Motion Studio User's Guide

Contents

1 Welcome

Congratulations on your purchase! APDM movement monitors are the most advanced in the world, and provide a complete feature set in a small, attractive, and unobtrusive package.

Motion Studio provides an easy to use software interface to our movement monitors and supporting hardware, and will enable you to:

- Configure your monitor's settings and features
- Use your hardware for synchronized, wireless streaming of data (Opals only)
- Use your hardware for synchronized logging of data (Opals and Emeralds only)
- Use your hardware for long duration, non-synchronized logging of data (Opals, Emeralds, and Sapphires)
- Organize and view your recorded data
- Keep your hardware up-to-date with firmware updates

2 Quick Start

The following steps are required to get up and running:

1. Make sure that all of the hardware drivers are installed. See the "Hardware Driver Installation" section of this document for details.
2. Download and install Motion Studio. See the "Downloading the Latest Software" section of this document for details.
3. Plug the access point(s) into the your computer.

4. Plug the docking station(s) into your computer. If multiple docking stations are chained together, external power is required.

5. Dock the movement monitors into their docking stations. You should see the light on the monitors turn dark blue.

6. Open Motion Studio, and click on the “Configure” button. Choose your desired recording mode, and click “Finish”.
7. Undock the monitors.
8. Wireless streaming mode
    a) After about 5-15 seconds, you’ll notice that the LED’s on the monitors will blink green in unison, and that the access point will have a blinking green LED, indicating that it is receiving data from the monitors.
    b) Press the “Stream” button in the toolbar. You can view live data streaming in the real-time chart.
    c) Press the “Record” button to start recording data.
9. Logging modes
    a) Undock the monitors from their docking stations. They will start recording within several seconds. If using the synchronized logging mode, the LEDs on the monitors will blink in unison.
    b) When you are done recording, dock the monitors, and press the “Import Data” button in the toolbar to retrieve the data from the monitors. See “Import Manager” section of this document for details.

3 System Overview

The APDM movement monitoring system allows the user to record data from multiple monitors; each integrating a suite of sensors. The system can be configured in 3 recording modes allowing for a wide rage of applications. Some movement monitors are limited to a subset of these modes allowing for a lower cost solution. The modes of operation are synchronized streaming, synchronized logging, and low power logging. Regardless of the mode the movement monitor always will record data to its local memory card which can be downloaded for offline analysis.

3.1 Movement Monitors

Movement monitors are the key element of the system and combine a complement of sensors within a single package. Sensors include a 3 axis accelerometer, a 3 axis gyro, a 3 axis magnetometer, and a temperature sensor. The accelerometers can be configured in a high 6G mode, or a low 2G mode depending on the target application. There are a number of options for securing the monitors on subjects using a selection of straps.

The Opal movement monitor

3.1.1 The Opal

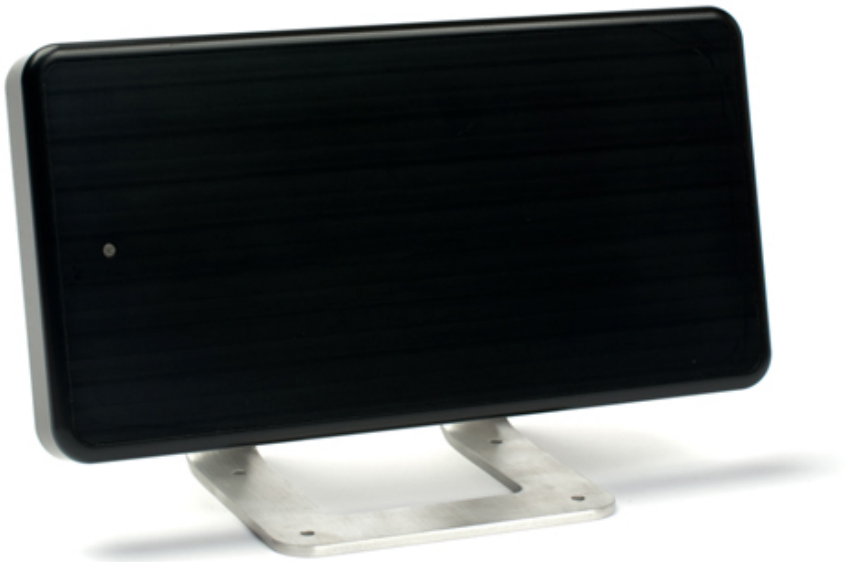
The Opal is APDM's full featured movement monitor allowing for use of all 3 modes of operation.

3.1.2 The Emerald

The Emerald is an option that allows for logging only without the ability to stream data in real time. This version allows for synchronized and low power logging giving the user the ability to do long term studies with subjects at home or in a clinical environment. It is recommended for users that require multiple movement monitors to be recording on a subject at one time.

3.1.3 The Sapphire

The Sapphire allows only for the low power logging mode. This version of the movement monitor has no wireless capabilities and may be the optimal choice for RF sensitive environments or where a single movement monitor is needed without synchronization.



The access point, for communicating wirelessly with your movement monitors

3.2 Access Point

The wireless access control point (access point for short) allows for wireless communication between the host computer and Opal movement monitors. A single access point can support up to 6 Opals.

The docking station, for charging, configuring, and downloading data from your movement monitors

3.3 Docking Station

The docking station is used to configure, charge, and download data from the movement monitors.

3.4 Recording Modes

Depending on the application of the movement monitor system one of the three available configuration options can be selected. Each will have different requirements so not all configurations may be available.

3.4.1 Synchronized Streaming

In the synchronized streaming mode, access points attached to a PC collect data transmitted wirelessly from the movement monitors. Each movement monitor is also saving all data to its on board memory for download later as a backup collection mechanism. This mode allows for near real time collection and processing of data from multiple synchronized movement monitors. Only the Opals can be used in this mode.

3.4.2 Synchronized Logging

Synchronized logging gives the user the ability to collect data with multiple movement monitors and tightly correlate the individual recordings during offline analysis. The synchronization is achieved through wireless communication between the monitors. In this mode, up to 32 monitors can be synchronized within a single “mesh”. Only Emeralds and Opals are able to use this mode.

3.4.3 Low Power Logging

All movement monitor products (Opals, Emeralds, and Sapphires) are able to operate in the low power logging mode. In this mode, the monitors’ wireless radios are disabled, decreasing the power required for operation. This enables the system to run for longer periods of time. Since the mode does not use any wireless synchronization, each movement monitor will collect data independently and potentially at slightly different rates due to clock drift. This mode is recommended when tight correlation of data between multiple movement monitors is not

needed.

3.5 Motion Studio

Motion Studio is the default software suite bundled with the APDM movement monitor system. It provides an easy way to get up and running collecting data with your movement monitors.

3.6 APDM Software Development Kit

The APDM Software Development Kit (SKD) provides a programming interface to configure and stream data from the movement monitors. In addition, it also provides functions for converting the raw data files found on the monitor's memory card into either a HDF5 (recommended) format or CSV. The SDK provides the same low level interface to the hardware that Motion Studio is built upon.

4 Downloading the Latest Software

Motion Studio is supported on the following platforms:

- Apple Macintosh OSX 64-bit
- Apple Macintosh OSX 32-bit
- Windows 32-bit (XP, Vista, Windows 7)
- Windows 64-bit (Vista, Windows 7)
- Linux 32-bit
- Linux 64-bit

To download the latest version of Motion Studio, visit:

http://share.apdm.com/motion_studio/

and select the version that matches your operating system.

Note: To simplify the Java configuration on the Windows platform, the 32- and 64- bit versions of Motion Studio come pre-bundled with the appropriate Java Runtime Environment (JRE). This adds about 70 Mb to the download size, but removes a major variable in the installation process.

Note: Motion Studio requires Java 1.6 to run. Make sure your Java installation is up to date before attempting to launch the application.

Note: In order to use the 64-bit version of Motion Studio, you also need to have the 64-bit Java JRE installed.

Unzip the contents of the download into your preferred installation directory.

The download includes everything you need to get started, including:

- Drivers
- Firmware
- The Motion Studio desktop application

5 Hardware Driver Installation

5.1 Macintosh OSX (x32/x64)

- Copy the file found at your installation's "MotionStudio/drivers/libftd2xx.0.1.6.dylib" to your "/usr/local/lib" directory. You will need administration privileges to do so.

