

## 1 Features

- Multiple configuration options
- Accurate time stamped data using Real Time Clock (RTC)
- Convenient on/off button
- Data recorded to a removable microSD card (8GB included)
- Easily readable comma separated text data files
- Data transfer compatible with Windows or Linux via USB interface (micro-B type USB cable)
- System appears as USB Mass Storage Device to Windows and Linux OS's.
- Standard replaceable "D" type battery
- LED indicator lights for system status
- Weighs 500g (1.1lbs) with batteries

### -x16 (16g Accelerometer)

- 3-axis  $\pm 16g$  accelerometer
- 16-bit resolution
- User selectable sample rate of 12, 25, 50, 100, 200, 400 Hertz

### -x2 (2g Accelerometer)

- 3-axis  $\pm 2g$  high sensitivity accelerometer
- 15-bit resolution
- User selectable sample rate between 4 and 512 Hertz

### -b (Barometer)

- 30000 – 110,000 Pa pressure range
- Absolute accuracy of  $\pm 250$  Pa, max
- User defined sample period of 10Hz to once per day

## 2 Applications

The MEL logger is applicable to:

### -x16 (16g Accelerometer)

- Continuous time stamped shock and motion monitoring of critical freight.
- Automotive performance monitoring

### -x2 (2g Accelerometer)

- Low amplitude vibration analysis
- Earthquake monitoring

### -b (Barometer)

- GPS navigation enhancement
- Vertical velocity indication
- Calculating absolute altitude
- Calculating pressure at sea level

## 3 Description

The Multifunction Extended Life (MEL) Logger uses precise time stamped data logging, microSD memory storage, real-time data access and USB connectivity. When connected via the USB to a personal computer, the MEL logger appears as a standard mass storage device containing the comma delimited data files and user setup files. The commercial standard "D" batteries (IEC R20) provides up to 60 days of data acquisition.

## 3.1 Operating Instructions

### 3.1.1

The MEL data logger is a simple, economical solution to capture extended length data sets and quickly deliver the information for analysis. The following instructions outline the steps to begin using the data logger. Configuration settings and mounting methods will depend on the particular application.

- Step 1: Pull the latch to open the enclosure. Place the “D” size batteries into the battery holder as indicated by the battery labels (series connection). Close the enclosure and lock latch to ensure a proper seal. Be careful not to pinch the battery wires in the gasket.
- Step 2: Plug the MEL data logger into a computer and allow the computer operating system to register the device as a Mass Storage Device.
- Step 3: Configure the MEL data logger by editing the appropriate tags in the config.txt file located in the root directory of the microSD card. Use a standard text editor such as Wordpad or Notepad++ to modify and save the configuration file. See section 3.2.6 for configuration options.
- Step 4: If necessary, initialize the RTC clock by creating a time.txt file (see section 3.2.8). Unplug the logger and press the power button to load the time.txt file to the RTC. After initialization, the time.txt file is deleted and the RTC maintains time for the duration of the battery life.
- Step 5: Firmly attach the system to the target object. Depending on the g-force intensity expected, tape, tie-wraps, and clamps are suitable methods of attachment.
- Step 6: Press the button located at the top of the enclosure to initiate data recording, (see Figure 1). The “Data” LED will blink as the configuration file is accessed. Then, the “Status” LED will begin to blink at a 1 second interval indicating the system is operating. The data LED will blink periodically as data is written to the microSD card.
- Step 7: To stop recording, press and hold the on/off button for about 3 seconds. The LEDs will begin to blink rapidly for 2 seconds. Release the button and the MEL data logger turns off. Data recording is restarted by pressing the button again (see Step 5).



**Figure 1: Starting the MEL Data Logger**

# Multifunction Extended Life (MEL) Data Logger

## 3.2 Electrical

The three varieties of the MEL data logger are designated by the product identification extension. The MEL-x16 includes an Analog Devices ADXL345 16g digital accelerometer sensor. The MEL-x2 includes a Kionix KXB2050 high sensitivity 2g accelerometer sensor. The MEL-b includes a Bosch Sensortec BMP085 high precision barometric pressure sensor. In the case of the accelerometer sensors, the sensors are oversampled 8X, averaged, and processed through a finite impulse response (FIR) filter to improve the signal fidelity.

The following tables include basic performance characteristics of each sensor. Refer to the manufacturer specifications for more detailed information.

