Gulf Coast Data Concepts
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# Human Activity Monitor
## (HAM)
## User Manual

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# 1 Introduction

## 1.1 About This Manual

Thank you for purchasing the Human Activity Monitor (HAM). Gulf Coast Data Concepts spent considerable efforts developing an easy to use data logger for the scientific researcher, student, or hobbyist. This product collects data from multiple sensor types simultaneously to provide an advanced insight into motion analysis. Please read this manual to understand the operation and capabilities of the HAM.

## 1.2 Document Conventions

The quick start guide in section 1.7 provides a basic summary of operation to begin using the HAM data logger. This user manual continues into further details of configurations and capabilities starting in section 2. Each section also presents relevant tips and warnings to help the user.

This icon indicates a helpful tip that may enhance the performance of the logger or aide in the application of the logger.

This icon indicates a warning, restriction, or limitation that the user should be aware of regarding the logger operation.

## 1.3 Product Summary

The HAM is a compact self-recording data logger available with several sensor variants. Data from the digital sensors are time stamped using a real time clock and stored to flash memory in simple text format. When connected via the USB to a personal computer, the HAM appears as a standard mass storage device containing the comma delimited data files and the user setup file. The HAM includes an internal 250mAh lithium-polymer rechargeable battery, which will recharge using USB power. The HAM logger can be packaged into an alternative enclosure and fitted with different battery configurations.

Figure 1: HAM Data Logger

## 1.4 Feature List

### 1.4.1 General Features

The HAM is available with three sensor configurations. The following features are common to each of the three product types.

- User selectable sample rates
- Accurate time stamped data using Real Time Clock (RTC)
- Data recorded to internal 8GB flash memory
- Easily readable text data files
- Data transfer compatible with Windows or Linux via Universal Serial Bus (USB) interface (no special software required)
- Operates from internal 250mAh lithium-polymer rechargeable battery
- Weight 0.9oz (25g)
- Size 2.21L x 1.55W x 0.60H inch (56.1x39.4x15.2 mm)

### 1.4.2 HAM-x16

- 3-axis ±16g accelerometer (Analog Devices ADXL345)
- 16-bit resolution
- Selectable sample rates of 12, 25, 50, 100, 200, 400 Hertz
- Finite Impulse Response filter

### 1.4.3 HAM-x16+alt

- Same features as HAM-x16 plus additional high precision barometric pressure sensor (Bosch Sensortec BMP-384)

### 1.4.4 HAM-IMU+Alt

- 3-axis accelerometer, gyroscope, and magnetometer (9-DOF)
- Selectable sample rates of 12, 26, 52, 104, 208, 416 Hz
- High precision barometric pressure sensor (Bosch Sensortec BMP-384)

## 1.5 Items Included with HAM

### 1.5.1 Single Unit Purchase

The HAM is packaged with the logger, a fabric mounting strap, a USB extender cable, and a magnetic screwdriver.


**Figure 2: HAM and Accessories**

### 1.5.2 5 Unit Kit

A kit includes 5 HAM loggers, 5 mounting straps, a USB extender cable, and a magnetic screwdriver.


**Figure 3: 5 Unit kit of Loggers**

## 1.6 Component Names

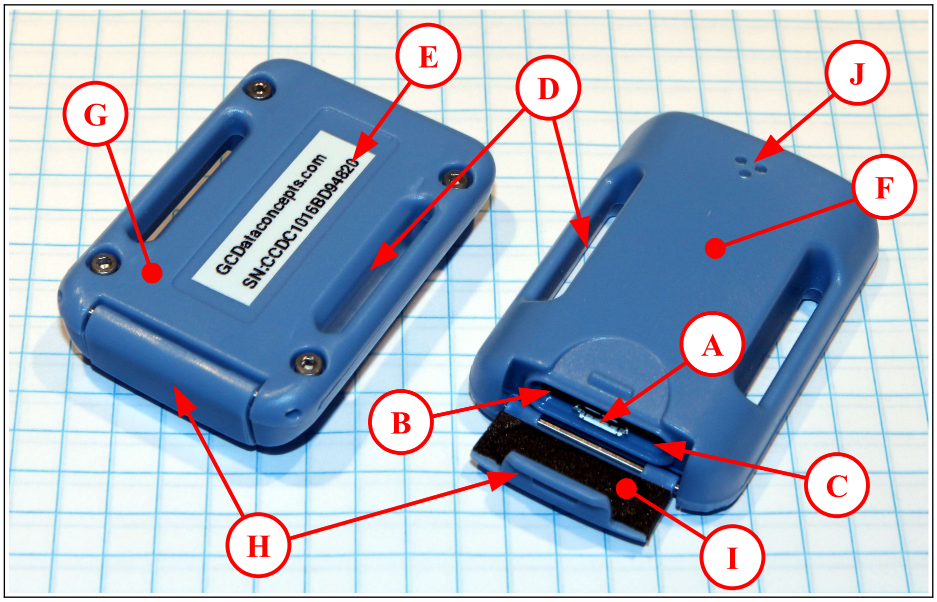



**Figure 4: HAM Data Logger Components**

| | | | |
|---|---|---|---|
| A | microB USB connector | F | Enclosure top |
| B | Blue LED status indicator | G | Enclosure bottom |
| C | Orange LED data indicator | H | Enclosure cap |
| D | Mounting slots | I | Cap rubber gasket |
| E | Serial Number Sticker | J | Air vent (+Alt only) |

## 1.7 Quick Start Guide

The HAM 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 HAM. Configuration settings and mounting methods will depend on the particular application.

Step 1: Plug the HAM into a computer and allow the computer operating system to register the device as a Mass Storage Device. Notice that the logger will mount with a drive label using the last digits of the serial number. An orange LED located within the enclosure will indicate the battery is charging. The LED will turn off when the battery is fully charged, which takes about 1 hour.

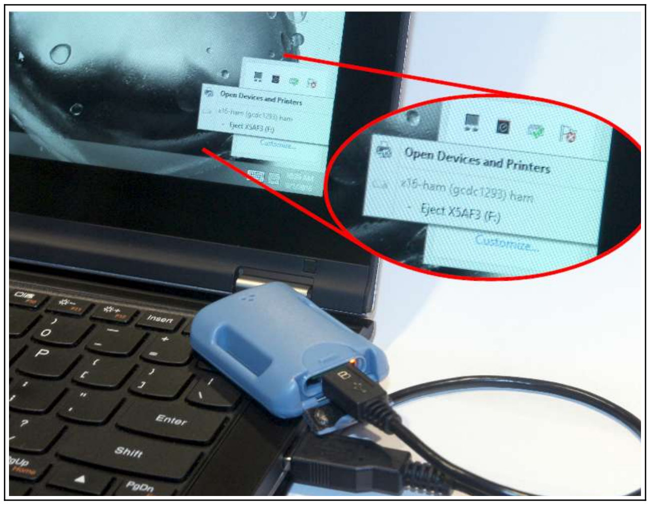
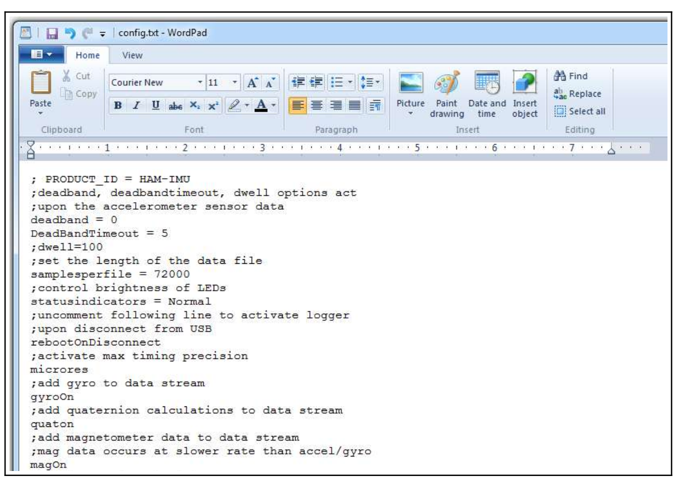



