Open Acoustic Devices

AudioMoth Operation Manual

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This operation manual is designed for both new and experienced AudioMoth users. It describes how configure an AudioMoth device and how to change its on-board firmware. It also presents general tips for deployment, along with additional information, useful for maximising the utility of AudioMoth.

Contents

1 AudioMoth overview

AudioMoth is a low-cost, full-spectrum acoustic logger, based on the Gecko processor range from Silicon Labs. Just like its namesake the moth, AudioMoth can listen at audible frequencies, well into ultrasonic frequencies. It is capable of recording uncompressed audio to microSD card at rates from 8,000 to 384,000 samples per second.

Figure 1: *AudioMoth 1.1.0: A low-cost, low-power acoustic monitoring device developed for a wide variety of conservation projects.*

Released in 2017, AudioMoth has received constant support in the form of hardware, firmware and supporting software updates from the Open Acoustic Devices team.

The following manual was written to describe the operation of the following firmware and software:

- AudioMoth Firmware 1.4.4
- AudioMoth Configuration App 1.3.6
- AudioMoth Flash App 1.1.0
- AudioMoth Time App 1.0.5

1.1 Support

If you require assistance on any topics not covered by this operational manual, or wish to report a bug, contact the Open Acoustic Devices team and we will be happy to assist:

- Email us at: *theteam@openacousticdevices.info*
- Post on the support forum: *www.openacousticdevices.info/support*

