1 Features

- 3-axis 14-bit ±8g accelerometer
- 3-axis magnetometer
- User selectable sample rates of 6, 12, 25, 50, 100, and 200 Hz
- Internal Li-Poly battery charges via USB
- Accurate time stamped data using Real Time Clock (RTC)
- Data recorded to 2GB internal flash memory
- Easily readable comma separated text data files
- Data transfer compatible with Windows or Linux via Universal Serial Bus (USB) interface (no special software required)
- System appears as USB Mass Storage Device to Windows and Linux OS's.
- Real-time data acquisition via Human Interface Device (HID) access
- Up to 8 days operating life per charge with 500mAh battery

2 Applications

The X8M-3 is applicable to:

- Monitoring human motor activity, or actigraphy, such as exercise intensity or sleeping disorders.
- Monitoring wildlife daily activity and feeding habits
- Educational purposes

3 Description

The X8M-3 records a constant stream of time stamped accelerometer and magnetometer data to flash memory. Acceleration is collected in X, Y, and Z axes and stored at a user selectable rate of up to 200Hz. The magnetometer data is recorded at sub-intervals to the accelerometer rate. The X8M-3 mounts as a standard mass storage device, which facilitates easy access to the comma delimited text data files and user setup files. Several configurations of the X8M-3 are available but each type operates the same.
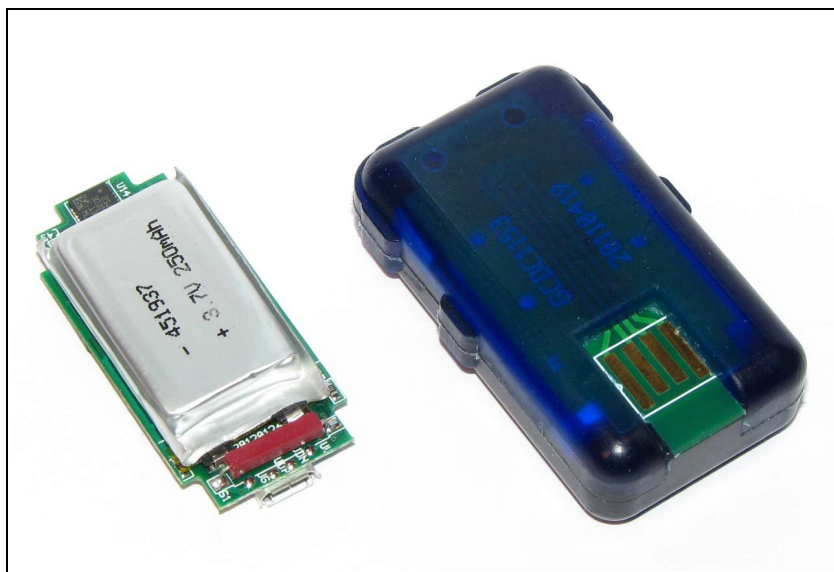

Figure 1: X8M-3 Data Loggers

3.1 Operating Instructions

The X8M-3 is a simple, economical solution to capture continuous motion and magnetic field data and quickly deliver the information for analysis. The following instructions outline the steps to begin using the X8M-3. Configuration settings and mounting methods will depend on the particular application.

Step 1: Ensure the internal Li-Poly battery is fully charged by plugging the X8M-3 into a computer USB port. Approximately 90 minutes will fully charge a depleted 250mAh battery.

Step 2: Configure the X8M-3 by editing the appropriate tags in the config.txt file. Choose faster sample rates to capture fast acceleration events. Setting the deadband will filter small sensor readings, reduce the number of write operations to the flash memory, and extend the battery life. For example, a deadband of 100 will cause the X8M-3 to record g-force changes greater than 0.1g – other events, such as sitting at rest, will be ignored. Refer to section 3.2.3 for configuration options.

Step 3: If necessary, initialize the RTC clock by creating a time.txt file (see section 3.2.5).

Step 4: Unplug the X8M-3 from the USB port and firmly attach the system to the target object.