**Figure 5: Connecting to PC**

Step 2: Configure the HAM by editing the appropriate tags in the config.txt file using a simple text editor. In Windows, do not use Notepad, as the editor does not terminate new lines properly. GCDC recommends Windows Wordpad or Notepad++ to edit the config.txt file. Refer to section 2.6 for a complete list of configuration options.




```
; PRODUCT_ID = HAM-IMU
;deadband, deadbandtimeout, dwell options act
;upon the accelerometer sensor data
deadband = 0
DeadBandTimeout = 5
;dwell=100
;set the length of the data file
samplesperfile = 72000
;control brightness of LEDs
statusindicators = Normal
;uncomment following line to activate logger
;upon disconnect from USB
rebootOnDisconnect
;activate max timing precision
microres
;add gyro to data stream
gyroOn
;add quaternion calculations to data stream
quaton
;add magnetometer data to data stream
;mag data occurs at slower rate than accel/gyro
magOn
```

**Figure 6: Editing the Config.txt File**

Step 3: If necessary, initialize the RTC clock by creating a time.txt file (see section 2.4). Once the time.txt file is saved, immediately unplug the logger to start the initialization process. The logger will load the time.txt file, initialize the clock, and delete the time.txt file. Initializing the RTC ensures the data files include the correct year, month, and day and that the data samples can be correlated to a specific date and time.

Step 4: After removing from the USB port, attach the HAM logger to the target object.

Step 5: Pass a magnet near the top of the HAM enclosure to activate the logger (see Figure 7). The magnetic switch minimizes inadvertent disabling of the logger. Logging will start about 3-5 seconds after activation, and orange LED will blink as data is written to the flash memory. Then, the blue LED will begin to blink at a 1 second interval, indicating the system is operating.


**Figure 7: Starting the HAM**

Step 6: To stop recording, hold a magnet near the enclosure top for about 3 seconds. The orange and blue LEDs will begin to blink rapidly for 2 seconds and then turn off. Remove the magnet, and the HAM turns off.

Step 7: Plug the logger into a PC and allow the logger to mount as a USB drive. The data files will appear in the "GCDC" directory.

Step 8: The raw data recorded in the files requires conversion to engineering units. The conversion method depends on the sensor type and configuration. See section 3.3 for a complete discussion of data conversion.

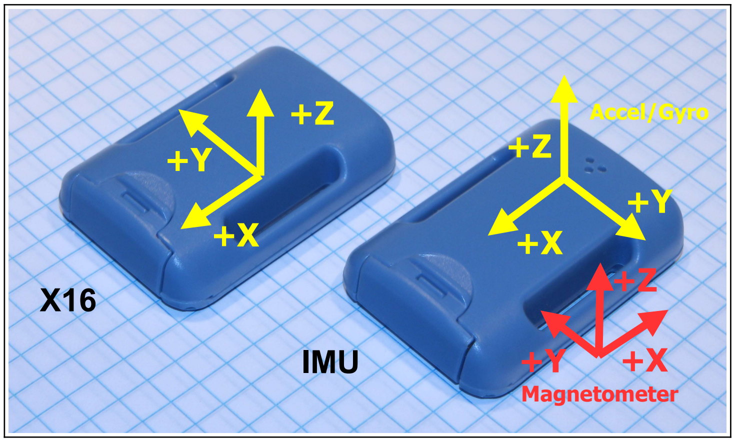


**Figure 8: Sensor Orientation**

> *The HAM-x16 follows the same sensor orientation used with other GCDC accelerometer products. However, the IMU implements a different sensor orientation to maintain consistency with quaternion solutions.*

# 2 Operation

## 2.1 USB Interface

The HAM connects to a PC using a standard micro-B USB connector and supports the USB mass storage device interface for file access and file transfers. Nearly all computer operating systems recognize the HAM as a typical USB external memory drive. Therefore, the HAM will allow file transfers to the internal flash memory like a common USB flash drive. When connected to a PC, the HAM deactivates logging and operates only as a USB interface to the flash memory. Note that some tablet operating systems block access to USB mass storage devices and will not recognize the HAM.

## 2.2 Internal Flash Memory

The HAM stores data to an internal 8GB flash memory chip. Data is maintained even if the logger is off or the battery is dead.

The logger needs only the config.txt file to operate. The HAM will use default configuration settings if the config.txt is not present. The "config.txt" and "time.txt" files must occur in the root directory (see section 2.6 and section 2.4). The HAM will create a folder called "GCDC", if not already present, to place the data files.

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

## 2.3 Battery

The HAM is powered by an internal 250mAh lithium-polymer rechargeable battery pack. The internal battery management system recharges the battery when the HAM is plugged into a USB port or attached to a USB 5v power adapter. The orange charge indicator LED turns on (see Section 2.5) when the battery is charging and off when the battery reaches full charge.

Figure 9 illustrates the expected battery life for each sensor configuration and sample rate.

The data logger can be customized by GCDC to use a non-rechargeable battery but “disableCharger” must be added to the config.txt file to deactivate the charge controller. The non-rechargeable battery must have a nominal 3.7 volts, maximum 4.2 volts, and the logger is set to shutdown at 3.2 volts. A non-rechargeable lithium-thionyl chloride (LTC) chemistry battery meets these requirements. Note that LTC batteries must be de-passivated to ensure a consistent discharge performance. Please contact GCDC for further information regarding this battery configuration.

The RTC continues to operate from the battery when the device is “off”. The RTC should be reinitialized (see Section 2.4) if the battery is completely depleted, which may occur after several months of shelf-time.