1.2 Visual tour

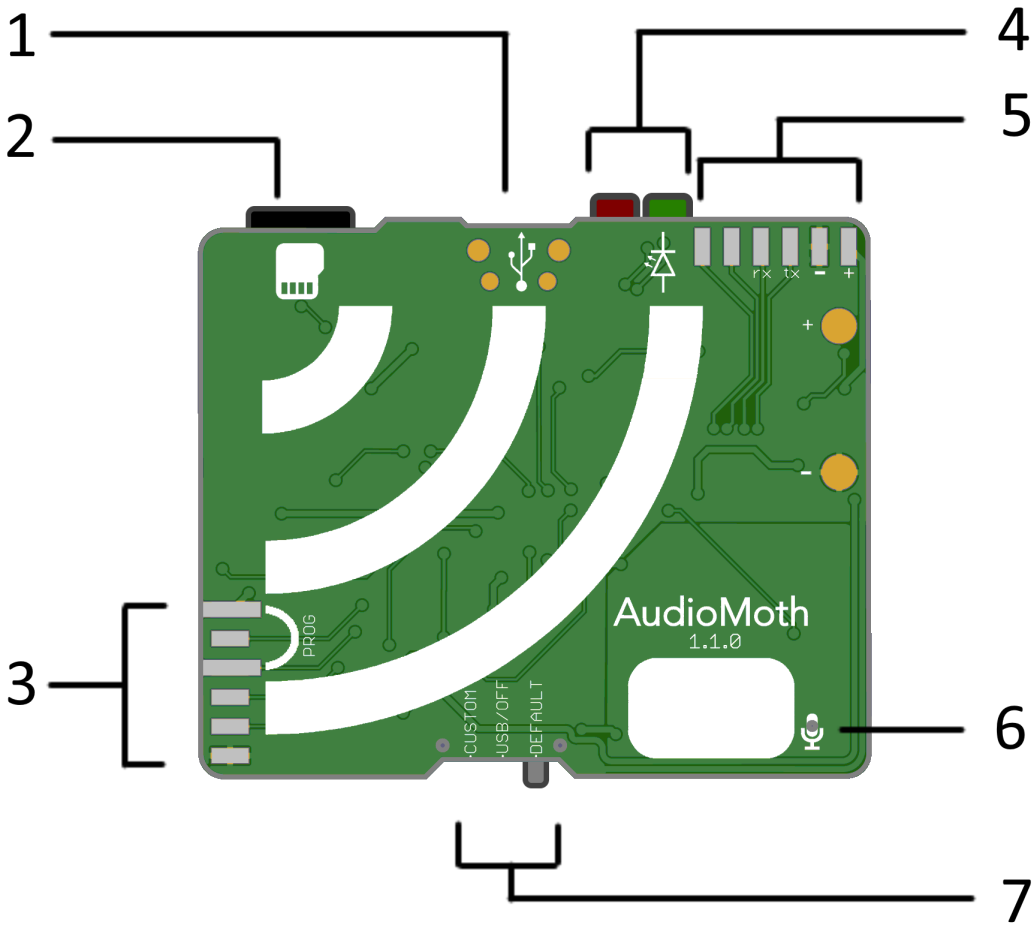


Figure 2: *Annotated diagram of an AudioMoth.*

1	**USB port:** Connect your AudioMoth to a computer using a standard microUSB cable.
2	**microSD slot:** Insert microSD card here to store recordings. For advice on purchasing the correct card, see Section 2.1.
3	**Programming header:** A series of pins which can be used to apply firmware to the AudioMoth.
4	**Status LEDs:** A green and a red LED used to communicate the status of the AudioMoth. See Section 3.2 for more information.
5	**Exposed GPIO pins:** A set of general purpose pins which can be used to communicate with and power external modules.
6	**Microphone:** An analogue MEMS microphone.
7	**Mode switch:** Change between three modes: CUSTOM, USB/OFF, and DEFAULT. See Section 3.1 for more information.

2 Preparation

2.1 Purchasing SD cards

AudioMoth supports microSD cards of any size, however performance may vary depending on the speed of the card.

We recommend using Sandisk Extreme UHS Speed Class 3 (U3) microSDHC and microSDXC cards due to its performance and wide availability. Other cards may also be used but be sure to test them first. Slower cards, such as Class 10 or UHS Speed Class 1 (U1) cards, may not work consistently at high sampling rates.

SD cards typically come formatted in one of two systems. Cards that are 32GB or less in size are normally supplied formatted using the MS-DOS (FAT32) system. Cards greater than 32GB are typically supplied formatted using the exFAT system.

From AudioMoth firmware version 1.2.2 onwards both FAT32 and exFAT file formats are fully supported. However, if you are using an earlier version of the AudioMoth firmware ensure that your SD card is reformatted as a MS-DOS (FAT32) card prior to use, or re-flash you AudioMoth to use the newer firmware (for instructions on how to do this, read Section 6).

2.2 Purchasing batteries

On average, good quality alkaline AA batteries have a capacity of approximately 2600 mAh, whereas equivalent lithium batteries have approximately 3600 mAh. Due to the low power consumption of the AudioMoth in general, any AA battery is suitable for standard deployments. For more intensive deployments involving long recordings or high sample rates, we advise using lithium batteries to maximise lifetime. AudioMoth battery cells are arranged in series.

3 Usage

3.1 Modes

The switch on the side of the AudioMoth controls the current mode of the device. AudioMoth has three modes of operation: USB/OFF, CUSTOM, and DEFAULT.

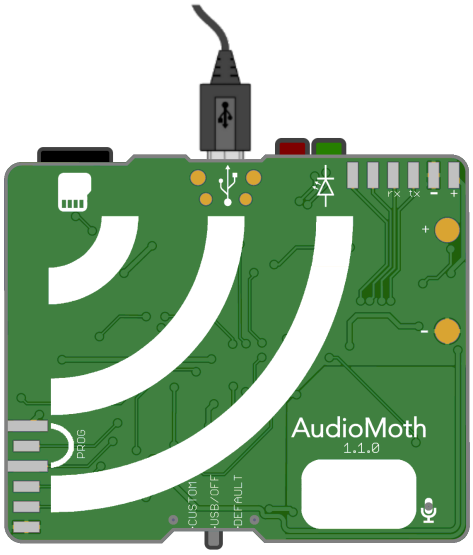


Figure 3: *An AudioMoth plugged in and ready for communication with one of the many supporting applications.*

USB/OFF mode serves a dual purpose. When a USB cable is used to plug the device into a computer, this mode allows AudioMoth supporting software to communicate with the device and perform tasks such as configuring the recording schedule, setting the on-board clock, and applying new firmware. The steps required to performed each of these tasks are explained in Section 4 and 6 respectively. When not plugged in, an AudioMoth in USB/OFF mode is switched off, however will maintain any configured settings and the current time.

If a recording schedule has been configured on a device, switching it to CUSTOM mode will start running the configuration. During periods defined by the recording schedule, the AudioMoth will alternate between recording and sleeping if cyclic recording is enabled or record constantly until the period ends if it is disabled.

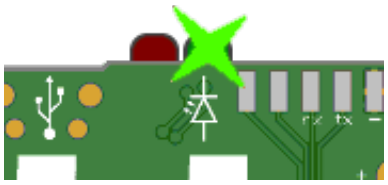
If you wish to start a recording outside an applied schedule, switch to DEFAULT mode and your AudioMoth will start recording continuously. This mode will use the sample rate and gain level of the current configuration.

3.2 What do the flashing LEDs mean?

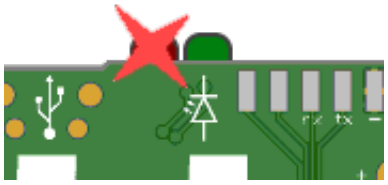
AudioMoth has 2 colour LEDs, visible on the side of the device. Various combinations of these two LEDs flashing represent different modes of operation or tasks it is carrying out.