Step 5: To start the X8M-3, pass a magnet near the small rectangular red reed switch located near the USB connector. For the polyurethane encapsulated models, the reed switch is located on the opposite end from the USB contact points. 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 LED will begin to blink at a 1 second interval indicating the system is operating. The red LED will blink periodically as data is written to the microSD card.

Step 6: Hold a magnet near the on/off switch for about 3 seconds to stop recording. The LEDs will begin to blink rapidly for 2 seconds. Remove the magnet and the X8M-3 turns off.

Step 7: Connect the X8M-3 to a computer USB port to access the data files. The X8M-3 requires a micro-B USB connector or the GCDC USB adapter, depending on product configuration. Data is saved to a text file located in the "GCDC" directory of the microSD card. The accelerometer raw counts are converted to "g" by dividing the value by 1024. The magnetometer raw counts are converted to "gauss" by dividing the value with the appropriate factor listed in Table 2.

3.2 Electrical

3.2.1 Sensor

The accelerometer sensor axes and magnetometer sensor axes are oriented in the same direction, as depicted in Figure 2. The accelerometer range is permanently set to ±8.0 g. The magnetometer range is set to ±4.0 gauss by default but the sensor range can be configured by the user (see section 3.2.3.10).

Table 1: Sensor Characteristics

Parameter		Condition	Min	Typical	Max	Units
Accelerometer	Range			±8.0		g
	Resolution			0.001		g/count
	Zero-g Offset Level Accuracy	X, Y axis	-150		+150	mg
		Z axis	-250		+250	mg
Magnetometer	Range (see section 3.2.3.10)	Default for X, Y, Z axes		4.0		gauss
	Resolution	X, Y axis		450		counts/gauss
		Z axis		400		counts/gauss
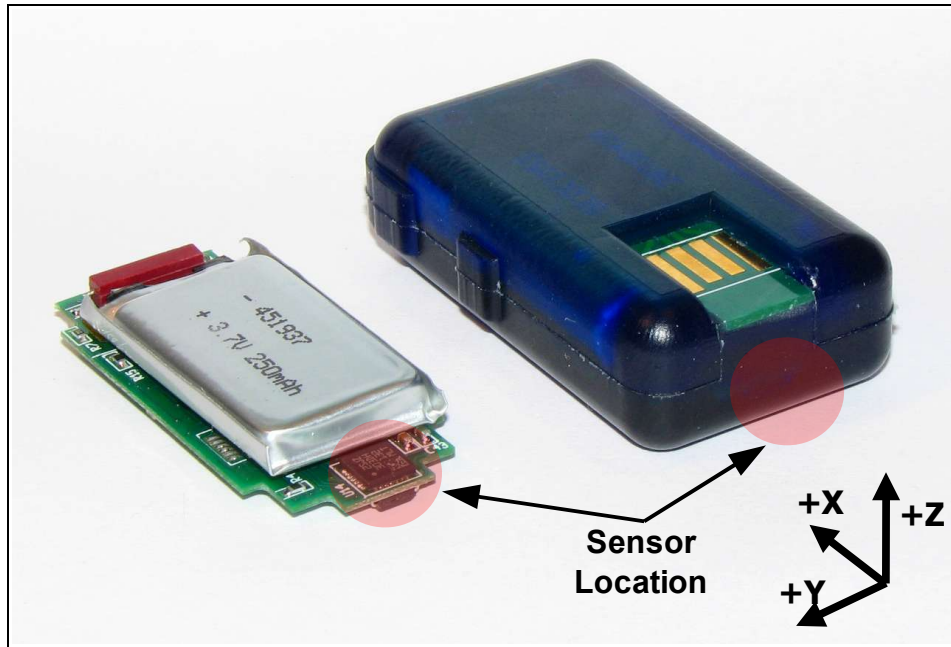
Figure 2: X8M-3 Accelerometer Sensor Orientation