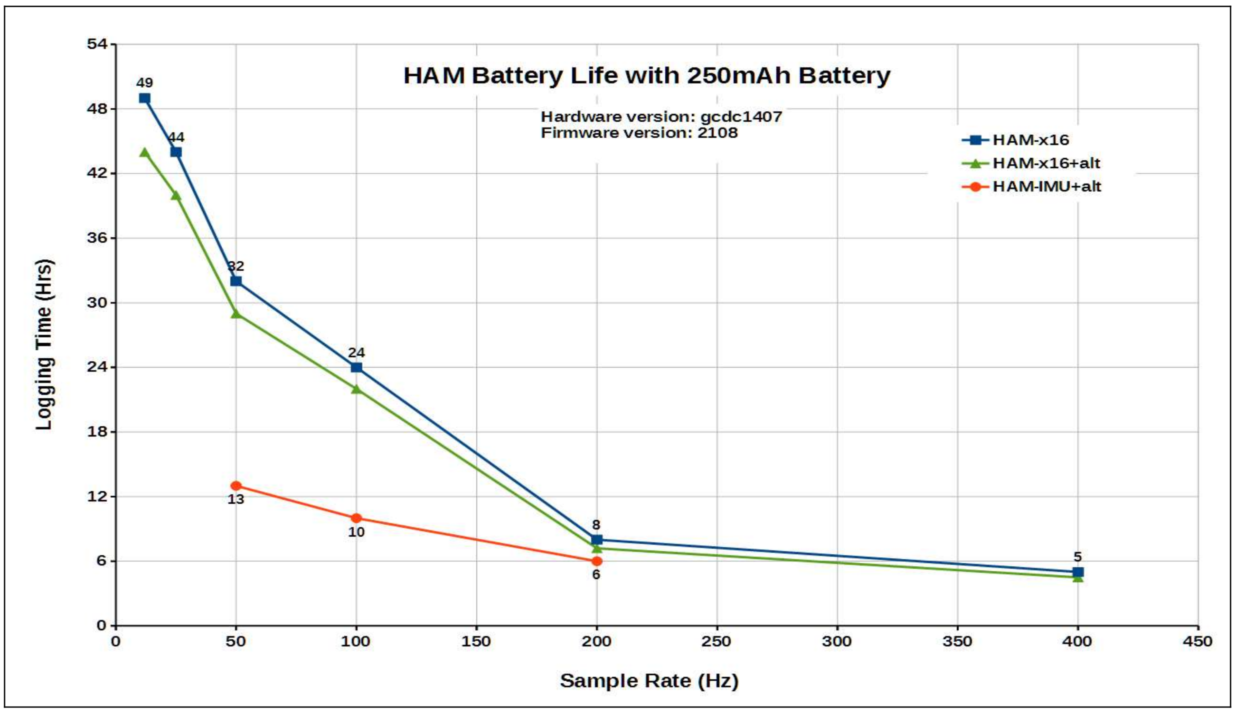



**Figure 9: Expected Battery Life**

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

> *The logger is always “on” as it maintains the real time clock and will eventually discharge the battery completely after several months. The HAM may require an additional hour of charging from a completely discharged state. Keep in a cool (20°C/ 68°F) dry environment to avoid damage of the battery pack.*

### 2.3.1 Power Saving Strategies

In regards to the HAM-x16, there are several feature configurations that will conserve power and help extend the battery life.

- Use the deadband feature to reduce the recorded data. Since the flash memory is the most significant power draw, then reducing the data writes will translate into much better battery life. For example, setting the deadband=1024 will keep the logger from writing data to a file when motion is less than 0.5g. Reducing the data by 20% can increase the battery life by 30%.
- Turn off the over-sample/FIR filter feature using the “filteroff” option. This will reduce the power consumption about 20% but the accelerometer data will have a lower effective resolution (see the discussion in section 4.1.1.1)

## 2.4 Setting The RTC

A real time clock (RTC) integrated into the HAM determines the time for each line of data recorded. The RTC is initialized using a user-created text file named “time.txt” that is loaded by the logger upon booting. The time file method of setting the RTC does not require special communication drivers, so it can be implemented using a simple text editor. Direct initialization of the RTC is possible but requires specific device drivers and software from Gulf Coast Data Concepts.

Initializing the RTC with a time.txt file is accomplished as follows:

Step 1: Use Wordpad, or an equivalent text editor, to create a simple text file called “time.txt”.

Step 2: Enter on the first line the current date and time as “yyyy-MM-dd HH:mm:ss” in 24-hr format. Figure 10 provides an example time.txt file that will initialize the RTC to 2:26:30 pm June 16, 2014.

Step 3: Save this file to the root directory of the logger memory (same location as the config.txt file) and close the text editor.

Step 4: Remove the logger form the PC. The logger will automatically find the time.txt file and intialize the RTC with the time stored in the file. The file is deleted after initialization.

The RTC maintains ±50ppm accuracy (-40°C to +85°C), which means that the accuracy may drift about 4 seconds every day. The RTC is powered by the battery at all times, even when the logger is “off”.

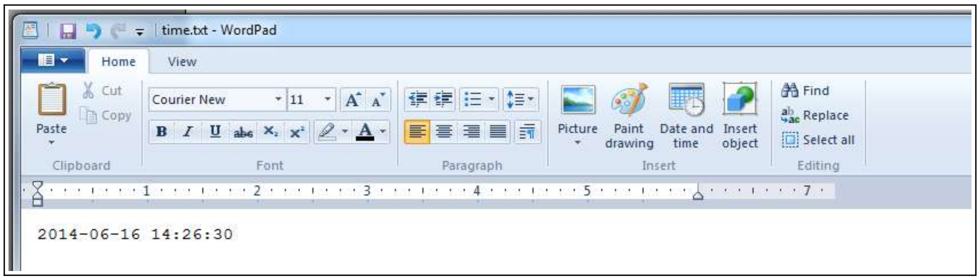



**Figure 10: Example Time Entry in time.txt File**

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

*Initialization of the RTC is limited to +/-1 second. The RTC register that handles the fractional seconds counter is not accessible so the initialization process cannot reset the seconds to an even value.*

*After unplugging the logger from the USB port, the logger will load the config.txt file and time.txt file, if present. Therefore, there is a delay between when the time.txt was created and when the logger actually loads the time information. For most applications, this simple method of initializing the clock results in sufficient accuracy.*

## 2.5 Status Indicators

System status is indicated by the two LEDs located near the USB connector. The blue LED indicates system operation and blinks once per second to indicate a properly operating system. The blue LED blinks when the HAM is recording data, in standby mode, or is connected to a computer via the USB port. The red LED blinks when data is written or read from the flash memory. In data logging mode, the period at which the red LED blinks depends on the sample rate and other configuration settings. The LEDs will flicker during user initiated shutdown. The “statusindicators” tag in the configuration file turns off or changes the brightness of the status indicators (see section 2.6.1.10). The red charge indicator LED is located on the reverse side of the circuit board and illuminates when charging is in process (see Figure 11). The charge indicator LED will turn off when the battery is fully charged. A fully discharged battery will charge in about 2 hours. A blinking charge indicator LED means there is a problem with the lithium-polymer battery pack.

**Figure 11: LED Status Indicators**

## 2.6 System Configuration Options

The HAM 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 memory. The system reads the configuration file at boot time. Tags that require a setting must be followed by an equal sign (“=”) and an applicable tag setting. A line finishes with a newline character. 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.

> ! *Do not use the Windows Notepad editor because it does not terminate new lines properly. GCDC recommends Windows Wordpad or Notepad++ to edit the config.txt file.*

### 2.6.1 Common Configuration Options

All of the HAM variants recognize the set of configuration options listed in Table 1.

**Table 1: Common Configuration Tags and Descriptions**

| Tag | Valid Settings | Description |
|---|---|---|
| absoluteTime | - | Time stamps relative to epoch (Jan 1, 1970) |
| deadBand | An integer between 0 and 16384 | 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 16384 | Specifies the period in seconds when a sample is recorded regardless of the deadband setting. This feature ensures that periodic data is recorded during very long periods of inactivity. |
| dirName | Character text | Defines directory name to store data files |
| disableCharger | - | Turns off battery charger |
| dwell | An integer between 0 and 65535 | The number of samples recorded after a deadband threshold triggered event |
| fileName | Character text | File name prefix for the data files |
| minBattVoltage | An integer between 0 and 16384 | Sets the low-battery cutoff voltage that initiates a shutdown of the logger |
| samplesPerFile | An integer greater than 0 | The number of lines of data per data file before a new file is created |
| statusIndicators | "Normal", "Off" | LED status indicators can be activate (Normal) or deactivated (Off). |
| wakeUpTime | Integer between 1-60 | Specific minutes past the hour to wake up and record a period of data |

#### 2.6.1.1 absoluteTime

By default, the time stamps represent the elapsed seconds since the start_time listed in the file header. "absoluteTime" changes the start reference to midnight January 1, 1970, otherwise known as "epoch" or Unix time 0.