5.2 Windows XP (x32)

5.2.1 Update Registry

1. Double click on the "MotionStudio/drivers/apdm_usb_serial_number.reg" file and click through the resulting dialogs.
2. If double clicking on the file does not automatically import the registry entry:
   a) Click on the "Start" button.
   b) Click on "Run"
   c) Type "regedit" and press return.
   d) Select "File→Import..." and select the file at "MotionStudio/drivers/apdm_usb_serial_number.reg"

5.2.2 Access Point

1. Plug the access point into your computer.
2. The "Welcome to the Found New Hardware Wizard" dialog will popup
3. Select "No, not this time"
4. Click "Next"
5. Check "Install from a list or specific location"
6. Click "Next"
7. Uncheck "Search removable media"
8. Check "Include this location in the search"
9. Click the "Browse" button and navigate to your installation's "MotionStudio/drivers/apdm_accesspoint_drivers" folder
10. Click "Ok"
11. Click "Next"
12. If Windows prompts you about the driver not being signed, click 'Continue Anyway'
13. Click "Finish"

5.2.3 Docking Station

1. Copy the file “MotionStudio/drivers/ftd2xx.dll” to the folder located at “C:/Windows/system32”. You will need administrator priviledges to do so.
2. Attach a USB cable to the docking station. If more than one docking stations are chained together into a single unit, then external power has to be connected as well.
3. Plug the docking station into your computer.
4. The “Welcome to the Found New Hardware Wizard” dialog will popup
5. Select “No, not this time”
6. Click “Next”
7. Check “Install from a list or specific location” and click “Next”
8. Uncheck “Search removable media”
9. Check “Include this location in the search”
10. Click the “Browse” button and navigate to the “MotionStudio/drivers/apdm_docking_station_drivers” folder
11. Click “Ok” and Click “Next”
12. If Windows prompts you about the driver not being signed, click ’Continue Anyway’
13. Click “Finish”
14. This action may need to be repeated for each docking station installed. Docking stations that are plugged in but are not yet installed will blink blue.

5.3 Windows Vista (x32/x64)

5.3.1 Update Registry

1. Double click on the “MotionStudio/drivers/apdm_usb_serial_number.reg” file and click through the resulting dialogs.
2. If double clicking on the file does not automatically import the registry entry:
   a) Click on the “Start” button.
   b) Click on “Run”
   c) Type “regedit” and press return.
   d) Select “File→Import...” and select the file at “MotionStudio/drivers/apdm_usb_serial_number.reg”

5.3.2 Access Point

1. Plug the access point into your computer.
2. A “Found New Hardware” dialog will pop-up.
3. Select the “Locate and install driver software” option
4. Select “I don’t have the disc. Show me other options”.
5. Select “Browse my computer for driver software”.
6. Click on the “Browse” button and navigate to the “MotionStudio/drivers/apdm_accesspoint_drivers” folder.

7. Check “Include Subfolders”.
8. Click “Next”.
9. A warning message will be presented indicating that “Windows cannot verify the publisher of this driver software”.
10. Click “Install this driver software anyway”.
11. Close the confirmation dialog.

5.3.3 Docking Station

1. Copy the file “MotionStudio/drivers/ftd2xx.dll” to the folder located at “C:/Windows/system32”. You will need administrator priviledges to do so.
2. Attach a USB cable to the docking station. If more than one docking stations are chained together into a single unit, then external power has to be connected as well.
3. Plug the docking station into your computer.
4. A “Found New Hardware” dialog will pop-up.
5. Select the “Locate and install driver software” option
6. Select “I don’t have the disc. Show me other options”.
7. Select “Browse my computer for driver software”.
8. Click on the “Browse” button and navigate to the “MotionStudio/drivers/apdm_docking_station_drivers” folder.
9. Check “Include Subfolders”.
10. Click “Next”.
11. A warning message will be presented indicating that “Windows cannot verify the publisher of this driver software”.
12. Click “Install this driver software anyway”.
13. Close the confirmation dialog.
14. This action may need to be repeated for each docking station installed. Docking stations that are plugged in but are not yet installed will blink blue.

5.4 Windows 7 (x32/x64)

5.4.1 Access Point

1. Plug the access point into your computer.
2. There may be an notification that the device driver could not be installed.
3. Click on the Windows “Start” button
4. Right-click on the “Computer” button and select “Manage”
5. Select the “Device Manager”
6. Under “Other Devices” there should be an entry for “AccessPoint” with a yellow exclamation point next to it.
7. Right-click on the “AccessPoint” entry and select “Update Driver Software...”

8. Select “Browse my computer for driver software”
9. Click on the “Browse” button and navigate to the “MotionStudio/drivers/apdm_accesspoint_drivers” folder.
10. Check “Include Subfolders”
11. Click “Next”
12. A warning message will be presented indicating that “Windows cannot verify the publisher of this driver software”.
13. Click “Install this driver software anyway”.
14. Close the confirmation dialog.

5.4.2 Docking Station

1. Copy the file “MotionStudio/drivers/ftd2xx.dll” to the folder located at “C:/Windows/system32”. You will need administrator priviledges to do so.
2. Attach a USB cable to the docking station. If more than one docking stations are chained together into a single unit, then external power has to be connected as well.
3. Plug the docking station into your computer.
4. There may be an notification that the device driver could not be installed.
5. Click on the Windows “Start” button
6. Right-click on the “Computer” button and select “Manage”
7. Select the “Device Manager”
8. Under “Other Devices” there should be an entry for “DockingStation” with a yellow exclamation point next to it.
9. Right-click on the “DockingStation” entry and select “Update Driver Software...”
10. Select “Browse my computer for driver software”
11. Click on the “Browse” button and navigate to the “MotionStudio/drivers/apdm_docking_station_drivers” folder.
12. Check “Include Subfolders”
13. Click “Next”
14. A warning message will be presented indicating that “Windows cannot verify the publisher of this driver software”.
15. Click “Install this driver software anyway”.
16. Close the confirmation dialog.
17. This action may need to be repeated for each docking station installed. Docking stations that are plugged in but are not yet installed will blink blue.

5.5 Linux (x32/x64)

The user running the APDMsoftware libraries will need to have appropriate permissions to interface with particular USB devices. This can be configured via the udev system. The user will need access to devices with the following vendor ID (VID) and product ID (PID):

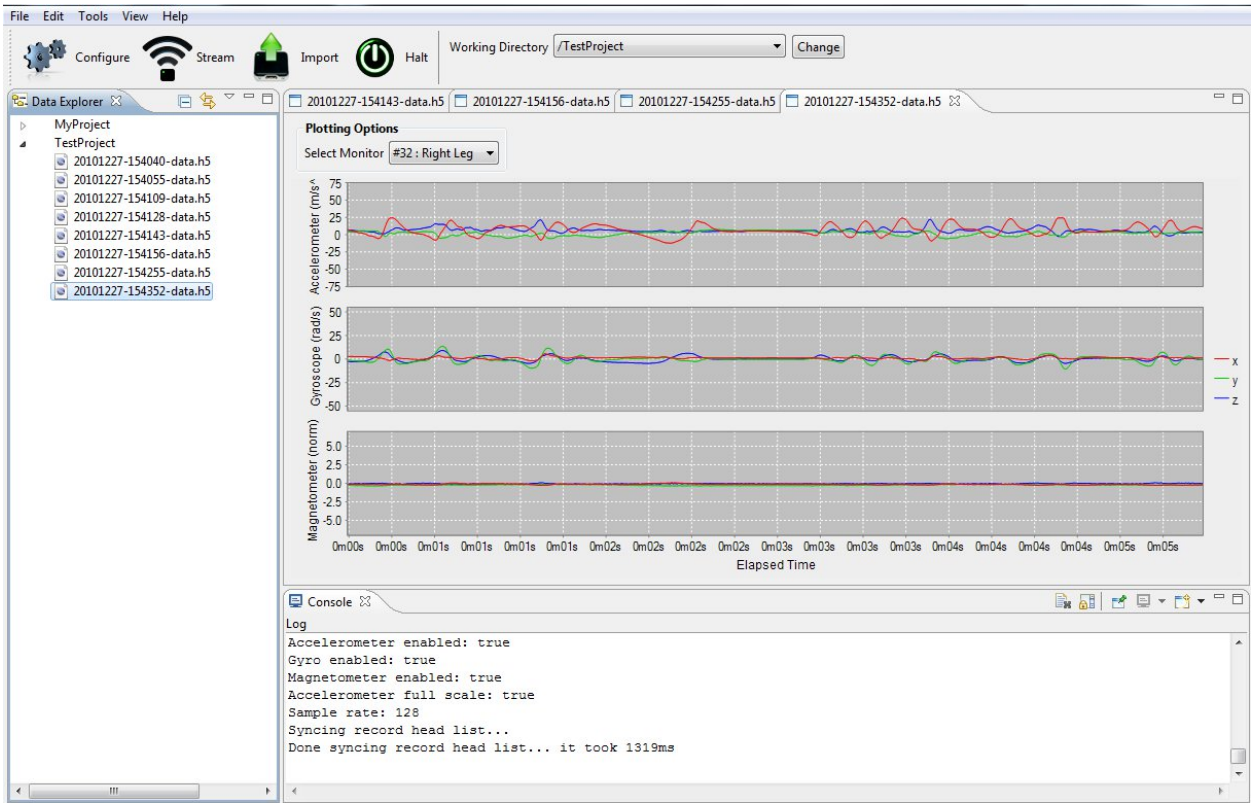
Access Point:	**VID:** 0x224F	**PID:** 0x0001
Docking Station:	**VID:** 0x224F	**PID:** 0x0002