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3.2.2 Battery

The X8M-3 is powered by an internal, hardwired lithium-polymer rechargeable battery. Available battery configurations are 250mAh, 500mAh, and 1000mAh. The internal battery management system recharges the battery when the X8M-3 is plugged into a USB port. A depleted battery is fully charged in about 90-120 minutes. The battery life depends on the sample rate and write operations to the microSD card. Figure 3 illustrates estimated operating times of the X8M-3 when configured to collect continuous time stamped data. Greater operating times are achieved with slower sample rates, use of the deadband limit, or implementing the "coarsetime" feature. 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).
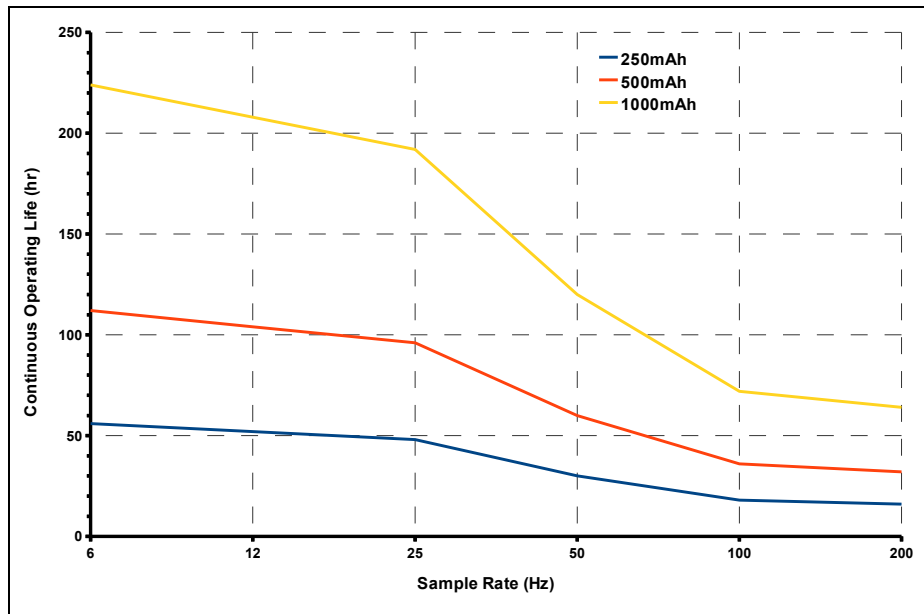

Figure 3: Estimated Operating Life of X8M-3

3.2.3 System Configuration Options

The X8M-3 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 when the device turns on. 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* or *Notepad++* is recommended for editing the config.txt file. Standard *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 X8M-3 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
coarsetime	-	Off	Sets device to enter very low power mode to maximize battery life
deadband	An integer between 0 and 32767	0	Sets the deadband to a range expressed in "counts". A new sample is recorded if any accelerometer 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.
dwell	An integer between 0 and 65535	1	The number of samples recorded after a deadband threshold triggered event
interleave	An integer between 1 and 255	5	
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.
samplesperfile	An integer greater than 0	28800	The number of lines of data per data file before a new file is created
samplerate	6,12,25,50,100,200	50	Sets the rate at which data is collected and recorded to the microSD card.
smbDevice, smbOffset, smbWrite	See Section 3.2.3.10	128	A set of commands to configure the magnetometer sensor gain
starttime and stoptime	See section 3.2.3.11	-	Defines when to start and stop recording
stoponvusb	-	Off	Stops data logging if 5v USB power is present (see section 3.2.3.12)
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 3.2.3.14)

3.2.3.1 coarsetime

The "coarsetime" option maximizes the battery life by setting the device to enter a very low power mode. The low power mode can not support the precision timing so the time stamps are not included in the data stream. The data stream includes only the accelerometer data and magnetometer data. The last line of the data file contains a comment stating the total elapsed time of the data file. The elapsed time and the number of lines in the data file determines the actual sample rate, which should be within 5% of the requested sample rate. The coarsetime mode can double the operating life and is intended for sample rates ≤50Hz.