#### 2.6.1.2 deadBand

"deadband" defines the minimum difference between recorded accelerometer sensor readings. A new sample from the accelerometer sensor must exceed the previous recorded reading before the logger records the data. The deadband setting is expressed in "counts" units and is applied to the output of each axis. The deadband value can be set to an integer between 0 and 16384. The deadband function is an effective way to reduce the amount of data collected by defining the granularity of the data.

The deadband functions as a event threshold limit when used in conjunction with the "dwell" feature.

Figure 12 illustrates the deadband feature filtering out small changes in acceleration from the recorded data. Only when the deadband limit is exceeded will a new data sample be pushed to the file. Note that this feature will result in samples with inconsistent time periods. Therefore, the data sets should be re-sampled to establish uniform time periods.

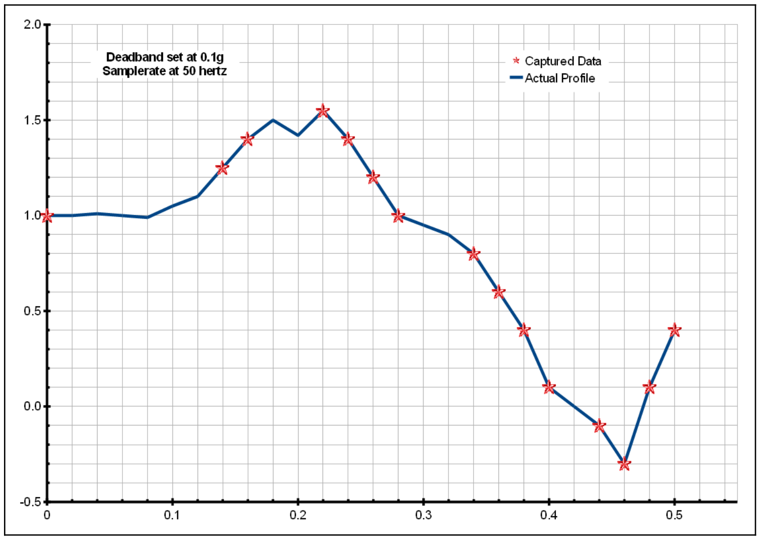


**Figure 12: Graphical Illustration of the Deadband Feature**

### 2.6.1.3 deadBandTimeOut

"deadbandtimeout" defines the period in seconds when a sample is recorded by the logger 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 16384.

### 2.6.1.4 dirName

The logger will store data files into the directory defined by "dirName". The directory must be defined with a preceding slash, such as "dirName=/GCDC". By default, the data directory is set to the root location /GCDC.

### 2.6.1.5 disableCharger

Specialized variations of the HAM logger allow a primary non-rechargeable type battery, as opposed to the standard lithium-polymer rechargeable battery configuration. "disablecharger" deactivates the charge controller when the logger is attached to a PC or USB power source, which avoids charging a non-rechargeable battery.

### 2.6.1.6 dwell

Use "dwell" together with "deadband" to create an event trigger configuration. 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. See section 2.7.2 for an example implementation of the deadband/dwell features.

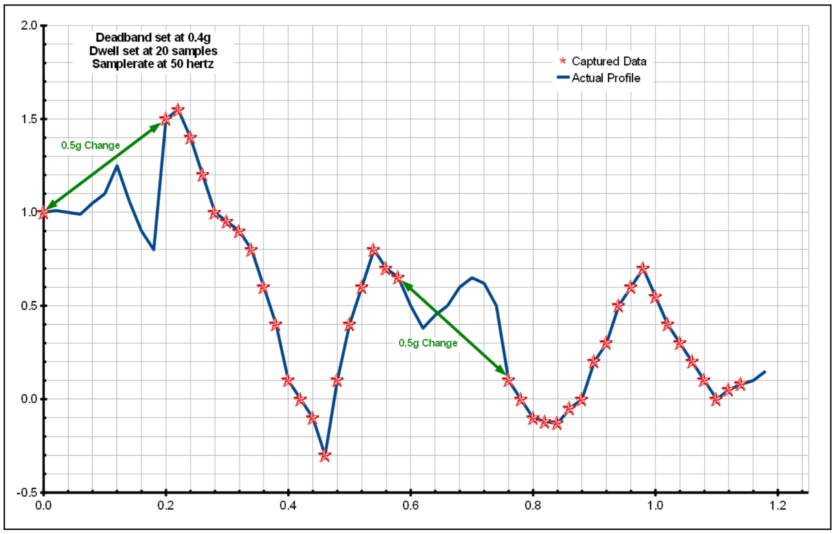



**Figure 13: Graphical Illustration of the Dwell Feature**

#### 2.6.1.7 fileName

"filename" sets the prefix name of the data files. By default, filename is set to "DATA-". The filename length is limited to 8 characters, 3 of which are dedicated to the file number. Therefore, the filename prefix must be kept to 5 characters or less.

#### 2.6.1.8 minBattVoltage

The logger will initiate a low-battery shutdown when the minbattvoltage is detected. By default, the minbattvoltage is set to 3500 millivolts. In the case of non-rechargeable type battery configurations, the minbattvoltage can be set to a custom value to optimize the battery usage. Minbattvoltage value is millivolts.

#### 2.6.1.9 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 software application for data limitations.

#### 2.6.1.10 statusIndicators

The brightness intensity of the LED status indicators is defined using the "statusindicators" tag and valid settings of "normal" and "off". In "off" mode, the LEDs will blink normally for a few seconds upon start-up and then deactivate. The "off" mode keeps the LEDs deactivated even when the logger is connected to a USB port.

#### 2.6.1.11 wakeUpTime

The "wakeup" option configures the logger to turn on at specific times each day. Parameters are in order of minutes then hours and are separated by spaces. Multiple parameters are separated by commas. For example, "wakeup=5,20 4,15" turns the logger on at 5 minutes and 20 minutes past the hour of 4am and 3pm. "wakeup=*" will turn the logger on with each minute. There are three additional parameters needed to complete the wakeup option and each must be on a separate line in the config.txt file:

"secsToRecord" defines the number of seconds to record. For example, "secsToRecord=50" will record 50 seconds of data after a wakeup event.

"fileappend" will append the new data to the previous available data file. The logger will create a new file with each wakeup event if fileappend is not used.

"offOnEndRecord" turns the logger off after the completion of each wakeup event. This option saves power since the logger is not active between wakeup events. Otherwise, the logger will stay in a standby mode (blue LED blinks) while waiting for the next wakeup event.

Each time the logger completes a wakeup event, the remaining portion of the memory sector is filled with a repeating comment string (";sectalign"). This procedure ensures that the next wakeup event starts on a new memory sector, which makes flash memory allocation easier for the logger. For the end-user, ignore these ";sectalign" comment strings.