### 3.2.1 MEL-x16

**Table 1: 16g 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      |      | %       |



**Figure 2: MEL-x16 Sensor Orientation**

## 3.2.2 MEL-x2

**Table 2: 2g Accelerometer Sensor Characteristics**

| Parameter                                      | Condition    | Min | Typical | Max | Units   |
|--|--------------|-----|---------|-----|---------|
| Acceleration range                             | Low Gain     |     | 2       |     | g       |
|  | High Gain    |     | 1.25    |     | g       |
| Resolution                                     | Low Gain     |     | 6,554   |     | count/g |
|  | High Gain    |     | 13,107  |     | count/g |
| Non-Linearity                                  | X, Y, Z axis |     | 0.1     |     | %FS     |
| Zero-g Offset Level Accuracy                   | X, Y, Z axis | 100 |         | 100 | mg      |
| Sensitivity Variation from RT over Temperature | X, Y axis    |     | 0.01    |     | %/°C    |
|  | Z axis       |     | 0.02    |     | %/°C    |
| Cross-Axis Sensitivity                         |              |     | 2       |     | %       |
| Operating Temperature                          |              | -10 |         | 55  | °C      |



**Figure 3: MEL-x2 Sensor Orientation**

**3.2.3 Barometric Pressure Sensor (MEL-b)**

**Table 3: -b Barometric Sensor Characteristics**

| <b>Parameter</b>                                    | <b>Condition</b>                   | <b>Min</b> | <b>Typical</b> | <b>Max</b> | <b>Units</b> |
|---|------------------------------------|------------|----------------|------------|--------------|
| Operating temperature                               | Operational                        | -40        |                | +85        | °C           |
|   | Full Accuracy                      | 0          |                | +65        | °C           |
| Absolute accuracy pressure<br>$V_{DD}=3.3\text{ V}$ | 70000 - 110000 Pa<br>(0 to +65 °C) | -250       | ±100           | +250       | Pa           |
|   | 30000 - 70000 Pa<br>(0 to +65°C)   | -300       | ±100           | +300       | Pa           |
|   | 30000 - 110000 Pa<br>(-20 to 0 °C) | -400       | ±150           | +400       | Pa           |
| Resolution of output data                           | Pressure                           |            | 1.00           |            | Pa           |
|   | Temperature                        |            | 0.1            |            | °C           |
| Relative accuracy pressure                          | 70000 – 110000 Pa<br>(@ 25°C)      |            | ±20.0          |            | Pa           |
|   | 0 – 65°C<br>(@ p constant)         |            | ±50.0          |            | Pa           |
| Absolute accuracy temperature                       | @ +25°C                            | -1.5       | ±0.5           | +1.5       | °C           |
|   | 0 - 65°C                           | -2.0       | ±1.0           | +2.0       | °C           |

## 3.2.4 Indicator LEDs

System status is indicated by the two LEDs located on the outside box lid (see Figure 1). The “Status” LED indicates system operation. A steady blinking “Status” LED, once per second, indicates a properly operating system. The LED blinks once per second when the MEL data logger is recording, in standby mode, or is connected to a computer via the USB port. The “Data” LED blinks when data is written from the internal cache to the microSD memory card. The period at which the “Data” LED blinks depends on the deadband setting and sample rate. The LED will also blink with Human Interface Device (HID) communication activity when connected to a PC. The “statusindicators” tag in the configuration file turns off or changes the brightness of the status indicators.

## 3.2.5 Battery

### 3.2.5.1 Main Battery

The MEL data logger is powered by two “D” sized batteries (IEC R20) connected in series. Figure 4 illustrates the battery orientation. Operation times depends on system configuration, battery quality, and microSD card type. Typically, two alkaline batteries will operate over 60 days. The RTC continues to operate from the batteries when the device is “off”. The RTC should be reinitialized if the batteries are removed or depleted. The batteries are not used when the device is connected to a computer USB port.