3.2.3.2 deadband

"deadband" defines the minimum difference between recorded accelerometer 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.
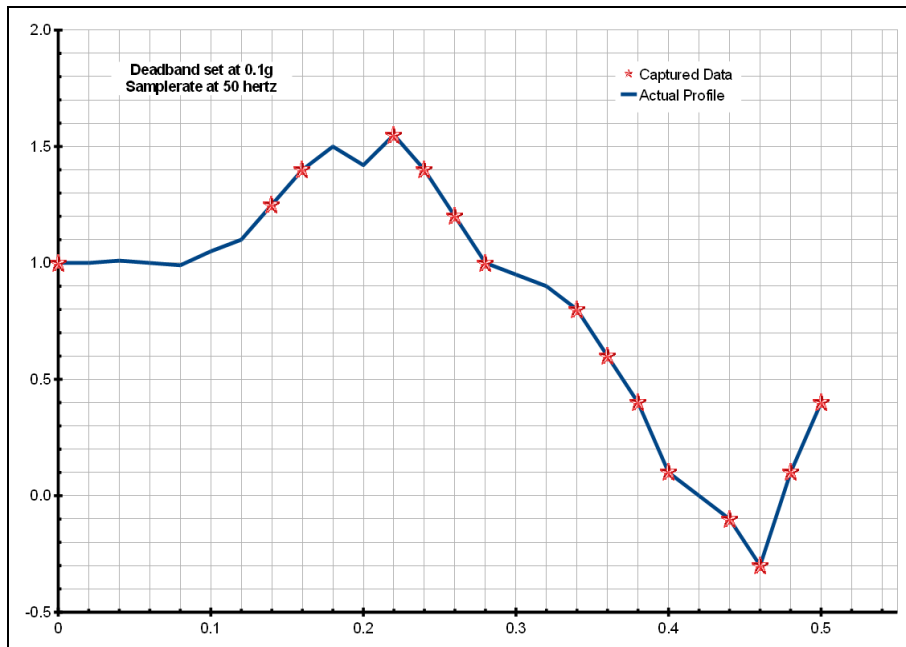

Figure 4: Graphical Illustration of the Deadband Feature

3.2.3.3 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.

3.2.3.4 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.
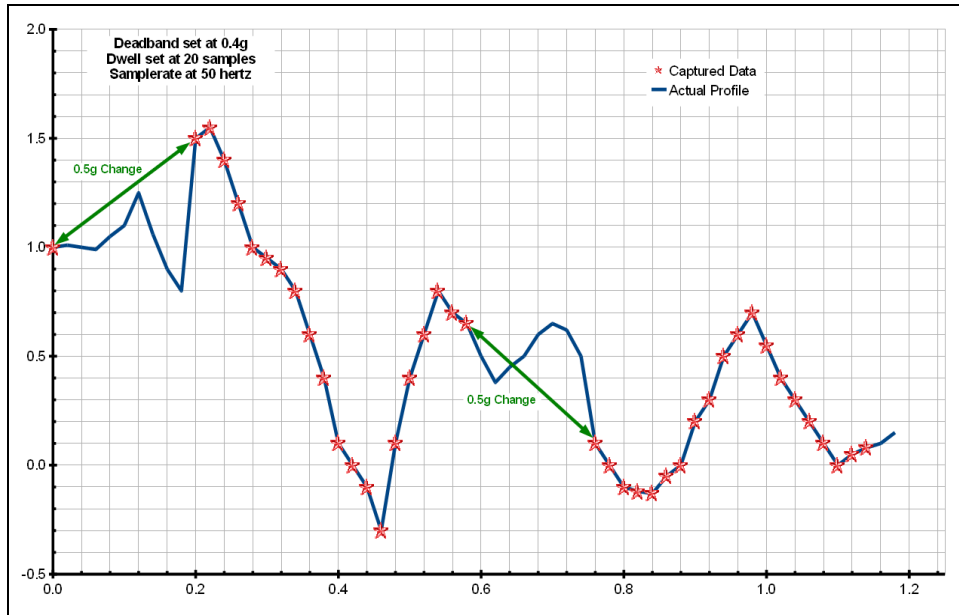
Figure 5: Graphical Illustration of the Dwell Feature

3.2.3.5 interleave

Magnetometer data is sampled from the sensor at sub-intervals to the acceleration readings. The "interleave" tag defines the number of acceleration readings between each temperature reading. For example, "interleave=5" means magnetometer data is included with every 5th sample of acceleration.