> *A wakeUpTime event is triggered upon the first time the logger is turned on, regardless of the clock time. After this event completes, the logger will record data at the times specified by the wakeUpTime option.*

### 2.6.2 x16 Options

The HAM-x16 requires the additional configuration option for setting the accelerometer sample rate, as described in Table 2.

**Table 2: x16 Configuration Tags and Descriptions**

| Tag | Valid Settings | Description |
|---|---|---|
| sampleRate | 12, 25, 50, 100, 200, 400 | Sets the rate at which data is collected and recorded to the data file |

#### 2.6.2.1 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. See section 4.1 for special features regarding the sample rates.

### 2.6.3 IMU Options

The HAM-IMU+alt requires the additional configuration option for setting the accelerometer, gyroscope, and magnetometer, as described in Table 3.

**Table 3: IMU Configuration Tags and Descriptions**

| Tag | Valid Settings | Description |
|---|---|---|
| sampleRate | 12, 26, 52, 104, 208, 416 | Accelerometer/Gyroscope sample rate (Hz) |
| ag_GyroHpf | 0, 16, 65, 260, 1000 | Gyroscope cutoff frequency (milli-Hz) |
| ag_GryoFullScale | 125, 250, 500, 1000, 2000 | Gyroscope range in degrees per second |
| mag_SampleRate | 1, 10, 20 | Magnetometer sample rate (Hz) |
| ag_AccelFullScale | 2,4,8,16 | Accelerometer range (g) |

#### 2.6.3.1 ag_SampleRate

The accelerometer sensor and gyroscope sensor are packaged within the same chip and their sample rates are tied together. Therefore, the "ag_SampleRate" setting defines the sample rate for both the accelerometer and gyroscope data. The tag defines the sample rate in Hertz, or samples per second. Valid sample rate settings are 12, 26, 52, 104, 208, and 416.

#### 2.6.3.2 ag_GyroHpf

"ag_GryoHpf" defines the cut-off frequency for a high pass filter implemented on the gyroscope data. The frequency is defined in milli-Hz and valid settings are 0, 16, 65, 260, and 1000.

#### 2.6.3.3 ag_GryoFullScale

"ag_GyroFullScale" sets the fulls scale range of the gyroscope, expressed in degrees per second units. Valid settings are 125, 250, 500, 1000, and 2000.

#### 2.6.3.4 mag_SampleRate

"mag_SampleRate" sets the magnetometer sample rate in Hz. Valid settings are 1, 10, and 20.

The magnetometer sensor operates independently of the accelerometer/gyroscope. The magnetometer data is appended to the most recent gyroscope sample so the magnetometer sensor sample rate must be set less than the gyroscope sample rate.

#### 2.6.3.5 ag_AccelFullScale

"ag_AccelFullScale" sets the fulls scale range of the accelerometer, expressed in G's. Valid settings are 2, 4, 8, and 16 G. A "G" is 32.17 ft/sec^2 or 9.81 m/sec^2.

### 2.6.4 +Alt Options

The "+Alt" product configuration includes the additional barometric pressure sensor options listed in Table 4.

**Table 4: +alt Configuration Tags and Descriptions**

| Tag | Valid Settings | Description |
|---|---|---|
| press_tempOn | - | Adds temperature samples to data file |
| press_pressOn | - | Adds pressure samples to data file |
| press_pressureInterval | Integer between 50 and 32768 | Sets the period in milliseconds between pressure samples |
| press_tempSubSample | Integer between 1 and 255 | Sets the number of pressure samples between temperature samples |

#### 2.6.4.1 press_tempOn

"press_tempOn" adds the temperature readings to the adds sample line. Without press_tempOn, the temperature values are not recorded to the data file but the BMP384 continues the temperature compensation algorithm for pressure.

#### 2.6.4.2 press_pressureInterval

"pressureInterval" defines the time period, in milliseconds, between pressure samples. The data logger will support intervals between 50 milliseconds (20 Hz) and 32678 milliseconds (9 hr interval). The pressure and temperature data is added to the previously available accelerometer/gyroscope sample stored in the cache. Therefore, the rate at which pressure data is collected and when it appears in the data stream will be different. This is rarely a problem in post-process analysis since pressure changes much slower than accelerometer data.

#### 2.6.4.3 press_pressOn

"pressOn" adds the temperature compensated pressure readings from the BMP384 to the data stream

The BMP180 pressure sensor includes a temperature sensor that is used for temperature compensation of the pressure measurements. "tempOn" adds the temperature values to the data stream. Remove "tempOn" or comment the term (";") to hide the temperature data, but the compensation algorithm will continue to operate.

#### 2.6.4.4 press_tempSubSample

The temperature samples are collected at sub-intervals of the pressure readings. "interleave" defines the number of pressure samples taken before a temperature sample is collected. The temperature data is used in the temperature compensation algorithm.

.

## 2.7 Example Configuration Files

### 2.7.1 Example A: HAM-x16

The following configuration records data at 100 hertz. Deadband and deadbandtimeout are set to zero, so the logger will record constantly at the set sample rate. Each data file is 90,000 lines long, which is 15 minutes of data. The status indicators are active and the logger is activates upon removal from the USB port ("rebootondisconnect" is active).

```
;Example HAM-x16 config file
;set sample rate
;available rates 12, 25, 50, 100, 200, 400
samplerate = 100
;record constantly
deadband = 0
deadbandtimeout = 0
;set file size to 15 minutes of data
samplesperfile = 90000
;set status indicator brightness
statusindicators = high
rebootOnDisconnect
;see HAM user manual for other config options
```

**Figure 14: Configuration File Example A**

### 2.7.2 Example B: HAM-x16+alt

The recorded sample rate is set to 50 Hz and the file size is 15 minutes. Temperature and pressure values are collected every 1 second. The logger will activate using the magnetic on/off switch.

```
; PRODUCT_ID = HAM-x16+alt
;set sample rate
samplerate = 50
;record constantly
deadband = 0
deadbandtimeout = 0
;set file size to 15 minutes of data
samplesperfile = 45000
;set status indicator brightness
statusindicators = normal
;do not start after PC disconnect, use magnet
;rebootOnDisconnect
;add temperature to data stream
tempOn
; add pressure to data stream
pressOn
; pressure measurement interval, in milliseconds
pressureInterval = 1000
; interleave is the number of samples to skip between temp
interleave = 1
```