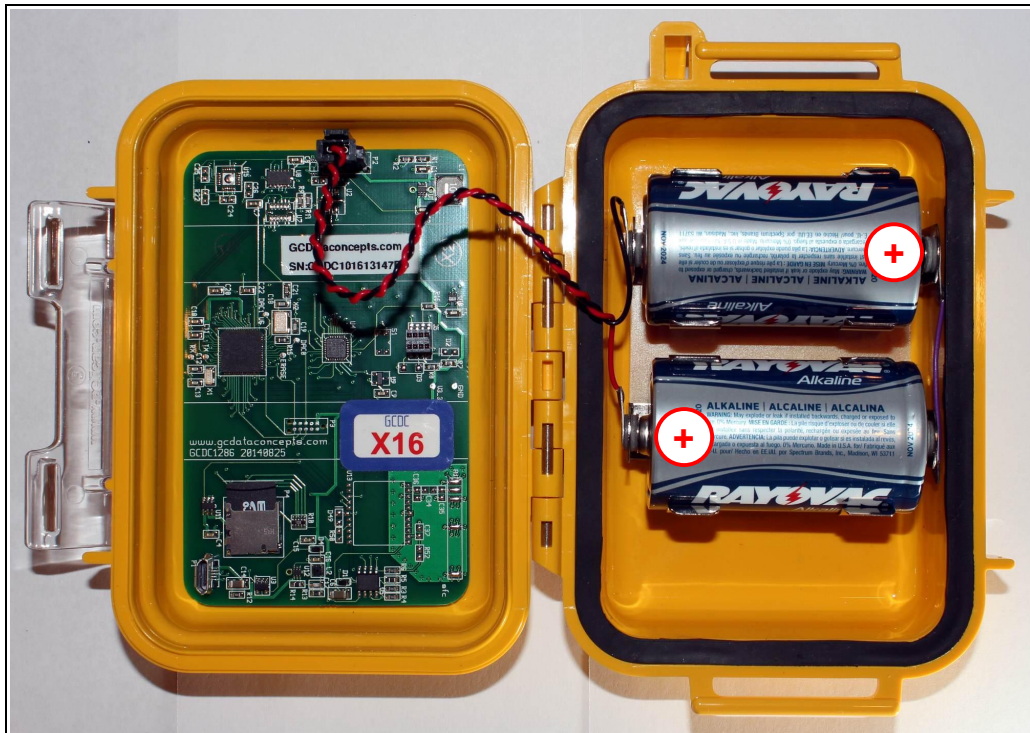


Figure 4: Battery Installation

# Multifunction Extended Life (MEL) Data Logger

## 3.2.6 System Configuration Options

The MEL data logger 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. A tag is followed by an equal sign (“=”) and an applicable tag setting. A line finishes with a newline character (For Windows systems, *Wordpad* is recommended for editing the config.txt file. *Notepad* does not terminate lines appropriately). Tags are not case sensitive. Tab and space characters are ignored. Lines starting with a semicolon (“;”) are treated as comments and ignored by the system.

The different MEL data logger versions use the same configuration file syntax but the valid tags are particular to the sensor type. Table 4 and Table 5 list the configuration file tags for the -x and -b loggers, respectively. The system will use the default settings listed in the table if the config.txt file is not found.

### 3.2.6.1 MEL-x16 and MEL-x2 Configuration Settings

**Table 4: Accelerometer 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  |
| gain                   | “low” or “high”                            | Low               | <b>Valid for MEL-x2 only</b><br>Sets the range to $\pm 1.25g$ (high) or $\pm 2g$ (low)   |
| 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                  | 28896             | The number of lines of data per data file before a new file is created   |
| samplerate             | -x16: 12, 25, 50, 100, 200, 400            | 25                | Sets the rate at which data is collected and recorded to the microSD card.   |
|                        | -x2: Integer between 4 and 512 (inclusive) |                   |  |
| starttime and stoptime | -  | -                 | Defines when to start and stop recording. Provide time in the format of MM HH DD.  |
| stoponusb              | -  | Off               | Stops data logging if 5v USB power is present  |
| statusindicators       | “Normal”, “High”, “Off”                    | Normal            | LED status indicators can be activated with normal brightness (Normal), activated with high brightness (High), or completely deactivated (Off).                                      |

## Multifunction Extended Life (MEL) Data Logger

### 3.2.6.1.1 Example MEL-x16 Configurations

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 37500 lines long or about 25 minutes.

```
; Example MEL Config file
; record constantly at 25Hz
samplerate = 25
deadband = 0
; set file length
samplesperfile = 37500
; LEDs on
statusindicators = normal
; make device start upon USB disconnect
rebootondisconnect
```

**Figure 5: Configuration File Example A**

Example B) Setting the deadband to 50 counts 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 MEL Config file
; set to 50Hz
samplerate = 50
; record motion > 0.05g
deadband = 100
; force a sample every minute
deadbandtimeout = 60
; set file length
samplesperfile = 30000
; LEDs on
statusindicators = off
; make device start upon USB disconnect
rebootondisconnect
```

**Figure 6: Configuration File Example B**

Example C) The micro-resolution is activated to provide the best timing precision at the 200 Hz sample rate. If motion exceeds 410 counts (0.2g), the device captures continuous data 200 times a second for 3 seconds or until the change in acceleration falls below 0.2g.