3.2.3.6 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 100 hertz or greater to provide the best timing precision. The power saving features of the X8M-3 are disabled in micro-resolution mode and battery life is shortened accordingly.

3.2.3.7 rebootondisconnect

The X8M-3 incorporates an magnetic sensitive on/off switch 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. The device will stop recording when returned to a computer USB port or utilitizing the magnetic on/off switch.

3.2.3.8 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.

3.2.3.9 samplerate

The "samplerate" tag defines the data rate in Hertz, or samples per second. Valid sample rate settings are 6, 12, 25, 50, 100, and 200 Hz. At 100 Hz or greater, the configuration file should also include the "microres" tag to provide the best timing precision (see section 3.2.3.6).

3.2.3.10 smbDevice, smbOffset, smbWrite

A sequence of three commands sets the sensitivity of the magnetometer sensor. The first two commands are always set as "smbDevice = 60" and "smbOffset = 01". The third command establishes the sensitivity setting according to Table 3 below. The value of 128 is a nominal condition useful in most applications. Some situations may require a different sensitivity setting since Earth's magnetic field changes with geographic location. For example, a polar environment will require a lower sensitivity to ensure the sensor output is not saturated. See section 3.2.3.15 for examples.

Table 3: Magnetometer Sensitivity Settings

smbWrite setting	Range (gauss)	Magnetometer Sensitivity (counts/gauss)	
		X, Y	**Z**
32	±1.3	1100	980
64	±1.9	855	760
96	±2.5	670	600
128	±4.0	450	400
160	±4.7	400	355
192	±5.8	330	295
224	±8.1	230	205

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3.2.3.11 starttime and stoptime

The X8M-3 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 X8M-3 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 *

3.2.3.12 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.

3.2.3.13 statusindicators

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

3.2.3.14 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.

3.2.3.15 Example Configuration Files

Example A) The following configuration records data constantly at 25 hertz with magnetometer data every 5th sample. The device will boot and begin logging data once removed from a computer USB port. Each data file is 67,500 lines long or about 45 minutes.

```
; example X8M-3 config file
; set to record constantly at 25hz
samplerate = 25
deadband = 0
deadbandtimeout = 0
; magnetometer data at 5Hz
interleave = 5
; set file length
samplesperfile = 67500
; make device start upon USB disconnect
rebootondisconnect
; commands to configure magnetometer
; do not change following settings
smbDevice = 60
smbOffset = 01
smbwrite = 128
```

Figure 6: Configuration File Example A

Example B) This example sets the device to record events changing greater than 0.05g. Each event will include at least 100 samples at 50 Hz. A 2 second segment of data is recorded every minute regardless of motion. Status indicators will turn off about 10 seconds after the device turns on. The device is turned on using a magnet.

```
; example X8M-3 config file
; set to 50Hz
samplerate = 50
; record motion > 0.05g
deadband = 50
; record 2 seconds of data
dwell = 100
;force a write operation every minute
deadbandtimeout = 60
; magnetometer data at 5Hz
interleave = 10
; set file length
samplesperfile = 30000
; turn off LEDs
statusindicators = off
; commands to configure magnetometer
; do not change following settings
smbDevice = 60
smbOffset = 01
smbwrite = 128
```

Figure 7: Configuration File Example B

Example C) Data is recorded constantly at 25 Hz with magnetometer data at once per second. The coarsetime option is implemented to maximize the battery life. Once the device is turned on it enters a standby condition and waits for 4pm to start logging. Recording continues until the battery is depleted since there is no stop time defined.

```
; example X8M-3 config file
; set to 25Hz
samplerate = 25
; magnetometer data at 1Hz
interleave = 25
; turn on coarsetime
; to extend battery life
coarsetime
; record constantly
deadband = 0
deadbandtimeout = 0
; set file length to 1hr
samplesperfile = 90000
statusindicators = normal
; start recording at 4pm
; no stop time so logging
; continues until battery dead
starttime = 00 16 *
; commands to configure magnetometer
; do not change following settings
smbDevice = 60
smbOffset = 01
smbWrite = 128
```

Figure 8: Configuration File Example C

3.2.4 Data Files

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, the raw accelerometer sensor readings from the X, Y, and Z axes, and the raw magnetometer 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 accelerometer raw counts are converted to "g" by dividing the value by 1024. The magnetometer raw counts are converted to "gauss" by dividing the value with the appropriate factor listed in Table 2.