With switch set to CUSTOM

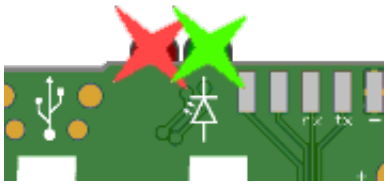
When sleeping between recordings a single green light will flash.



When making a recording a single red light will flash.

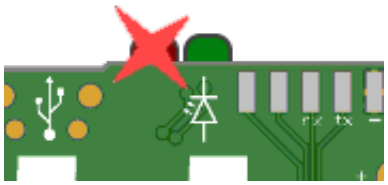


Both lights flashing signifies that an error has occurred. Either the time is not set or no recording periods set.



With switch set to DEFAULT

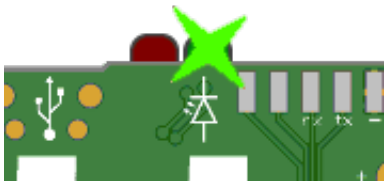
When making a recording a single red light will flash.



Both lights flashing signifies that an error has occurred. Check that the SD card is inserted correctly.

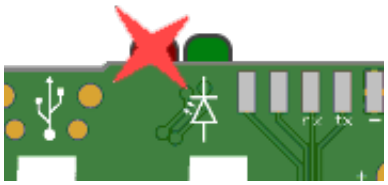
With switch set to USB/OFF

When connected to USB the green LED will remain on constantly.



When first switched to USB/OFF, the red LED will flash a number of times corresponding to the current battery level of the device.

4 flashes	> 4.6 V
3 flashes	> 4.4 V
2 flashes	> 4.0 V
1 flash	> 3.6 V
10+ flashes	< 3.6 V



3.3 Recordings

Every AudioMoth recording is timestamped to let you know the exact date and time it was created. This timestamp is included in the file name in the format "*YYYYMMDD_hhmmss.WAV*", as well as the metadata of each file.

Each recording's metadata includes information such as the recording date/time, the sample rate and gain level it was recorded at, the unique ID of the device which recorded it, and the battery level at the time of recording. Metadata editing software such as *exiftool* is required to view this information.

The AudioMoth timestamp and recording schedule is either set according to the local timezone of the user or UTC (Co-ordinated Universal Time). UTC is equivalent to GMT (Greenwich Mean Time) and does not change with daylight savings. Whether an AudioMoth uses local time or UTC time is a setting which is chosen when its configuration is applied (see Section 4.4).

3.4 Clock

In order to use the current time and date to name each recording, AudioMoth devices must keep track of the current time. When the batteries are removed and power to the device is lost, it is unable to keep track of the time and resets to 01/01/1970 at 00:00. For this reason, whenever the batteries are removed from your device, you must connect it to a computer and set the clock using either the AudioMoth Configuration App (usage described in Section 4) or the AudioMoth Time App (described in Section 7).

As well as the current time and date, any applied settings which alter how the AudioMoth behaves are lost when the batteries are removed. Once configured for deployment, make sure to set each AudioMoth to USB/OFF and secure the batteries until deployment.

4 Configuring a device

4.1 AudioMoth Configuration App

The AudioMoth Configuration App is one of several pieces of supporting software designed for use with your AudioMoth device. It allows you to alter the behaviour of an AudioMoth, create a recording schedule, save and load configurations, and expand recordings which have been compressed using amplitude threshold recording. For more information on amplitude threshold recording, see Section 4.6.