```
; Example MEL Config file
; set to 200Hz
samplerate = 200
; activate precision timing
microres
; set threshold to 0.2g
deadband = 410
; record two seconds
dwell = 600
deadbandtimeout = 600
; set file length
samplesperfile = 100000
; LEDs on
statusindicators = normal
```

**Figure 7: Configuration File Example C**



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## 3.2.6.1.2 Example MEL-x2 Configurations

Example A) The following configuration records data constantly at 120 hertz with the gain set to 2g. The device will boot and begin logging data once removed from a computer USB port. Each data file is 180,000 lines long, which is 25 minutes.

```

; Example X2-2 Config file
; 2g range
gain = low
; set to record constantly at 128Hz
samplerate = 120
deadband = 0
; set file length
samplesperfile = 180000
; LEDs on
statusindicators = normal
; make device start upon USB disconnect
rebootondisconnect
    
```

**Figure 8: Configuration File Example A**

## 3.2.6.2 MEL-b Configuration Settings

**Table 5: MEL-b 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 Pascals. A new sample is recorded if a sensor reading exceeds the previous recorded reading by the deadband value |
| deadbandtimeout        | An integer between 0 and 65535      | 0                 | Specifies the period in seconds when a sample is recorded regardless of the deadband setting.   |
| dwel                   | 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        | 1                 | Number of pressure samples between temperature samples  |
| 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.   |
| sampleperiod           | An integer between 1000 and 4194303 | 2000              | The period in milliseconds between samples. Use for slow data rates.  |
| samplesperfile         | An integer greater than 0           | 28896             | The number of lines of data per data file   |
| samplerate             | Integer between 1 and 20            | 2                 | Sets the rate at which data is collected and recorded to the microSD card. Use for fast rates >1Hz  |
| starttime and stoptime | -                                   | -                 | Defines when to start and stop recording  |
| stoponvusb             | -                                   | Off               | Stops data logging if 5v USB power is present (see section Error: Reference source not found)   |
| statusindicators       | “Normal”, “High”, “Off”             | Normal            | LED status indicators can be activated with normal brightness (Normal), activated with high brightness (High), or completely deactivated (Off).             |

## 3.2.6.2.1 Example MEL-b Configurations

Example A) The example configuration file sets the MEL-b to record pressure twice per second with temperature interleaved every two seconds. Each data file includes one hour of data. The device will boot and begin data logging once disconnected from the host computer.

```
;Example MEL-b config file
;set sample rate
samplerate = 2
;set file size to 60 minutes of data
samplesperfile = 7200
;sample temp every 4th pressure sample
;or every 2 seconds
interleave = 4
;set status indicator brightness
statusindicators = normal
;start when disconnected from PC
rebootOnDisconnect
```

**Figure 9: Configuration File Example A**

Example B) This configuration sets the MEL-b to record pressure and temperature once every 5 seconds. Each data file will include one day of data. The logger will start when the on/off button is pressed.

```
;Example MEL-b config file
;set sample period
sampleperiod = 5000
;set file size to 1 day of data
samplesperfile = 17280
;sample temp every pressure sample
interleave=0
;set status indicator brightness
statusindicators = high
;use on/off button
;comment out rebootondisconnect
;rebootOnDisconnect
```

**Figure 10: Configuration File Example B**

## 3.2.7 Data Files

The MEL logger 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 MEL data logger 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. 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 (“;”).

# Multifunction Extended Life (MEL) Data Logger

## 3.2.7.1 MEL-x Data Format

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. Divide the raw data by the factors listed in Table 6 to determine acceleration in “g” units. The time entry is seconds elapsed from the start time recorded in the header. Add the elapsed time to the start time to determine the complete time record of the sample.

**Table 6: MEL-x Data Conversion Factors**

| Logger Type | Configuration | Conversion Factor (counts/g) |
|-------------|---------------|------------------------------|
| MEL-X16     | -             | 2048                         |
| MEL-x2      | Low Gain      | 6554                         |
|             | High Gain     | 13108                        |

