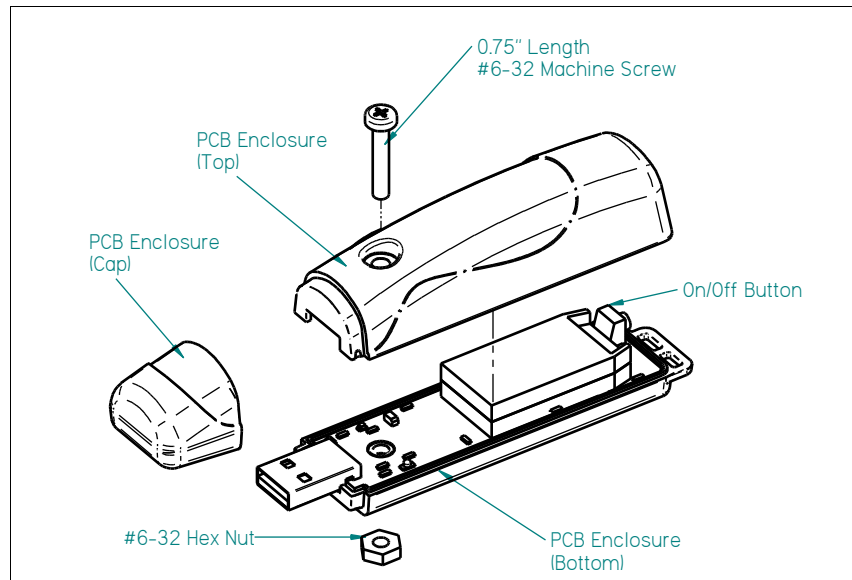


Figure 12: Exploded View of USB Accelerometer X16-2

## 4 Software

The X16-2 records data to comma delimited text files and uses text based files for configuration settings. Therefore, no special software is required to utilize the X16-2. 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 X16-2 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 MatLab, Mathcad, Microsoft Excel, OpenOffice Calc, Octave, R, or similar applications.