An example set of udev rules for the access point and docking station are as follows:

```
ACTION=="add", ATTRS{idVendor}=="224f", ATTRS{idProduct}=="0001", MODE:="0666"
ACTION=="add", ATTRS{idVendor}=="224f", ATTRS{idProduct}=="0002", MODE:="0666"
```

6 Motion Studio

Motion Studio is the default software suite bundled with the APDM movement monitor system. It provides an easy way to get up and running collecting data with your movement monitors. It also provides advanced configuration, recording, and data management features that enable you to take full advantage of the APDM movement monitor system.



The main Motion Studio screen

7 Configuration

APDM movement monitors can be configured in a number of ways to match your recording needs. To open the configuration dialog: Make sure your access points and docking stations are plugged into the computer and that your monitors are inserted into their docks. Press the “Configure” button in the application tool bar.

The “Configure” button in the toolbar

The configuration dialog will enable you to configure the settings of your individual monitors, in addition to system-wide settings.

7.1 Automatic Firmware Updates

Whenever you press the “Configure” button, your hardware is first checked to ensure that the latest firmware is installed. If not, you will be prompted to automatically update your hardware to the latest versions of the firmware bundled with Motion Studio.

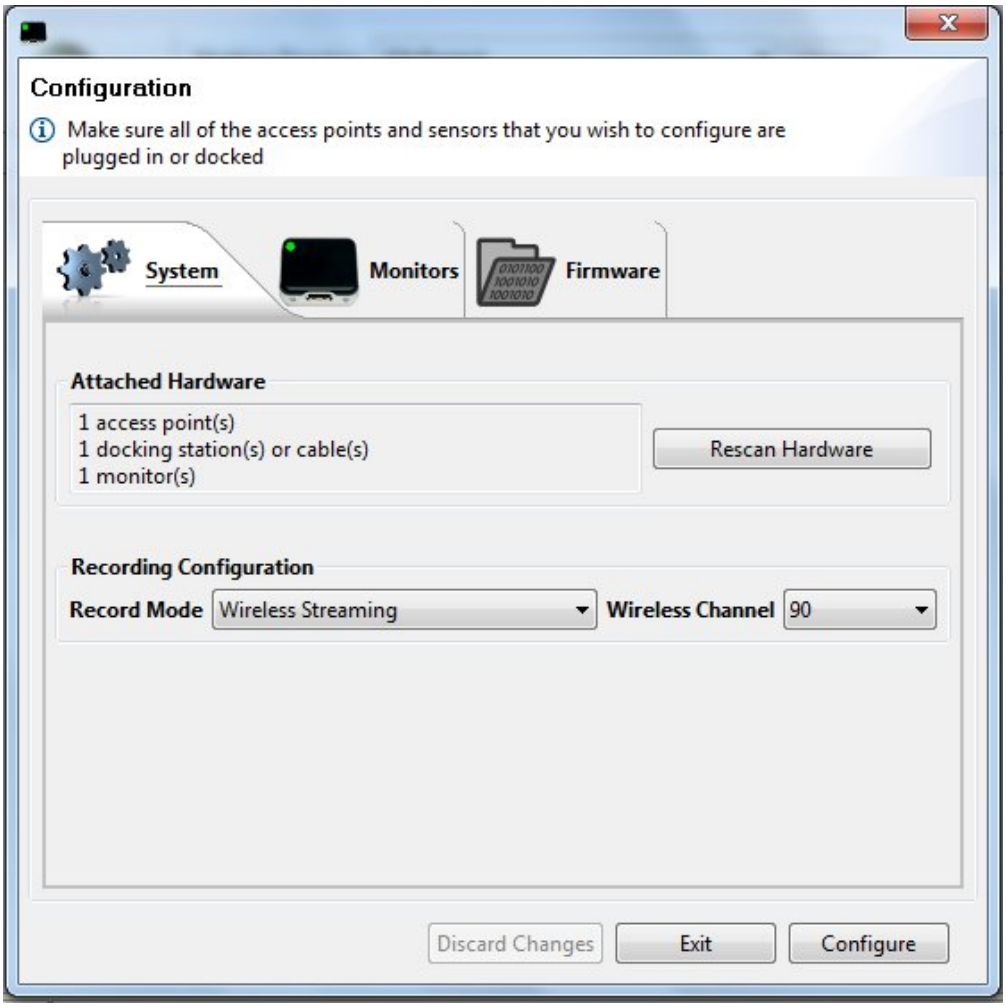
7.2 System Configuration

7.2.1 Attached Hardware

This window displays the APDM hardware that is detected on your computer. If this list does not accurately specify the hardware that you have attached, you should press the “Rescan Hardware” button (see the next topic) to initiate the scan again.

7.2.2 Rescan Hardware

This option will search for APDM hardware attached to your computer.



The system configuration options of the configuration dialog

7.2.3 Record Mode

Use this option to specify how you wish to record data from your monitors:

- **Wireless Streaming (Opals only).** Use this mode to stream data from one or more synchronized monitors wirelessly to your computer.
- **Synchronized Logging (Opals and Emeralds only).** Use this mode to log data from more than one synchronized monitor to their on-board flash memory. The monitors are synchronized wirelessly with each other.
- **Low Power Logging (Opals, Emeralds, and Sapphires).** Use this mode to log monitor data to their on-board flash memory. Wireless radios are turned off to save power. Multiple monitors will not be synchronized, and some level of clock drift will occur for long

recordings.

7.3 Wireless Channel

Movement monitors configured for wireless streaming or synchronized logging transmit data in the 2.4 ghz wireless spectrum range. Channel zero corresponds to roughly 2.40 ghz, and channel 90 corresponds to roughly 2.49 ghz. Many other consumer electronic devices make use of radio frequencies in the 2.4 ghz spectrum, such as WiFi routers, cordless phones, and blue-tooth devices. Because of this, it's important to choose a channel that is not already in use by another device. The most common source of interference is from wireless network access points. You can determine the channel that the WiFi router is running on and determine its corresponding frequency from the following URL: http://en.wikipedia.org/wiki/IEEE_802.11

7.4 Monitor Configuration

Use the "Select Monitor" combo box to specify the monitor you wish to individually configure.