```
;Title, http://www.gcdataconcepts.com, x2-2,Kionix KXR5-2050
;Version, 638, Build date, Apr 22 2014, SN:CCDC1002131D68D
;Start_time, 2014-04-23, 10:04:37.000
;Temperature, 25.25, deg C, Vbat, 4178, mv
;Gain, low
;SampleRate, 32,Hz
;Deadband, 0, counts
;DeadbandTimeout, 0,sec
;Headers, time,Ax,Ay,Az
0.019,-47,185,-6584
0.051,-55,181,-6591
0.082,-60,176,-6593
0.113,-53,176,-6591
0.144,-44,179,-6595
0.176,-38,183,-6591
0.207,-40,191,-6593
0.238,-47,185,-6593
0.269,-53,176,-6591
0.301,-47,183,-6589
0.332,-44,179,-6589
0.363,-45,176,-6599
```

**Figure 11: MEL-x2 Example Data File**

## 3.2.7.2 MEL-b Data Format

Data entries include a time stamp, the barometric sensor reading and temperature. The time stamp is seconds elapsed from the start time recorded in the header. The barometric pressure data is recorded in Pascal units. Temperature, as reported by the barometer sensor, is periodically recorded as a third column of data and is 10 times the value in °C (the decimal character is not present).

## 3.2.7.2.1 Converting Pressure to Altitude

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

$$Altitude = 44330 \times \left( 1 - \left( \frac{P}{P_0} \right)^{\frac{1}{5.255}} \right)$$

where *Altitude* = meters above baseline altitude

*P* = pressure in Pascal

*P*<sub>0</sub> = pressure in Pascal at the baseline altitude (mean sea level = 101325 Pa)

```
;Title, http://www.gcdataconcepts.com, B1100-2, BMP085
;Version, 836, Build date, Sep 10 2014,
SN:CCDC3110131FF88
;Start_time, 2014-09-19, 17:38:25.000
;Temperature, 30.-10, deg C, Vbat, 1396, mv
;SamplePeriod, 200,msec
;Deadband, 0, counts
;DeadbandTimeout, 0,sec
;Time,Pressure (Pa),Temp (C*10)
0.013,101190
0.201,101189
0.419,101198,302
0.606,101196
0.801,101199
1.004,101197
1.223,101196,302
1.402,101199
1.605,101228
1.808,101146
2.026,101109,302
2.206,101121
2.408,101119
2.603,101109
2.822,101111,302
```

**Figure 12: MEL-b Example Data File**

## 3.2.8 Real Time Clock

A real time clock (RTC) is integrated into the MEL system and is used to determine time for each line of data recorded. 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 and software from Gulf Coast Data Concepts.

The RTC maintains ±5ppm accuracy (-40°C to +85°C), which means that it will drift accuracy about 1 second every 2 days. The RTC is powered by the battery at all times, even when the logger is “off”.

# Multifunction Extended Life (MEL) Data Logger

## 3.2.9 Memory Card

The MEL system stores data to a removable 8GB microSD flash memory card and is compatible with microSD and microSDHC type cards. The logger connects to a host computer using a micro-B type USB connector located on the internal circuit board, near the microSD card. The logger functions as a Mass Storage Device to computer operating systems when transferring data to and from the microSD memory card. The Mass Storage Device interface is supported by all desktop operating systems and special device drivers are not required. Tablet computers may not recognize the logger due to USB device limitations set by the tablet manufacturer.

The logger needs only the config.txt file to operate. The logger 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 3.2.6 and section 3.2.8). The MEL system will create a folder called “GCDC”, if not already present, to place the data files (see section 3.2.7).

## 3.3 Mechanical

The MEL is packaged in a water resistant, crush proof, and dust proof enclosure. The MEL data logger weighs 500g (1.1 lbs ) with two alkaline batteries.

### 3.3.1 Dimensions



Figure 13: Enclosure Dimensions

### **4 Software**

The MEL logger records data to comma delimited text files and uses text based files for configuration settings. Therefore, no special software is required to utilize the logger. For data analysis, Gulf Coast Data Concepts recommends using a commercial or open source mathematics package, such as MatLab, Microsoft Excel, OpenOffice Calc, Octave, R, or similar applications.