**Figure 15: Configuration File Example B**

### 2.7.3 Example C: HAM-IMU+Alt

Example C sets the HAM-IMU+alt logger to record the accelerometer and gyroscope readings at 104 Hz and the magnetometer is set to 10 Hz. Notice the gyroscope high-pass filter is active so there will be a settling period when the logger is first activated. The pressure data is recorded every 100 milliseconds, or 10 hz. A temperature sample appears with every pressure sample. Time stamps are relative to Epoch.

```
; PRODUCT_ID = HAM-IMU+alt
; sensor data priority
; accel->gyro->mag->pressTemp
; sample rates must be in descending order
; load into spreadsheet as comma separated but
; do not merge delimitors

: ACCEL GYRO PARAMETERS
; available sample rates are 12, 26, 52, 104, 208, and 416
; sample rate affects both accel and gyro
ag_sampleRate = 104
; available HPF filter rate are 0, 16, 65, 260, 1000 milliHz
ag_gyroHpf = 65
; available full scale ranges are 125 250, 500, 1000 and 2000 degrees per sec (dps)
ag_gyroFullScale = 250
; available full scale ranges are 2, 4, 8 and 16 g
ag_accelFullScale = 4

; MAGNETOMETER PARAMETERS
; availble sample rates are 1, 10, 20 50, 100 and 200 Hz, YES
mag_SampleRate= 10

; PRESSURE SENSOR PARAMETERS
;add pressure to data stream
press_pressOn
; the pressure interval is the pressure transucer measurement interval, in milliseconds
press_sampleInterval=100
;add temperature to data stream
press_tempOn
press_tempSubSample=0
; the trigger is measured in meters above turn-on location
;press_triggerHeight = 50

; extra parameters to logger operation
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

; FILE PARAMETERS
;set file size to 60 minutes of data
samplesperfile = 180000
; custom directory name
;dirname = /DATA
; custom file prefix
;filename = areo
; EVENT DETECTOR PARAMETERS
deadband = 0
DeadBandTimeout = 5
dwell=100
; set timestamp to UTC seconds since Jan 1, 1970 instead of time since start of file
absoluteTime
;control brightness of LEDs, values are 'off' or 'high'
statusindicators = high
;uncomment following line to activate logger upon disconnect from USB
;rebootOnDisconnect
```

**Figure 16: Configuration File Example C**

### 2.7.4 Example D: HAM-x16 with wakeup

The following configuration uses the wakeup option to record 2 minutes of data at 20 minute intervals. The sample rate is set at 25 hertz and each file includes 60 minutes data. This wakeup example configuration can be applied to all HAM logger variants.

```
;Example HAM-x16 config file
;set sample rate and record constantly
samplerate = 25
deadband = 0
deadbandtimeout = 0
;set file size to 60 minutes of data
samplesperfile = 90000
;set status indicator brightness
statusindicators = high
rebootOnDisconnect
;wake up every 20 minutes
wakeup=0,20,40
;record 2 minutes of data
secsToRecord=120
;append data to previous file
fileappend
;turn logger off after each wakeup
offOnEndRecord
```

**Figure 17: Configuration File Example D**

# 3 Data Interpretation

## 3.1 Data Files

The HAM 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 HAM 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 18, Figure 19, and Figure 20 show example data files.

```
;Title, http://www.gcdataconcepts.com, HAM-x16, ADXL345
;Version, 2550, Build date, Aug  8 2023,  SN:CCDC1023A0931F2
;Start_time, 2023-07-01, 00:06:13.118
;Uptime, 5,sec,  Vbat, 3994, mv, EOL, 3500, mv
;Deadband, 0, counts
;DeadbandTimeout, 5.000,sec
;SampleRate, 50,Hz
;Time, Ax, Ay, Az
0.282990,-841,-20,-1606
0.303894,-863,-13,-1677
0.324829,-863,-27,-1665
0.345734,-881,-9,-1625
0.366638,-877,51,-1557
0.387574,-884,26,-1618
0.408478,-911,5,-1679
0.429383,-915,64,-1636
0.450318,-854,71,-1556
0.471222,-872,16,-1595
0.492157,-929,42,-1695
0.513062,-918,19,-1690
0.533966,-929,14,-1624
```

**Figure 18: Example Data File From HAM-x16**

```
;Title, http://www.gcdataconcepts.com, X16-ham, ADXL345, BMP280
;Version, 2550, Build date, Jan 11 2018,  SN:CCDC201696836A8
;Start_time, 2023-07-14, 10:49:23.466
;Temperature, -999.00, deg C,  Vbat, 3980, mv
;SampleRate, 50,Hz
;BMP384 SI, 0.100,s
;Deadband, 0, counts
;DeadbandTimeout, 5,sec
;Time, Ax, Ay, Az, P, T
0.286039,-277,-700,-1636,102832,28580
0.305540,-277,-679,-1618
0.325010,-272,-711,-1650
0.344511,-272,-722,-1707
0.364011,-261,-709,-1704,102829,28590
0.383482,-243,-708,-1661
0.402982,-254,-720,-1625
0.422453,-286,-722,-1640
0.441953,-295,-695,-1711
0.461454,-286,-683,-1713,102834,28590
0.480924,-268,-704,-1654
0.500425,-268,-720,-1643
```

**Figure 19: Example Data File From HAM-x16+Alt**

```
;Title, http://www.gcdataconcepts.com, HAM-IMU
;Version, 2550, Build date, Aug  8 2023,  SN:CCDC1023F2A3E00
;Start_time, 2023-07-11, 14:08:55.750
;Uptime, 4,sec,  Vbat, 4184, mv, EOL, 3500, mv
;Deadband, 0, counts
;DeadbandTimeout, 5.000,sec
;BMP384, SI, 0.100,sec, Units, Pa, mdegC
;Alt Trigger disabled
;LSM6DSM, SR,104,Hz, Units, mG, mdps, fullscale gyro 250dps, accel 4g
;Magnetometer, SR,10,Hz, Units, nT, Temperature, 36,degC
;Time, Ax, Ay, Az, Gx, Gy, Gz, Mx, My, Mz, P, T
1691762935.744597,172,-584,-836,,,,-35589,-59045,-18225
1691762935.754212,164,-581,-828,5837,-3238,-1348
1691762935.763827,-12,-278,-725,8864,-1488,-324
1691762935.773442,-50,-655,-762,-2038,-10693,-193
1691762935.783057,4,-269,-1129,16634,25882,73325
1691762935.792672,5,-180,-1024,113698,80018,128231
1691762935.802287,0,-62,-1057,237808,36662,15566
1691762935.811902,-46,-1,-1120,281409,105446,6046
1691762935.811463,-78,-60,-1160,269098,96740,-17439,-40930,-47418,-25579,101607,38158
1691762935.820790,-107,-102,-1203,244843,80403,-38754
1691762935.830117,-164,-110,-1141,209537,66535,-51503
1691762935.839444,-197,-42,-1054,155575,44353,-54058
1691762935.848771,-207,119,-992,92330,20300,-48475
1691762935.858098,-187,48,-1052,24343,-114,-50173
1691762935.867425,-208,27,-1164,-49043,-15602,-69895
1691762935.876752,-189,11,-990,-113968,-54487,-69790
1691762935.886079,-145,-57,-1020,-183356,-82950,-65092,-41033,-53906,-20446
1691762935.895405,-67,-90,-1095,-220675,-60297,-60725
1691762935.904731,-56,-234,-1068,-214033,-39017,-60743
1691762935.914057,-50,-355,-1189,-193060,-34274,-69327
1691762935.923383,-44,-421,-1054,-178176,-26285,-71295
1691762935.932709,-58,-421,-1092,-181177,-28193,-63770
1691762935.942035,-68,-406,-1012,-187845,-24369,-52308
1691762935.951361,-589,-885,-832,-186025,-27379,-44284
1691762935.960694,-74,-335,-1023,-173897,-31912,-28980,,,,101601,38156
1691762935.970020,170,-427,-866,-138967,-4489,92076
```

**Figure 20: Example Data File From HAM-IMU+Alt**

## 3.2 Data Format

Data is written to files in comma-separated text format starting with the file header information and followed by event data entries. The file header includes information about the logger type, firmware version, sensor configuration, file start time, sample rate, and sensor conversion factors. The file header is followed by the data samples. Each sample contains a time stamp entry followed by the sensor output readings. The time entry is seconds elapsed from the start time recorded in the header (default mode) or relative to Jan 1, 1970 (absoluteTime mode).

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 (";").