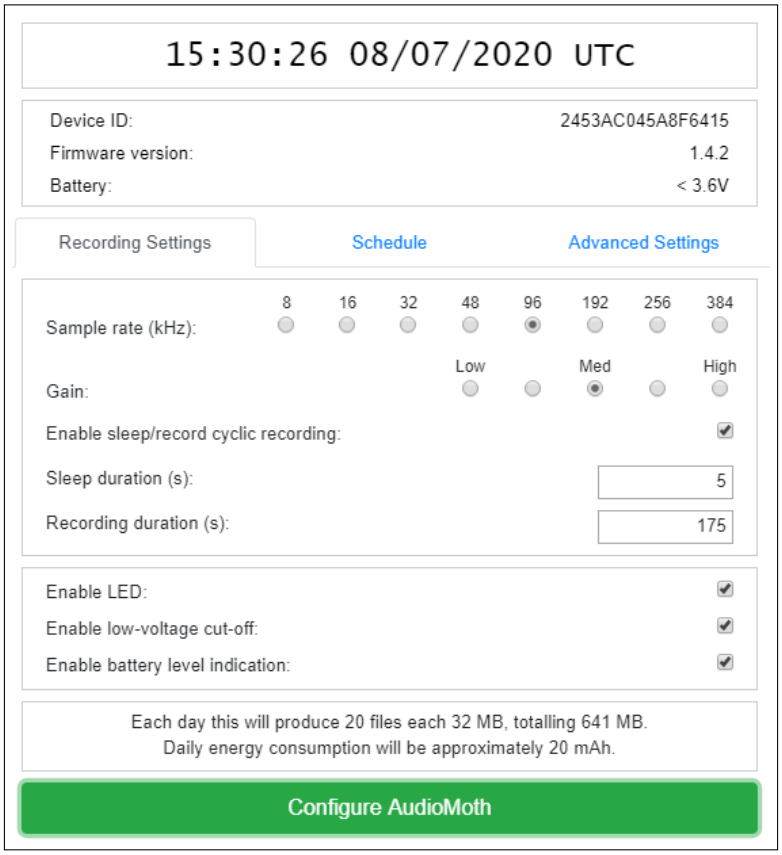


Figure 4: *The AudioMoth Configuration App, part of a family of software designed to support AudioMoth devices.*

The latest version of the AudioMoth Configuration App can be found at www.openacousticdevices.info/applications.

4.2 Choosing a sample rate

The first step to configuring an AudioMoth device is setting the sample rate. The sample rate is the number of audio samples captured per second. Higher sample rates result in recordings with a wider frequency bandwidth, but larger file sizes.

You should use a sample rate that is at least two times the highest frequency you wish to record. This is known as the *Nyquist rate* and is the minimum sample rate require to capture a particular frequency.

4.3 Choosing a gain level

The gain of a recording is the amount of amplification which is applied to audio as it is recorded. Assigning this value will require trial and error in your deployment conditions but can be left on medium for most locations without extreme background noise. If the gain is set too low, the target sound may not be audible in the recordings, if it is set too high, your recordings may clip and distort the original sound.

4.4 Creating a schedule

When configuring an AudioMoth for deployment you will likely wish to assign it a recording schedule. During the chosen recording periods an AudioMoth will either record constantly and produce files the length of the recording period or use the cyclic recording settings entered on the *Recording Settings* tab. If the *Enable sleep/record cyclic recording* checkbox is checked, your AudioMoth will alternate between recording and sleeping until the period ends.

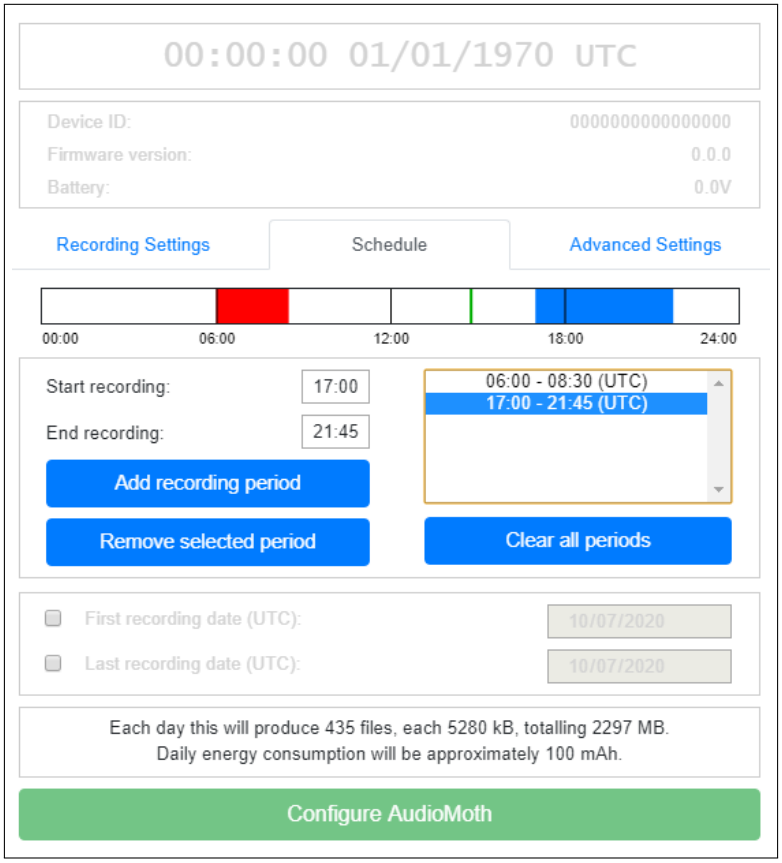


Figure 5: *An example recording schedule which will produce recordings in the morning and evening.*

You can create up to 4 recording periods of any length which will recur every 24 hours. Enter the start and end time of each desired period using the 24-hour format and press *Add recording period* to add each to the schedule. Recordings will always be split at midnight as a new day starts and the schedule restarts.