7.4.1 Sensors

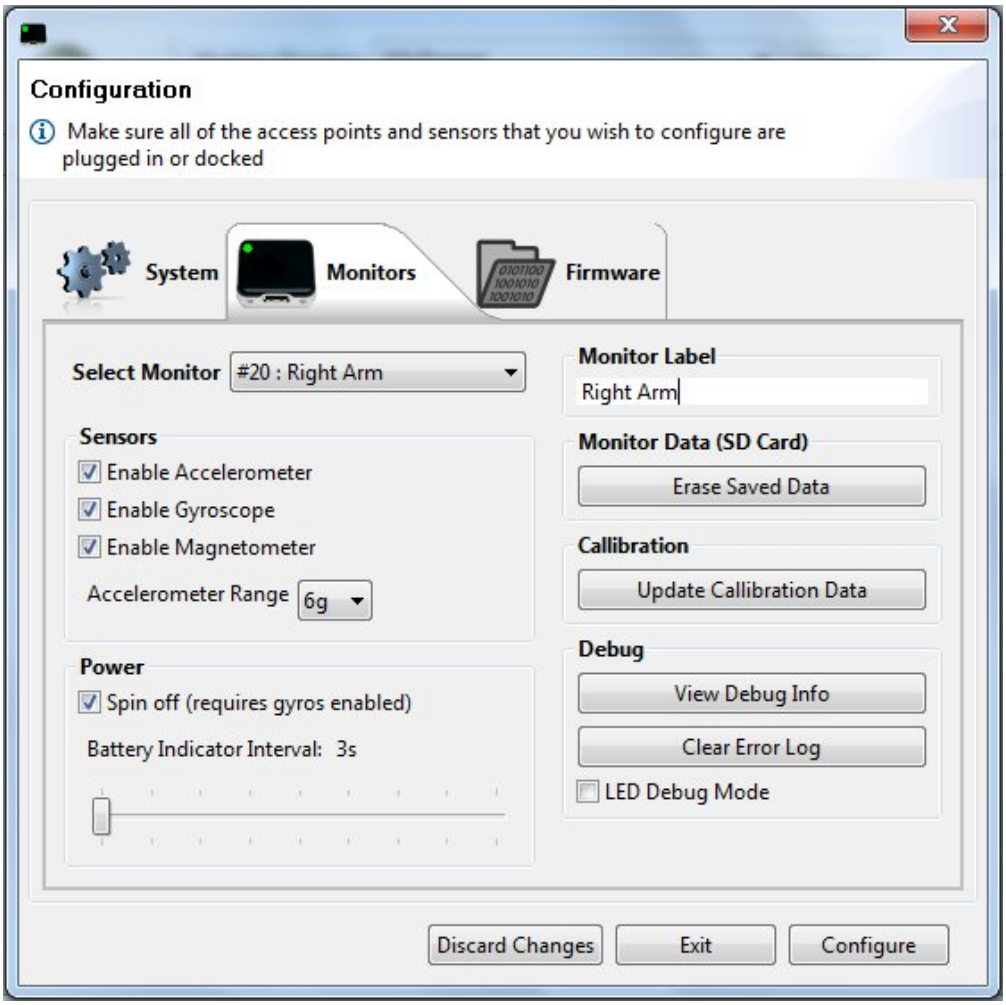
Enable or disable on-board sensors. If your application does not require data from a particular sensor type, turning them off can reduce file sizes and improve battery life. The gyroscopes in particular use a significant amount of battery power.

7.4.2 Accelerometer Range

Specifies whether the range of the accelerometer is ±2 g or ±6 g. This is approximately equal to ±20 or ±60 m/s^2, although some sensors may have a slightly larger range before saturating. If your application does not need the full ±6 g range, using the ±2 g range will slightly improve the signal to noise ration (SNR) of your accelerometer readings.

7.4.3 Power

Spin off. When this feature is enabled, the monitor will power down when spun clockwise or counterclockwise about it's z-axis. For example, spinning the monitor when it is lying flat on a



The monitor configuration options of the configuration dialog

table. Gyroscopes need to be enabled on the monitor in order to make use of this feature.

Battery Indicator Interval. Specifies how often the LED sequence indicating the current battery level is displayed. This can be set from a value of 3 s to 768 s.

7.4.4 Monitor Label

By specifying a label for a monitor, this label will be persisted along with the data. Example labels are “Right Arm” and “Jane Doe”. This is often easier than associating data with a monitor ID (e.g., “56”). There is a 15 character limit for the label.

7.4.5 Monitor Data (SD Card)

Erase Saved Data Pressing this button will delete all of the recorded data on the specified monitor. This does not include configuration data. The data is deleted the next time the monitor is undocked.

7.4.6 Calibration

Update Calibration Data Use this option in the event that your monitor needs to have its calibration data updated. You will have to specify the calibration file to use.

7.4.7 Debug

View Debug Info. This option allows you to print out detailed information about the monitor configuration and a log of any errors that have been encountered during its operation. The output is placed into a special page in the console view of the main application. Use the "Display Selected Console" button to select the appropriate console view.

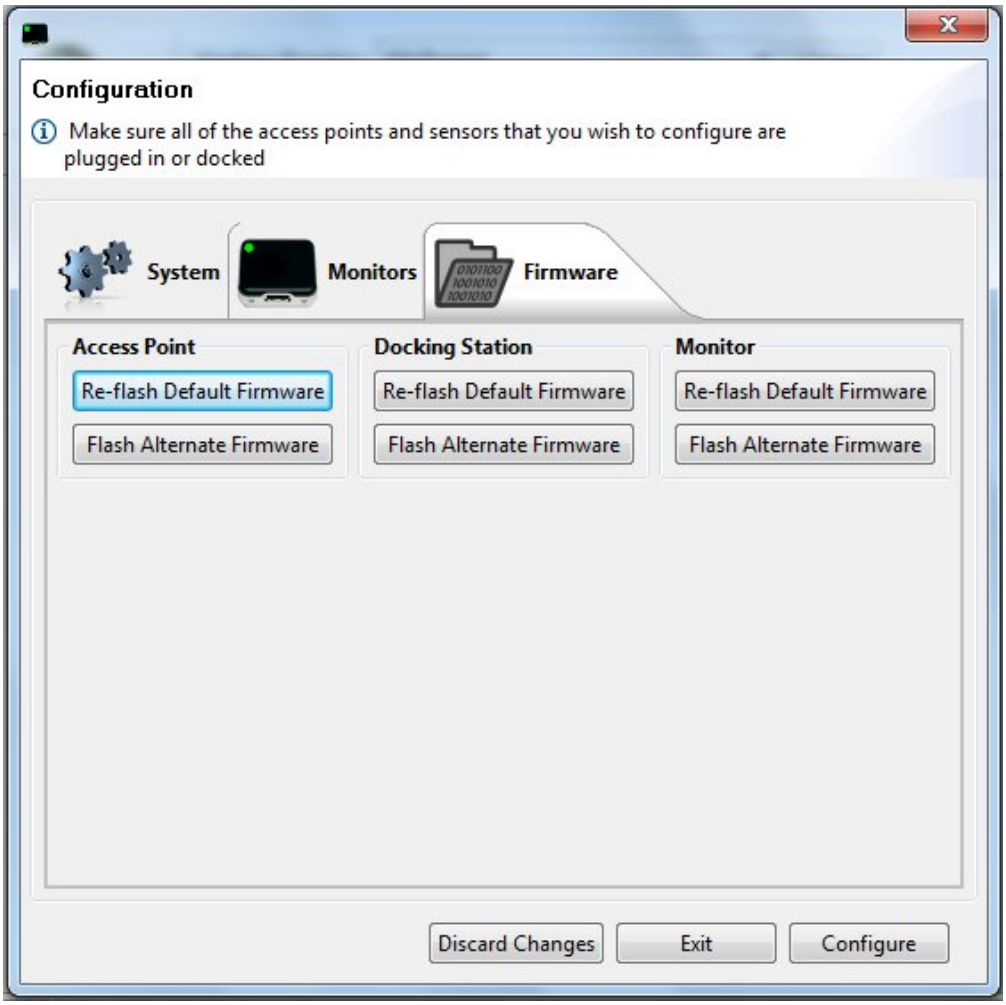
Clear Error Log. Use this option to clear the error log on the monitor. This is useful when debugging to ensure that error log entries are not historical.

LED Debug Mode. When this option is selected, the monitor's LED will display debug information while recording, instead of blinking in unison with the rest of the monitors. See Monitor Reference for details on the LED modes.

7.5 Firmware Configuration

7.5.1 Re-flash Default Firmware

Each version of Motion Studio comes bundled with an up to date version of the firmware. Pressing this button will re-flash this version of the firmware onto the specified monitor.