## 3.3 Data Conversion

### 3.3.1 Time Stamps: Relative Mode

By default, the time stamps represent the elapsed seconds relative to the start time listed in the file header. Add the time stamp to the start time to determine the complete date/time of each sample.

The time stamp calculation is incorporated easily into a spreadsheet, such as Excel or Calc. First, open the data file in a spreadsheet and parse on the comma (",") deliminator. Most spreadsheets will automatically parse the data using the "," character. The parsing operation will separate the start_time into two cells – date and time. Use the "trim" function to strip the white space around the date cell and use "concatenate" to combine the text into a new start date. The spreadsheet will automatically format the new text into a date. Next, divide the time stamp entry by 86400. This converts the time stamp into a value compatible with the spreadsheet date functions. Finally, add the new time stamp to the new start date and a complete data/time is generated. Format the column as a "time" category and include the trailing ".000" to present the millisecond precision.

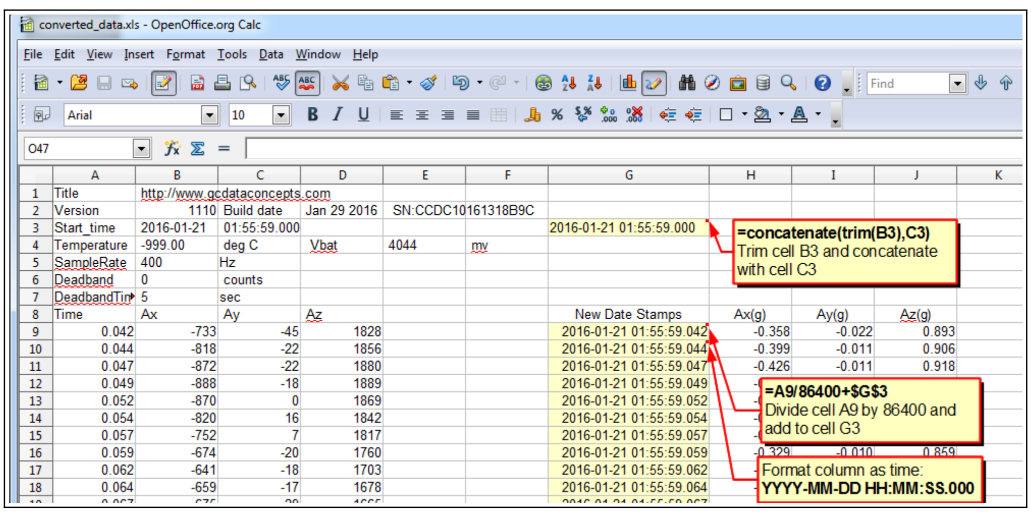



**Figure 21: Time Stamp Conversion Method**

The time stamps can be added directly to the start_time entry (no need to divide by 86400) when using Matlab, Octave, or R.

### 3.3.2 Time Stamps: Absolute Mode

Using the “absolutetime” parameter in the configuration file sets the time stamp format to absolute seconds elapsed since Epoch, which is January 1, 1970. Figure 20 includes an example data file using the absolute mode time stamps. Programs such as Matlab, Octave, and R will directly import this time stamp format and automatically convert it to a standard date and time format.

### 3.3.3 Motion Sensor Data

Sensor data follows the time stamp and the sensor with the fastest sample rate occurs first. Slower sensors are then added to the data stream. Referencing Figure 20, the column headers (line 14) lists the sensor order: accelerometer, gyroscope, magnetometer, pressure, and temperature.

The accelerometer, gyroscope, and magnetometer data are recorded in engineering units as described in the file header. The accelerometer and gyroscope range is listed after the units. For example, in Figure 20, the accelerometer is milli-G (mG) and set to 4g range, the gyroscope is degrees per second (dps) and set to 250 dps, and the magnetometer is nano-Tesla (nT).

### 3.3.4 Pressure and Temperature Data

The logger sets the BMP384 sensor to high-precision mode to provide the most accurate measurement of pressure. Pressure data is recorded to the data file in Pascal units and includes the appropriate compensation based on temperature collected at the pressure sensor.

Temperature is recorded in milli-degree Celsius. Divide the temperature value by 1000 to determine degrees Celsius.

#### 3.3.4.1 Converting Pressure to Altitude

Altitude is calculated from the pressure data using the following equation:

$$Altitude = 44330 \times \left(1 - \left(\frac{P}{Po}\right)^{\frac{1}{5.255}}\right)$$

where *Altitude* = meters above baseline altitude
*P* = pressure in Pascal
*Po* = pressure in Pascal at the baseline altitude (mean sea level = 101325 Pa)

Nominally, sea level pressure is 101325 Pa. However, *Po* should be the pressure at the baseline for which the calculated altitude is relative to.

# 4 System Details

## 4.1 Sensors

The sensors “push” data to the logger at selected rates based on a clock internal to the sensor. The sensor's clock precision and drift are undefined. For example, a selected sample rate of 50 Hz may actually push data at 52 Hz. The HAM incorporates a precise real time clock to independently time stamp the data as it leaves the sensor and to ensure that accurate timing is recorded to the data file. Therefore, the time stamps should be used as the reference for determining the actual sample rates of the accelerometer and gyroscope data. In the case of the IMU, the accelerometer and gyroscope data is synchronized within the sensor.

Additional sensor data, such as the magnetometer, pressure, and temperature values, arrive at slower sample rates than the accelerometer and gyroscope data. The logger appends the new data to the last accelerometer/gyroscope entry available in the memory cache. Therefore, the magnetometer, pressure, and temperature values are not synchronized to the particular time stamp. This method was chosen to simplify the data file format and allow easier parsing of the file. In most cases, the magnetometer, pressure, and temperature data change slowly relative to accelerometer and gyroscope data. The entire data sample line can be assumed to be synchronized.

#### 4.1.1 16g Accelerometer

The HAM uses the Analog Devices ADXL345 3-axis digital accelerometer sensor, which is based on micro-electro machined semiconductor (MEMS) technology. This accelerometer sensor is similar to those used in cellphones, laptops, hard drives and other consumer electronics. Table 5 lists the basic sensor and logger performance parameters. Refer to Analog Devices for detailed sensor specifications.

**Table 5: Accelerometer Sensor Characteristics**

| Parameter | Condition | Min | Typical | Max | Units |
|---|---|---|---|---|---|
| Acceleration range | | | ±16.0 | | g |
| Sensitivity | | | 2048 | | count/g |
| Sensitivity Deviation | | | ±1.0 | | % |
| Nonlinearity | X, Y, Z axis | | ±0.5 | | %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 | | % |

*The HAM-x16 accelerometer sensor will detect the acceleration of gravity, which is a convenient feature for validating the sensor operation. Setting the logger on a flat level surface will result in -2048 counts (-1g) in the z-axis.*

##### 4.1.1.1 Special Feature

The HAM-x16 implements an 8X over-sample and finite impulse response (FIR) filter algorithm at sample rates up to 400Hz. This means that the digital accelerometer sensor provides 8X the sample rate requested in the config.txt file. For example, “samplerate=400” sets the sensor to stream at 3200 Hz, which is the maximum capability of the ADXL345. The eight samples are averaged and processed through the FIR filter to improve the response characteristics. The oversampling and FIR algorithm increases the sensor's native 13-bit resolution to the 16-bit data recorded in the data file.