When you first open the AudioMoth Configuration App, it will use the Universal Co-ordinated Time (UTC) timezone. This is a timezone aligned to GMT which does not change with daylight savings time. If you wish to set a schedule using your local timezone instead, press ctrl + T (on Mac press cmd + T). This will switch the app and all assigned recording periods to use the timezone on the machine the app is running on.

When using a local timezone, the midnight split will still occur at the midnight in UTC. For example, if you use the app in GMT+2, this is offset from UTC by 2 hours and the split will occur at 02:00 (GMT+2).

On this tab you are also able to select a start and end date for the schedule. When a *First recording date* is

enabled, the device will remain in sleep mode when set to CUSTOM. When the chosen date is reached the schedule will start.

4.5 Filtering

The AudioMoth Configuration App comes with three filters which can be used to limit the frequency components present in recordings produced by a configured AudioMoth. These filters are a low-pass filter, a high-pass filter, and a band-pass filter.

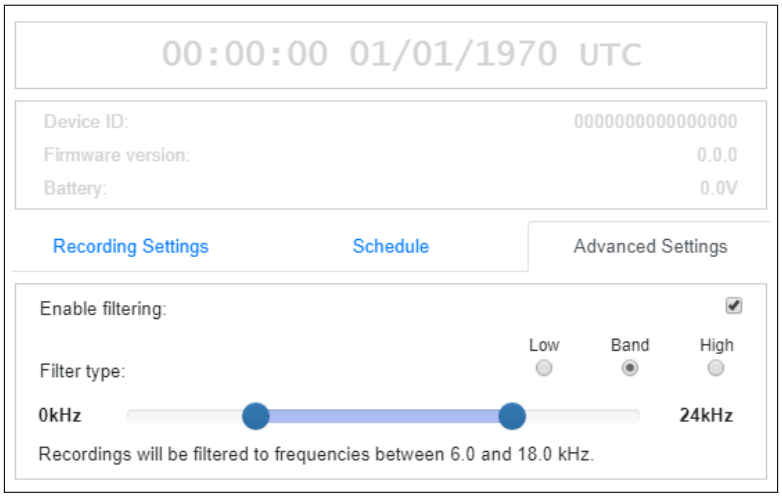


Figure 6: *Three optional filters which can be applied to recordings: low, high, and band-pass.*

The low-pass filter will reduce the amplitude of frequencies above the given frequency, the high-pass below the given frequency, and the band-pass outside a chosen band. The filters are first order Butterworth filters.

4.6 Amplitude threshold recording

4.6.1 Usage

Amplitude threshold recording is a recording mode where an AudioMoth will only collect samples when their amplitude exceeds a certain value. This value can be anywhere between 0 and the maximum amplitude value of 32,768, corresponding to 0 to 100% of full-scale amplitude. Gaps between these acoustic events are compressed down to reduce the size of the recording file.

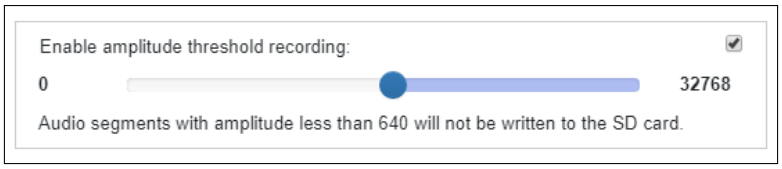


Figure 7: *Amplitude threshold recording settings allow you to cut recordings down to just samples above a given amplitude.*

This can be useful in scenarios such as bat detection, where a high-pass filter can be used in conjunction to only record when loud, high frequency echolocation sounds are picked up. This means that devices can be deployed for much longer without having to replace the SD card as high sample rate recordings can quickly fill the storage.

All amplitude threshold recordings will have *T* appended to their file name to make identifying them easier. Details of the the threshold chosen to create that file are included in the metadata.

4.6.2 Expanding amplitude threshold recordings

When an amplitude threshold recording is created, the gaps between samples above the chosen threshold are removed, thus reducing the size of the overall file. The lengths of these removed gaps is encoded into the resulting WAV file. If you wish to know exactly when within the recording period a specific acoustic event occurred, then the file must be expanded and the gaps put back in.