The X8M-3 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 switch is activated, 5v power is restored to the system via the USB connector, or when the X8M-3 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.

Table 4 lists the valid header tags, although not all tags may occur in the header.

Table 4: 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
GAIN	Always indicates "low"
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 X8M-3 unit
VERSION	The version control information of the USB Accelerometer firmware
VBAT	Battery voltage expressed in millivolts

```
;Title, http://www.gcdataconcepts.com, X8m-3
;Version, 1403, Build num, 0x206, Build date, 20120402 12:59:13,   SN:CCDC42011001678
;Start_time, 2012-04-11, 14:07:48.412
;Temperature, 26.00, deg C,  Vbat, 3857, mv
;Gain, low
;SampleRate, 50,Hz
;Deadband, 0, counts
;DeadbandTimeout, 0,sec
;Headers, time,Ax,Ay,Az,Mx,My,Mz
1.022,352,-468,-828
1.040,336,-460,-848
1.060,352,-480,-888
1.079,324,-472,-876
1.098,348,-444,-864,-8,144,136
1.117,368,-460,-884
1.136,340,-480,-884
1.155,364,-464,-828
1.174,372,-476,-852
1.193,356,-468,-828
1.212,316,-452,-880
1.231,332,-484,-860
1.250,372,-484,-860
1.269,392,-508,-876
1.288,300,-476,-836,-10,146,134
1.307,352,-456,-852
1.326,364,-460,-836
1.346,356,-464,-876
1.365,384,-424,-876
1.384,400,-456,-820
1.403,372,-444,-852
1.422,356,-456,-860
1.441,420,-452,-876
1.460,392,-428,-836
1.479,380,-428,-812,-15,150,132
1.498,412,-472,-848
1.517,420,-472,-832
1.536,404,-460,-852
1.555,392,-448,-828
```

Figure 9: Example Data File

3.2.5 Real Time Clock

A real time clock (RTC) is integrated into the X8M-3 system and is used to determine time for each line of data recorded. The RTC maintains ±5ppm accuracy (-40°C to +85°C) and is powered by the primary battery. The RTC will reset if the battery is completely depleted. The RTC also provides the system temperature (°C) recorded to the header of each data file.

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.

3.2.6 Memory Card

The X8M-3 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 3.2.3 and section 3.2.5). The X8M-3 functions as a Mass Storage Device to computer operating systems when transferring data to and from the microSD memory card.

The X8M-3 is compatible with microSD and microSDHC type cards but the card must be formatted to FAT16 for proper operation of the X8M-3. 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 X8M-3 will create a folder called "GCDC", if not already present, to place the data files (see section 3.2.4).

3.3 Mechanical

3.3.1 X8M-3 250mAh Bare Printed Circuit Board

The X8M-3 in the bare printed circuit board configuration is intended for monitoring small wildlife. The X8M-3 including a 250mAh battery weighs just 0.34oz (9.6 grams). The data logger is covered in plastic shrink wrap to protect the electronics from handling. However, the end-user is responsible for weatherproofing and mounting the device to the animal.
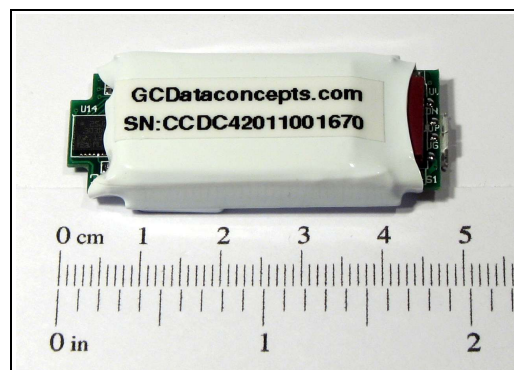