The firmware configuration options of the configuration dialog

7.5.2 Flash Alternate Firmware

For testing purposes or to address an issue in a timely fashion, it may be necessary to flash a monitor with a version of the firmware that is different than the bundled version. You will have to specify the alternate firmware file to use with this option.

7.6 When you are done configuring your system

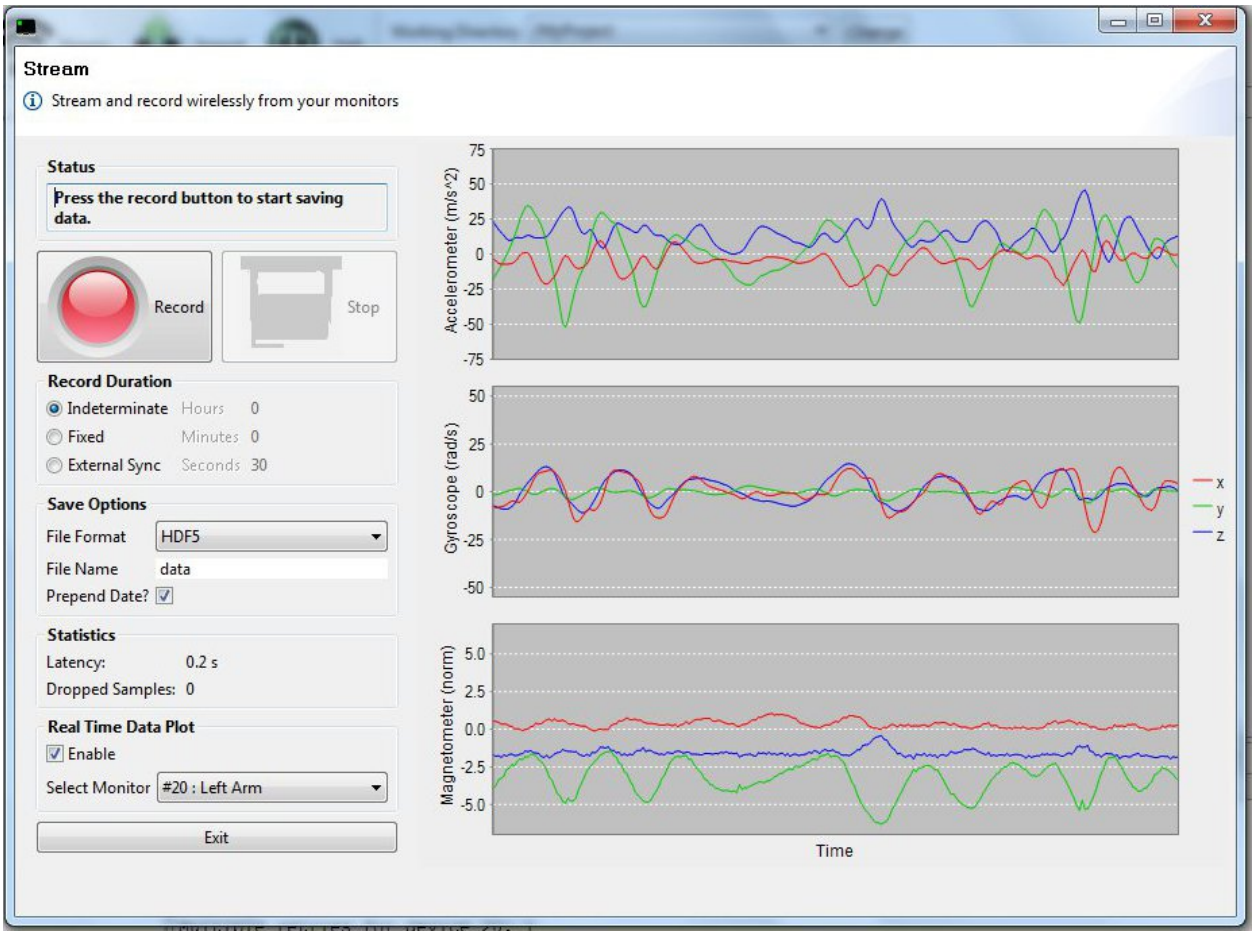
Press the “Finished” button to complete the configuration. When the configuration progress dialog completes, unplug your monitors from their docking stations.

7.7 Re-configuration

Wireless streaming configuration data is stored on the access points. Re-configuration is required whenever the access points are unplugged from the host computer or the host computer is rebooted. Re-configuration is not required if Motion Studio is shut down and restarted, or if one of the logging modes are currently configured.

8 Wirelesss Streaming Mode

If wireless streaming mode is selected in the configuration dialog (Opals only), you can stream data from multiple, synchronized monitors directly to your computer.



The wireless streaming dialog

8.1 Starting a Streaming Session

To start a streaming session, press the “Stream” button in the application tool bar to bring up the recording dialog.

The “Stream” button in the toolbar

The stream dialog will enable you to configure how you view and record streaming data from your Opals.

8.2 Real Time Chart

The real time chart allows you to view the data streaming from your monitors. Use the “Select Monitor” combo box to view the streaming data from different monitors.

Note: even when the monitors are within range of the access point and data is streaming freely, there may be as much as 400ms of latency between the time at which data is recorded and when it appears in the real time chart. If you notice excessive latency or a very slow frame rate, consider unchecking the “Enable” checkbox, which will stop the real time plotting of data and free up more processing power on your computer.

8.3 Record Duration

You can select between fixed and indeterminate recording durations:

Fixed duration. You can specify the number of hours, minutes, and seconds for each recording. You can press the “Stop” button to stop your recording before the specified duration has lapsed.

Indeterminate duration. Your recording will continue until you press the “Stop” button.

8.4 Save Options

8.4.1 File Format

You can record to either the HDF5 (http://www.hdfgroup.org/) or the CSV file format.

HDF5 is an open format for storing structured, binary data. Files are more compact than their CSV counterparts and can be opened directly in a number of analysis software packages, including Matlab. See the chapter on “Working with HDF5 Files” in this document for more information.

CSV is a plain-text format that can be opened in spreadsheet software applications, such as

Excel or OpenOffice, in addition to most analysis software.

8.4.2 File Name

Specify the name of the data file recorded to disk.

8.4.3 Prepend Date

If checked, the date and time of the start of the recording are added to the beginning of the file name.

8.5 Statistics

8.5.1 Latency

Displays the current latency between the time data is recorded to the time it is plotted to the screen. Latency may be increased by poor wireless reception or monitors that are occluded from the access point (e.g., against a metal chair back, around a corner, etc.).

8.5.2 Dropped Samples

Displays the number of samples dropped since the current streaming session was started. There are only a few extreme cases where samples will be dropped when recording wirelessly. In the event that data is dropped, all of the recorded data will be present on the monitor SD card(s).

8.6 Starting and stopping

When you are ready to record press the “Record” button in the stream dialog.

To stop your recording press the “Stop Button”. Your data will be saved to your current working directory and the recording will be plotted on the screen.

9 Synchronized Logging Mode

If synchronized logging mode is selected in the configuration dialog (Opals and Emeralds only), you can log data from more than one monitor to their on-board flash memory. The monitors are synchronized wirelessly with each other.

9.1 To start recording

Disconnect the monitors from their docking stations after configuration. After a few seconds to initialize, they will start recording to their flash memory. When within wireless contact with one-another, they will synchronize their clocks. To start an additional recording in a separate file, connect and disconnect the monitors from their cables or docking stations. No re-configuration is necessary.

9.2 To import recorded data

Plug the monitor into a docking station. Click on the ”Import Data” button in the toolbar.

10 Low Power Logging Mode

If your monitors are configured for low power logging (Opals, Emeralds, and Sapphires), you can log data from one or more monitors at a time to their on-board flash memory. Wireless radios are turned off to save power. Multiple monitors will not be synchronized, and some level of clock drift will occur during long recordings.

10.1 To start recording

Disconnect the monitors from their cables or docking stations after configuration. After a few moments to initialize, they will start recording to their flash memory. When within wireless contact with one-another, they will synchronize their clocks. To start an additional recording in a separate file, connect and disconnect the monitors from their cables or docking stations. No re-configuration is necessary.