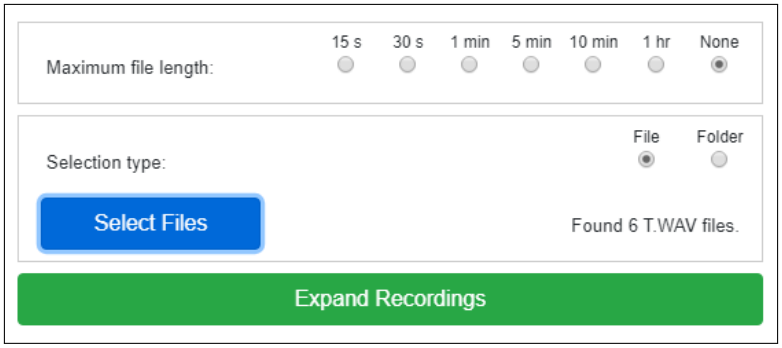


Figure 8: *Amplitude threshold recordings must be expanded to regain the spacing between acoustic events.*

This can be done within the AudioMoth Configuration App by opening the expansion window through the *File* menu, or by pressing ctrl + E (on Mac press cmd + E). Once the window is open you can select the maximum size of the expanded files. If the expanded recording exceeds the chosen length, it will be split into multiple files. Next, select the files you wish to expand and press *Expand Recordings*.

4.7 Estimating lifespan

The AudioMoth Configuration App uses the given recording settings and periods to calculate the approximate energy consumption of the device in mAh and storage consumption in bytes each day.

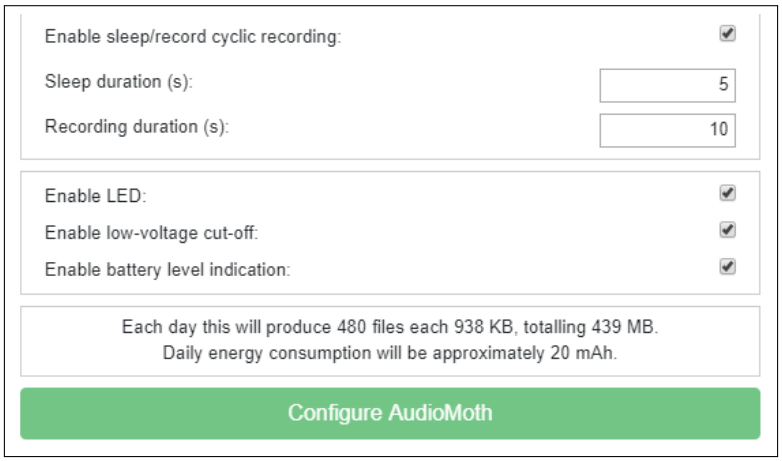


Figure 9: *Approximate energy and storage calculations produced by the AudioMoth Configuration App, given a recording schedule.*

Be sure to pick batteries and microSD cards with sufficient capacity for your deployment. If amplitude thresholding is used then the approximation will be of the upper limit if the device was triggered at every possible opportunity.

4.8 Saving and loading configurations

The schedule and settings assigned in the AudioMoth Configuration App can be saved to an external file and loaded on another machine. With this you can produce a standard configuration and distribute it to anyone carrying out a deployment.

AudioMoth configuration files use the "*.config*" file extension and can be read with a standard text editor. To save your current configuration, click *Save Configuration* in the *File* menu or press ctrl + S (on Mac press cmd + S). Load a configuration by clicking *Load Configuration* or pressing ctrl + O (on Mac press cmd + O).

4.9 Example configurations

AudioMoth can be configured for a wide variety of applications. Here are a couple of example configurations which can be copied to a text document, saved with the *.config* extension, and loaded by the AudioMoth Configuration App to be applied to a device.

```
{
    "timePeriods": [{"startMins":1080,"endMins":1260}],
    "ledEnabled": false,
    "lowVoltageCutoffEnabled": true,
    "batteryLevelCheckEnabled": true,
    "sampleRate": 256000,
    "gain": 2,
    "recordDuration": 60,
    "sleepDuration": 60,
    "localTime": false,
    "dutyEnabled": true,
    "passFiltersEnabled": true,
    "filterType": "high",
    "lowerFilter": 60000,
    "higherFilter": 65535,
    "amplitudeThresholdingEnabled": true,
    "amplitudeThreshold": 448
}
```