The HAM-x16 will support sample rates of 800, 1600, and 3200 Hz, but the HAM automatically deactivates the oversampling and FIR filter and records the native 13-bit resolution from the sensor. However, these sample rates are not guaranteed. The time stamps may become inaccurate, or the logger operation could become unstable.

Figure 22 shows an example configuration setting the logger to record at 800 Hz. The 13-bit data from the sensor is right padded (LSB) into a 16-bit value to maintain consistency with the over-sampled data. Therefore, the conversion factor is still 2048 counts/g.

> *Add “filteroff” to the config.txt file to remove the over-sample/FIR filter algorithm and the logger will record the native 13-bit resolution from the ADXL345 accelerometer sensor. The recorded data is “right padded” to a 16-bit value so the conversion factor remains 2048 counts/g. The resulting data is less sensitive and noisier than the filtered data but this option allows the end-user to implement custom filter algorithms post-process.*

```
; Example HAM-x16 Config file
; set to 800Hz
samplerate = 800
; record constantly
deadband = 0
deadbandtimeout = 0
; set file length
samplesperfile = 100000
; set status indicators
statusindicators = normal
```

**Figure 22: 800Hz Sample Rate Configuration**

### 4.1.2 Inertial Measurement Unit (IMU)

The HAM-IMU+alt logger incorporates the STMicroelectronics LSM6DMTR 6-DOF inertial sensor, which includes an accelerometer and gyroscope. Table 6 and Table 7 list the basic sensor and logger performance parameters. Refer to STMicroelectronics for detailed sensor specifications. The magnetometer sensor is made by Memsic, part number MMC5983MA, and is separate from the LSM6DMTR sensor.

#### 4.1.2.1 IMU-Accelerometer

**Table 6: IMU-Accelerometer Sensor Characteristics**

| Parameter | Condition | Min | Typical | Max | Units |
|---|---|---|---|---|---|
| Acceleration range | | | ±16.0 | | g |
| Sensitivity | | | 0.001 | | g |
| Sensitivity Deviation | | | ±1.0 | | % |
| Nonlinearity | X, Y, Z axis | | ±0.5 | | %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 | | % |

#### 4.1.2.2 IMU-Gyroscope

**Table 7: IMU-Gyroscope Sensor Characteristics**

| Parameter | Condition | Min | Typical | Max | Units |
|---|---|---|---|---|---|
| Sensitivity | ±250 °/sec | | 131.072 | | counts/°/sec |
| | ±500 °/sec | | 65.536 | | |
| | ±1000 °/sec | | 32.768 | | |
| | ±2000 °/sec | | 16.384 | | |
| Nonlinearity | X, Y, Z axis | | 0.1 | | %FS |
| Zero Rate | X, Y, Z axis | | ±5 | | °/sec |
| Sensitivity Tolerance | X, Y, Z axis | | ±1.5 | | % |
| Cross-Axis Sensitivity | | | ±2 | | % |

#### 4.1.2.3 IMU-Magnetometer

**Table 8: IMU-Magnetometer Sensor Characteristics**

| Parameter | Condition | Min | Typical | Max | Units |
|---|---|---|---|---|---|
| Full Scale Range | X, Y, Z axis | | ±800000 | | nT |
| Sensitivity Accuracy | | | ±5 | | % |
| Sensitivity Linearity | | | ±0.1 | | % |
| Null Field Output | | | ±50000 | | nT |

*The magnetic sensor detects the Earth's magnetic field lines, which is used to help determine orientation. Other magnetic fields, such as from permanent magnets and electromagnetic systems, will affect the sensor output. Therefore, do not use magnets as an attachment method for the IMU logger.*

### 4.1.3 Barometric Pressure

The HAM-IMU+alt logger includes the Bosch Sensortec BMP384 digital pressure sensor. Table 9 lists the basic sensor characteristics. Refer to Bosch for complete sensor details. The sensor is configured to operate in high-precision mode to maximize the measurement accuracy.
Refer to section 3.3.4.1 for converting the pressure values to altitude.

**Table 9: Pressure Sensor Characteristics**

| Parameter | Condition | Min | Typical | Max | Units |
|---|---|---|---|---|---|
| Operating temperature | Operational | -40 | | +85 | °C |
| Absolute accuracy pressure $V_{DD}$=3.3 V | 30000 - 70000 Pa (0 to +65°C) | | ±50 | | Pa |
| | 30000 - 110000 Pa (-20 to 65 °C) | | ±65 | | Pa |
| Resolution of output data | Pressure | | 0.016 | | Pa |
| | Temperature | | 0.1 | | °C |
| Relative accuracy pressure | 90000 – 110000 Pa (25° to 40°C) | -0.15 | ±9 | +15 | Pa |

## 4.2 Operating and Storage Conditions

The HAM is protected from normal handling and moderately wet conditions, such as rain, sweat, and splashes. The operating temperature range is limited primarily by the lithium-polymer battery capabilities.

**Table 10: Operating and Storage Conditions**

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

*Be careful opening the cap after the logger was exposed to water. Droplets of water will remain around the periphery of the cap and could enter the enclosure. After opening the cap, use a dry cloth to wipe any residual water from the cap and gasket region.*

## 4.3 Dimensions

The overall HAM dimensions are 2.21 inches long (56.1 mm), 1.55 inches wide (39.4 mm), and 0.60 inches high (15.2 mm), and it weighs 0.9 ounces (25g). The two slots are designed to allow a 1" wide (25mm) strap to loop around the enclosure.

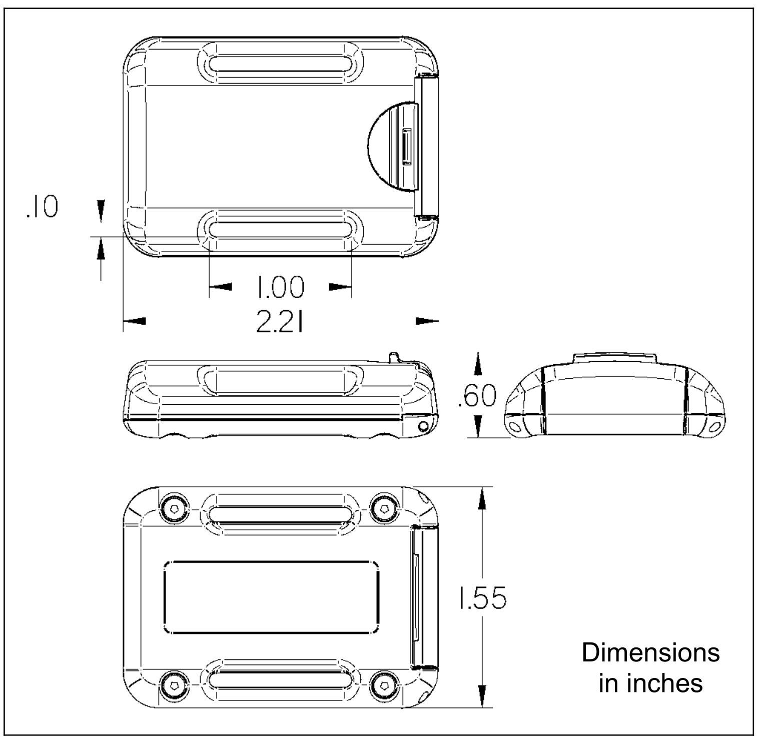



**Figure 23: Enclosure Dimensions**

End of User Manual