10.2 To import recorded data

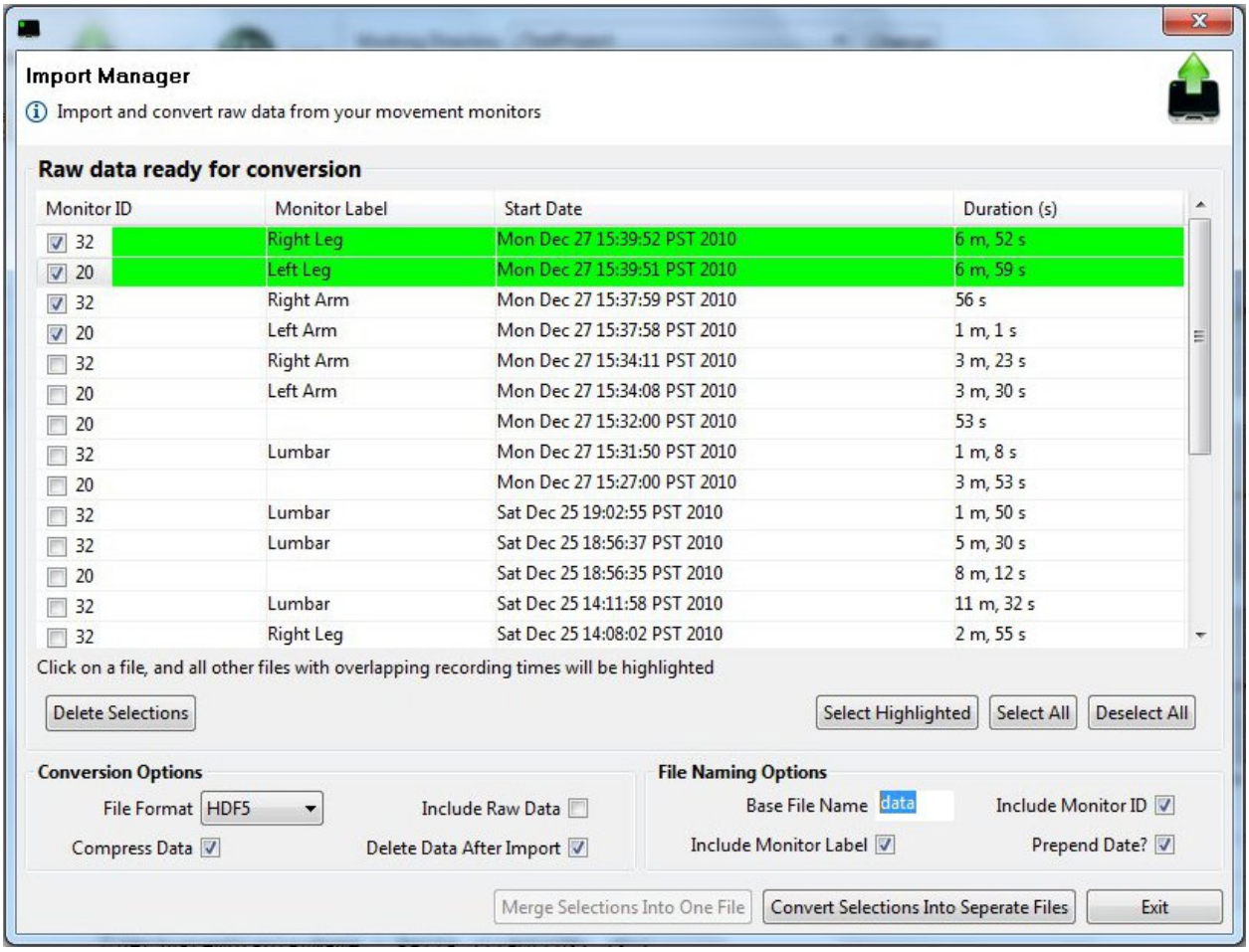
Plug the monitor into a docking station. Click on the ”Import Data” button in the toolbar.

11 Import Manager

The Import Manager enables you to import the data saved on the monitors, and to convert it to a format that can be read by a number of software analysis packages. Click on the “Import” button in the toolbar to open the Import Manager.

The import button in the toolbar

When you open the import manager, the data from all currently docked monitors are moved to an import directory on your PC. These raw data files are displayed in the table at the top of the import directory.



The Import Manager dialog window

11.0.1 Selecting Data For Import

In the table at the top of the Import Manager, you can select data for importing by clicking in the checkboxes on the left.

When you select a file in the table by clicking anywhere on the row, any other files that have overlapping recording times will be highlighted. This functionality aids in finding and merging of data that was recorded on multiple monitors synchronously.

11.0.2 Conversion Options

File Format. You can record to either the HDF5 (http://www.hdfgroup.org/) or the CSV file format. HDF5 is an open format for storing structured, binary data. Files are more compact than their CSV counterparts and can be opened directly in a number of analysis software packages, including Matlab. See the chapter on "Working with HDF5 Files" in this document for more information. CSV is a plain-text format that can be opened in spreadsheet software applications, such as Excel or OpenOffice, in addition to most analysis software.

Include Raw Data. Select this option if you want to include the raw sensor data in the import file. This is the raw sensor data, and has not been processed or converted to SI units.

Compress Data. When importing data into an HDF5 file, you can choose the compress the data. The resulting file will be significantly smaller, but it will take longer to perform the import. **Note:** Matlab versions before 2009a cannot read compressed HDF5 data.

Delete Data After Import. When selected, the raw data will be deleted after import.

11.0.3 File Naming Options

Base File Name. Specify the base name of the data file the data is being imported into.

Include Monitor ID. If selected, the case ID of the monitor being imported from will be embedded in the file name.

Include Monitor Label. If selected, the label of the monitor being imported from will be embedded in the file name.

Prepend Date. If checked, the date and time of the start of the recording are added to the beginning of the file name.

11.0.4 Import Options

Merge Selections Into One File. If clicked, all selections will be merged into a single HDF file after conversion. Multiple selections from the same monitor cannot be merged into a single HDF file.

Convert Selections Into Seperate Files. If clicked, each selection will be imported into a seperate file after conversion.

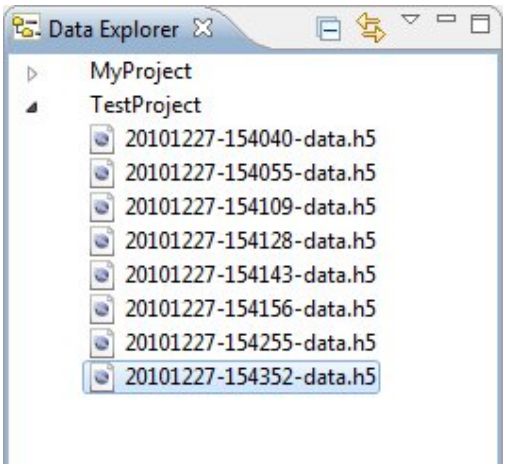
11.0.5 After Import

Imported data will show up in your current working directory. Right click on it and select ”Plot” to plot the data to the screen.

12 Managing Your Data

12.1 The Data Explorer

The Data Explorer can be used to help you organize and view your data.



The Data Explorer view

The Data Explorer shows a hierarchical view of your projects and folders. Projects are the top level containers in the Data Explorer, and can hold any number of folders. Folders hold other folders or data files.

12.1.1 Working Directory

Your current Working Directory Tool is displayed in the application's toolbar. You can change your Working Directory by clicking on the "Change" button and selecting a different project or folder.

The Working Directory Tool in the toolbar

Whenever you record data through wirelessly streaming or import logged data from your monitor(s), the data will appear in your current Working Directory.