This configuration is designed to record bats using a 250 kHz sample rate, recording using both a high-pass filter set at 60 kHz and amplitude threshold recording between 18:00 and 21:00. The LED is also disabled to prevent the device from being spotted while deployed.

```
{
    "timePeriods": [{"startMins":240,"endMins":420}],
    "ledEnabled": true,
    "lowVoltageCutoffEnabled": true,
    "batteryLevelCheckEnabled": true,
    "sampleRate": 16000,
    "gain": 2,
    "recordDuration": 30,
    "sleepDuration": 300,
    "localTime": false,
    "firstRecordingDate": "2020-07-19",
    "lastRecordingDate": "2020-08-19",
    "dutyEnabled": true,
    "passFiltersEnabled": false,
    "filterType": "band",
    "lowerFilter": 6000,
    "higherFilter": 8000,
    "amplitudeThresholdingEnabled": false,
    "amplitudeThreshold": 0
}
```

This configuration is designed to record a dawn chorus, recording at a much lower 16 kHz between 04:00 and 07:00. This configuration also only records between *19/07/2020* and *19/08/2020* (make sure you update these dates if you import this configuration).

5 Cases and protection

AudioMoth requires protection when deployed in most environments. Rain, moisture in the air, and insects can all damage your device and render it unusable. Producing your own bespoke protective case is one option, however special care must be take to avoid limiting the acoustic sensitivity of the AudioMoth's microphone. It is for this reason that we recommend either deployment in grip-sealed plastic bags or an official AudioMoth IPX7 Waterproof Case, depending on the level of protection required.

5.1 AudioMoth IPX7 Waterproof Case

The AudioMoth IPX7 Waterproof Case is the official protective enclosure for AudioMoth 1.0.0 and 1.1.0. The case is made from injection-moulded polycarbonate and comes with an adjustable velcro strap, which makes securing AudioMoth simple and easy. The case is compact and highly resilient and will house AudioMoth for extended periods of time in a wide variety of environments.

Figure 10: *The injection-moulded AudioMoth IPX7 Waterproof case.*

The case is sealed using a locking clasp and a compression o-ring which ensures water can't get in. The microphone port uses a Porelle acoustic vent to allow sound in while remaining waterproof. This way sound quality is maintained with the added protection.

6 Updating and applying new firmware

6.1 AudioMoth Flash App

AudioMoth is supported with regular firmware updates which fix bugs as they are discovered and add additional functionality to the device. In order to receive these updates you will need to use the AudioMoth Flash App to download and apply new firmware versions.

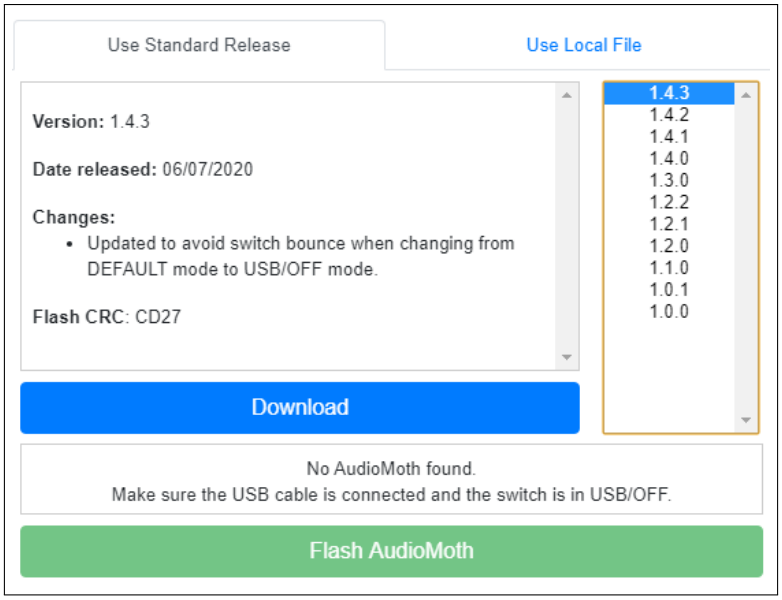


Figure 11: *The AudioMoth Flash App can be used to download and apply the latest AudioMoth firmware.*

The latest version of the AudioMoth Flash App can be found at www.openacousticdevices.info/applications.

6.2 Flashing with official firmware

When you first load the AudioMoth Flash App, ensure your machine has an internet connection so the app is able to pull information on all released firmware versions. Once the list has been loaded, click *Download* with the firmware version at the top of the list selected.

In order to apply firmware to your AudioMoth, it must be put into flash mode. From firmware version 1.3.0 onwards, AudioMoth devices can be automatically switched to flash mode using the AudioMoth Flash App. If you are updating from a newer version than 1.3.0, simply connect your AudioMoth using a USB cable and click *Flash AudioMoth*. Once the flash process is complete **be sure to disconnect the USB cable, then remove and reinsert batteries before use.** A newly flashed AudioMoth must have its power cycled before use.