Figure 10: X8M-3 250mAh Bare PCB

3.3.2 X8M-3 Polyurethane Encapsulated

The X8M-3 is available in a waterproof design rated to 30m depths. The soft polyurethane material (Shore A 85) and gold USB contacts provide durable protection in saltwater environments. The encapsulated X8M-3 is available in 500mAh and 1000mAh sizes. Note that a special USB adapter is required to connect to the encapsulated X8M-3. The adapter provides a common Type-A USB male connector for attaching to a computer.
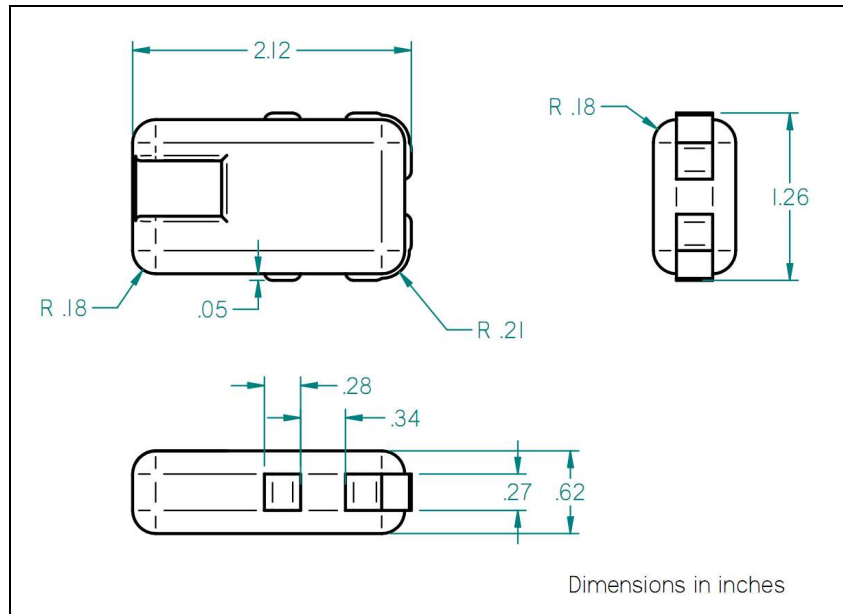

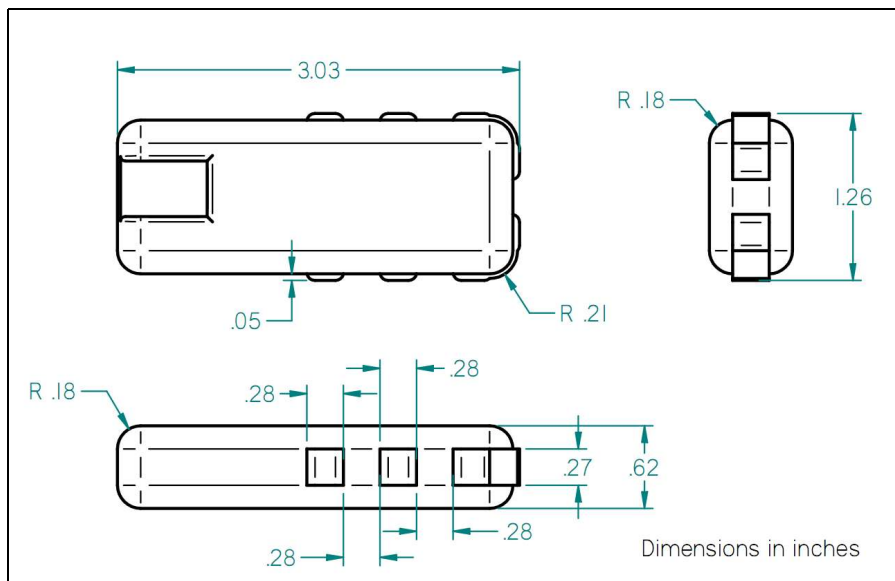**Figure 11: X8M-3 500mAh Encapsulated**

Figure 12: Enclosure Dimensions

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Figure 13: USB Adapter

4 Software

The USB Accelerometer X8M-3 records data to comma delimited text files and uses text based files for configuration settings. Therefore, no special software is required to utilize the X8M-3. 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 each X8M-3 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, Octave, R, S, or similar applications.