12.1.2 Creating new projects

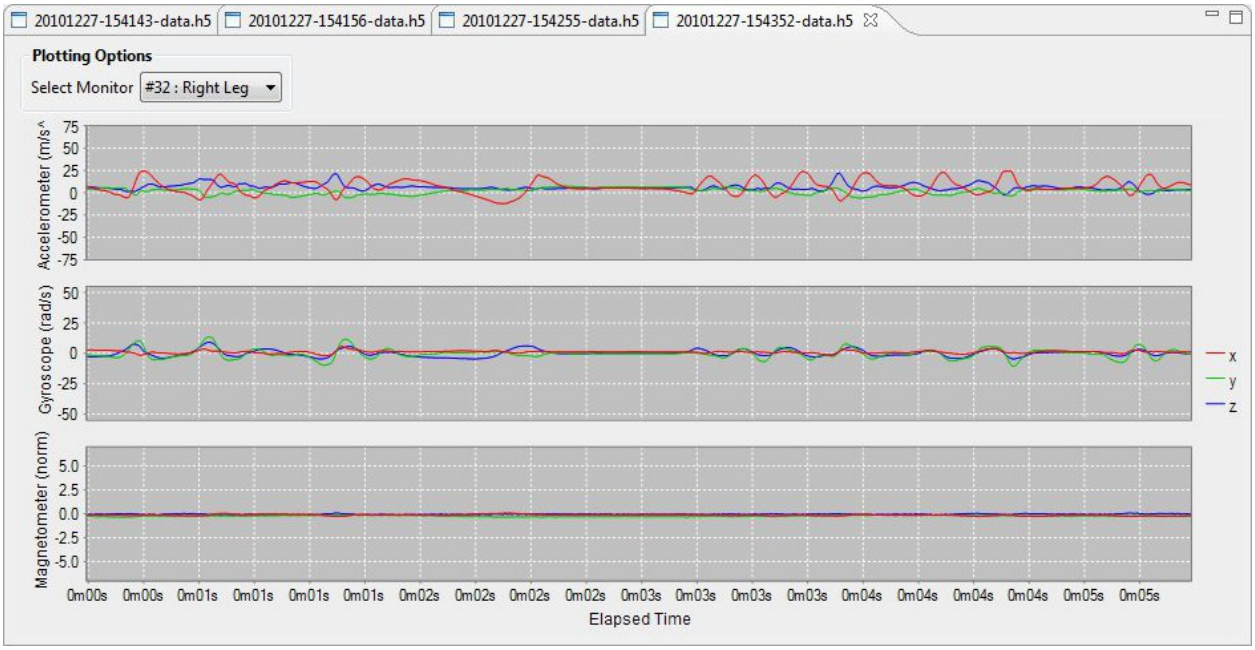
1. Right-click in the Data Explorer and select “New → Project...”
2. Select the “Project” option from the New Project Wizard
3. Specify the project name
4. By default, the project and all contained files will be placed in Motion Studio’s workspace directory, which is indicated in the console when Motion Studio is launched. If you wish to specify a different location on your hard drive to create the project, uncheck the “Use default location” checkbox and choose the location of the new directory.
5. Click “Finish”
6. To make this your current working directory, click on the “Change” button in the Working Directory Tool and choose the new project.

12.1.3 Creating new folders in projects

1. Right-click in the Data Explorer and select “New → Folder”
2. Select the parent project or folder for the folder you wish to create
3. Specify the folder name
4. By default, the folder will be created in the project’s directory structure on your hard drive. It is possible, however, to associate the folder with a project but to store the data in a different location. If you wish to specify a different location on your hard drive to create the folder, click the “Advanced” button, select the “Link to alternate location(Linked Folder)” option, and specify the folder on your hard drive that you wish to store this folder’s data in.
5. Click “Finish”
6. To make this your current working directory, click on the “Change” button in the Working Directory Tool and choose the new folder.

12.2 Plotting

To plot a recorded file, right-click on the file and select the “Plot” option.



The data plot view

13 Working with HDF5 Files

HDF5 is the preferred format for storing APDM movement monitor data. It is a standard format for scientific data that is efficient and widely supported. It uses less space than CSV, is faster to load, and supports more structured data. This section will cover the organization of the APDM movement monitor data and the basics of reading HDF5 files in MATLAB.

13.1 HDFView

A free program called HDFView (http://www.hdfgroup.org/hdf-java-html/hdfview/) can be used to explore, plot, and export this data into other formats. A variety of free open source tools for working with HDF files are also available at http://www.hdfgroup.org/HDF5/release/obtain5.html.

13.2 Data Organization

HDF5 files are organized like a file structure. The root of the file contains two attributes. One is a list of monitor IDs that have data stored in this file. The other is a version number for the organization of the HDF 5 file.

13.3 File Structure

13.3.1 Version 2

- **MonitorLabelList** Attribute containing an array of monitor labels in the same order as the CaseIdList
- **CaseIdList Attribute** containing an array of monitor case IDs in the same order as the MonitorLabelList
- **FileFormatVersion** Attribute containing the file format version (2)
- **Annotations** Table containing annotations
  - **Time** Annotation time in epoch microseconds
  - **Case ID** A movement monitor case ID associated with the annotation
  - **Annotation** The annotation string
- **AA-XXXXXX** A group is included in the file for each monitor in the CaseIdList, with the name equal to the case ID
  - **SampleRate** Attribute containing the output data rate for the monitor
  - **DecimationFactor** Decimation factor for the monitor's internal processing

- **ModuleID** The module ID for the monitor
- **TimeGood** Flag indicating whether the time has been set on the monitor since it powered on
- **RecordingMode** One of: ”Wireless streaming”, ”Synchronized logging”, or ”Unsynchronized logging”
- **DataMode** Indicates whether the data was retrieved wirelessly or copied from the monitor’s internal storage while docked. One of: ”Streamed wirelessly” or ”Logged to monitor”
- **AccelerometersEnabled** 1 for enabled, 0 for disabled
- **GyroscopesEnabled** 1 for enabled, 0 for disabled
- **MagnetometersEnabled** 1 for enabled, 0 for disabled
- **DecimationBypass** Internal use, deprecated
- **CalibrationVersion** Version of the calibration data used to convert from raw samples to calibrated SI units
- **VersionString1** Firmware version string 1
- **VersionString2** Firmware version string 2
- **VersionString3** Firmware version string 3
- **CalibratedDataPopulated** 1 for populated, 0 for unpopulated
- **LocalTimeOffset** Time in milliseconds to add to UTC to convert to local time
- **SyncValue** Dataset containing the internal sync value for each sample
  - **Units** Attribute string containing the timestamp units (1/2560th of a second since 0:00 Jan 1, 1970 UTC)
- **Time** Dataset containing a timestamp for each sample
  - **Units** Attribute string containing the units (microseconds since 0:00 Jan 1, 1970 UTC)
- **Calibrated** Group containing calibrated data
  - **Accelerometers** Dataset containing accelerometer data (Nx3)
    - **Units** Attribute string containing the accelerometer units (m/s^2)
    - **Range** Attribute containing the range setting for the accelerometer (2g or 6g)
  - **Gyroscopes** Dataset containing gyroscope data (Nx3)
    - **Units** Attribute string containing the gyroscope units (rad/s)
  - **Magnetometers** Dataset containing magnetometer data (Nx3)
    - **Units** Attribute string containing the magnetometer units (μT)
  - **Temperature** Dataset containing the temperature (Nx1)
    - **Units** Attribute string containing the temperature units (°C)
  - **TemperatureDerivative** Dataset containing the temperature derivative (Nx1)
    - **Units** Attribute string containing the temperature derivative units (°C/s)
- **Raw** Group containing raw data if selected during import
  - **Accelerometers**
  - **Gyroscopes**
  - **Magnetometers**
  - **DataFlags**
  - **OptData**
  - **Temperature**
  - **TemperatureDerivative**

13.3.2 Version 1

This version is deprecated. All new files created will use the most recent version.