If your device currently has a firmware version older that 1.3.0, you will have to manually switch to flash mode. This can be done by using the instructions found by clicking *Show Manual Switch Instructions* in the *File* menu, or pressing ctrl + I (on Mac press cmd + I). This process requires a metal paperclip.

6.3 Flashing with custom firmware

AudioMoth firmware is open-source and extensive documentation is available online for adapting the code used to produce the standard firmware implementation. Once the custom firmware has been compiled for distribution, the resulting *.bin* can be applied to a device using the AudioMoth Flash App by clicking the *Use Local File* tab.

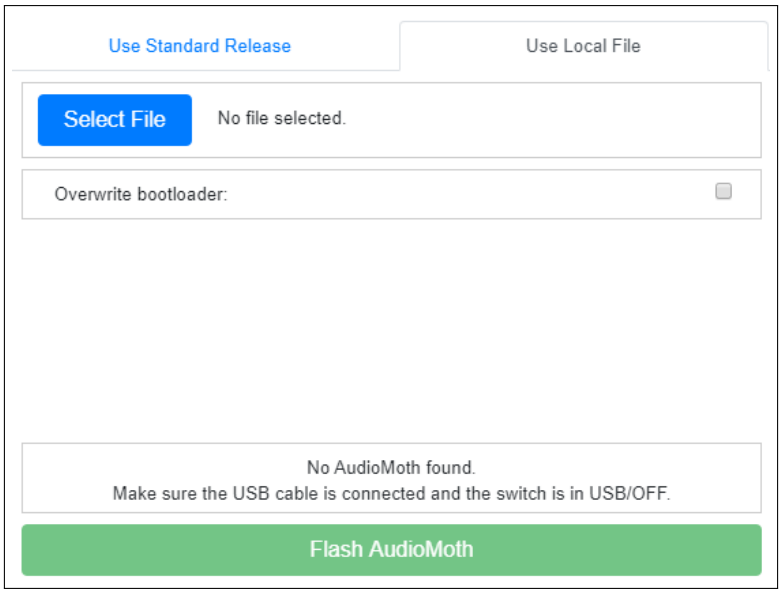


Figure 12: *The AudioMoth Flash App can apply custom firmware using binaries you have downloaded or compiled yourself.*

Once on the *Use Local File* tab, select the binary you wish to apply to your AudioMoth and click *Flash AudioMoth*. Once the flash process is complete **be sure to disconnect the USB cable, then remove and reinsert batteries before use.** A newly flashed AudioMoth must have its power cycled before use.

Certain firmware implementations will replace the bootloader of your AudioMoth and require the checkbox to be checked before flashing. **Use this setting with extreme caution as overwriting the bootloader can render your AudioMoth unusable.**

7 Setting the clock

For most users with the default AudioMoth firmware, setting the clock on an AudioMoth device is done using the AudioMoth Configuration App (described in Section 4). However, non-standard firmware is not required to support the Configuration App, meaning it may not be possible to set the clock this way.

7.1 AudioMoth Time App

The AudioMoth Time App allows users to both view information about a connected device (such as current firmware and battery level), as well as set the clock. Provided the variant firmware on your device uses the foundations laid out by the AudioMoth Project Github repository, the clock can always be set using the AudioMoth Time App.

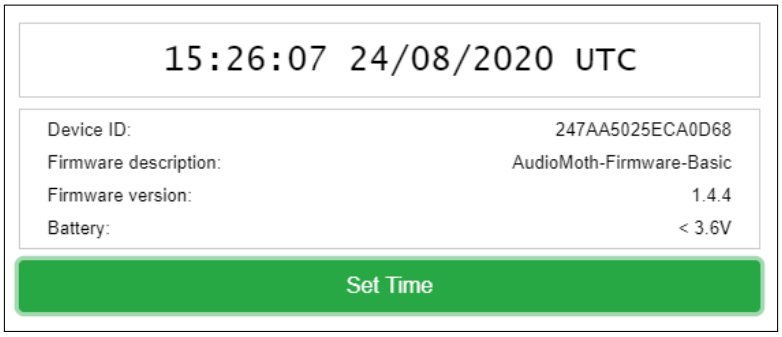


Figure 13: *The AudioMoth Time App, part of a family of software designed to support AudioMoth devices.*

The latest version of the AudioMoth Time App can be found at www.openacousticdevices.info/applications.

8 Acknowledgements

This operational manual was produced by Open Acoustic Devices. Thanks to Tessa Rhinehart who produced an early AudioMoth guide which has helped the AudioMoth community greatly and informed which topics are useful for a new AudioMoth user to include in this guide.