- **Device_List** Attribute containing a list of monitors present in the file
- **File_Format_Version** Attribute containing the file version
- **Annotations** Table containing annotations
  - **Time** Annotation time in epoch microseconds
  - **Device ID** A movement monitor ID associated with the annotation
  - **Annotation** The annotation string
- **Opal_xxx**/ Group containing information about and data from monitor ID xxx
  - **Sample_Rate** Attribute containing the output data rate for the monitor
  - **Decimation_Factor** Decimation factor for the monitor's internal processing
  - **Time_Good** Flag indicating whether the monitor has had its time set since turning on
  - **Decimation_Bypass** Internal use, deprecated
  - **Calibration_Version** Version of the calibration data used to convert from raw samples to calibrated SI units
  - **Version_String1** Firmware version string 1
  - **Version_String2** Firmware version string 2
  - **Version_String3** Firmware version string 3
  - **Acceleration** Dataset containing data from the accelerometers (Nx3)
    - **Units** Attribute string containing the acceleration units (m/s^2)
  - **Angular_Velocity** Dataset containing data from the gyroscopes (Nx3)
    - **Units** Attribute string containing the angular velocity units (rad/s)
  - **Magnetic_Field** Dataset containing data from the magnetometers (Nx3)
    - **Units** Attribute string containing the magnetic field units (a.u.)
  - **Temperature** Dataset containing the temperature of the monitor (Nx1)
    - **Units** Attribute string containing the temperature units (°C)
  - **Temperature_Derivative** Dataset containing the rate of change of temperature
    - **Units** Attribute string containing the temperature derivative units (°C/s)
  - **Sync_Value** Dataset containing the internal timestamp of each sample
    - **Units** Attribute string containing the timestamp units (1/2560th of a second since 0:00 Jan 1, 1970 UTC)
    - **Time** Dataset containing the time for each sample in microseconds since 0:00 Jan 1, 1970 UTC

Additional fields present when raw data is also stored:

- **Opal_XX**/
  - **Calibration_Data** Attribute containing binary block of calibration data

- **Raw_File_Version** Attribute containing the version string of the raw file (if this was converted from a .apdm file instead of streamed)
- **Accelerometers_Raw** Dataset containing raw accelerometer data ($Nx3$)
- **Gyroscopes_Raw** Dataset containing raw gyroscope data ($Nx3$)
- **Magnetometers_Raw** Dataset containing raw magnetometer data ($Nx3$)
- **Data_Flags** Dataset containing flags used for processing the raw data
- **Opt_Data** Dataset containing several measurements taken at a low data rate
- **Temperature_Raw** Dataset containing lowpass filtered, but uncalibrated temperature data ($Nx1$)

13.4 Working with HDF 5 in MATLAB

MATLAB contains two high level functions for working with HDF5 files. Additional help and examples are included in the built in help documentation for these functions.

`hdf5info` reads the structure of the file and all of the attribute values and returns them in an easy to browse MATLAB structure.

`hdf5read` reads a complete dataset or attribute from the HDF5 file.

Additionally, one more high level helper function is included with the APDM movement monitor software. This function also contains built in help documentation and examples.

`hdf5readslab` reads a portion of a dataset from the HDF5 file.

13.5 Examples

Below is simple example of loading acceleration data from an APDM movement monitor HDF5 file (version 2) in MATLAB.

```
filename = 'example.h5';
try
   vers = hdf5read(filename, '/FileFormatVersion');
catch
   try
      vers = hdf5read(filename, '/File_Format_Version');
   catch
      error('Couldn''t determine file format');
   end
```

```
end
if vers ~= 2
   error('This example only works with version 2 of the data file')
end
caseIdList = hdf5read(filename, '/CaseIdList');
groupName = caseIdList(1).data;
accPath = [groupName '/Calibrated/Accelerometers'];
fs = hdf5read(filename, [groupName '/SampleRate']);
fs = double(fs);
acc = hdf5read(filename, accPath)'; %Transposed to make Nx3 in MATLAB
t = (1:size(acc,1))/fs;
figure;
plot(t,acc);
```

A more complicated example using the flexibility of HDF5 to load and process only part of a data set. This can be useful when the data set is too large to fit into memory. Care is taken not to attempt to read beyond the end of the file.

```
filename = 'example.h5';
try
   vers = hdf5read(filename, '/FileFormatVersion');
catch
   try
      vers = hdf5read(filename, '/File_Format_Version');
   catch
      error('Couldn''t determine file format');
   end
end
if vers ~= 2
   error('This example only works with version 2 of the data file')
end
idList = hdf5read(filename, '/CaseIdList');
groupName = idList(1).data;
accPath = [groupName '/Calibrated/Accelerometers'];
fs = hdf5read(filename, [groupName '/SampleRate']);
fs = double(fs);
fhandle = H5F.open(filename, 'H5F_ACC_RDONLY', 'H5P_DEFAULT');
dset = H5D.open(fhandle, [groupName '/Calibrated/Accelerometers'], 'H5P_DEFAULT');
dspace = H5D.get_space(dset);
[ndims, dims] = H5S.get_simple_extent_dims(dspace);
nSamples = dims(1);
```

```
nSamplesRead = min(nSamples, 60*fs); %read at most one minute of data
accSegment = hdf5readslab(filename, accPath, [0,0], [nSamplesRead, 3])';
t = (1:nSamplesRead)/fs;
figure;
plot(t,accSegment);
```

13.6 Notes

- Arrays in MATLAB use the FORTRAN convention of storing them in memory by column then row, instead of the C convention (used by HDF 5) of row then column. This has the effect of making the returned arrays transposed from how this document (and many other interfaces to HDF5) claim they are laid out.
- Older versions of MATLAB (before 2009a) did not support the compression used in Motion Studio's HDF 5 files. If you are using one of these older versions, the free h5repack utility available from the HDF Group can remove the compression. This utility is available at:
  http://www.hdfgroup.org/HDF5/release/obtain5.html
  The command to repack the file is:
  `h5repack -f NONE example.h5 example_no_compression.h5`

14 Turning Off Your Monitors

14.1 Docking Monitors

In most situations, it is sufficient to simply dock your monitors when not in use. When docked, monitors stop recording, stop broadcasting, and start charging their batteries. Once fully charged, the batteries will enter a trickle charge mode to keep them topped off.

14.2 Spin Off

For transport or storage, it is often desirable to power off all system components. If a monitor's "Spin Off" feature is enabled (gyroscopes must be enabled to use this feature), you can spin the monitor around its z-axis to put it into a suspended state. One example would be placing the monitor on a flat surface and spinning it. The monitor's LED will blink cyan 3 times and then turn off, indicating that the monitors has powered down.

14.3 Halt Docked Monitors

To suspend all monitors that are currently in their docking stations, click on the "Halt" button.

The Halt button in the toolbar

The next time the monitors are undocked, they will power down.

15 Monitor Reference

15.1 Charging

A movement monitor charges its internal battery any time it is connected to a docking station. At the optimal charge rate the movement monitors internal battery will complete its bulk charge (80%-90%) within an hour for a fully discharged battery. It is recommended that the movement monitor be charged for up to 3 hours to provide a peak charge to the battery ensuring it has the longest run time and improves battery life. It is recommended for the health of the battery to to have at least a bulk charge for storage of the movement monitor.

15.2 Powering Down

If you wish to power down your monitors for storage or travel, dock or plug in the monitors you wish to power down and select the “Tools→Halt All Monitors” option in Motion Studio. After this is selected, all monitors will power down when they are undocked or unplugged.

15.3 Data Storage

The movement monitor utilizes a flash card to store data while logging. This data can be downloaded by using a docking station to dock the movement monitor. When the movement monitor is docked it finishes up writing to the internal flash card and then releases it to the docking station. At this time the docking station indicates to the PC that there is a new read only removable drive to be mounted. Using your file browser you can navigate to the removable drive and copy the files off of it. The files are in a proprietary raw format and need to be converted to either a HDF5 or CSV format that will provide data in calibrated SI units. This conversion happens automatically if Motion Studiois used to import the data. Alternately, there are functions in the SDK to do this conversion programmatically.

15.4 Cleaning and Storage

Cleaning the movement monitors case should be done by wiping the bottom of the case where it contacts the skin with Rubbing alcohol or other cleaning wipe. If the entire case needs to be cleaned use only an ethyl alcohol or isopropyl alcohol based wipe. Methyl alcohol should be

avoided for cleaning the top since it will cause degradation of the plastic over time. The movement monitor should not be submerged in any liquids or subjected to any high temperatures for cleaning. The straps on the monitor can be cleaned by wiping them down with Rubbing alcohol. Alternatively the straps can be removed and washed separately using mild soap and water. Storage of the movement monitor should be in a dry static fee location. An anti-static bag or in the supplied case is recommended. The movement monitor should also not be subjected to any large G forces to prevent damage or changes to the calibration of the sensors in the monitor. The movement monitor should also have an adequate charge to ensure a good battery lifetime.

15.5 Drivers

Drivers are provided as part of the library distribution and Motion Studio. Instructions for installing drivers are provide in the “Hardware Driver Installation” section of this document.

15.6 Firmware Updates

Updating the movement monitor firmware should be done using the Motion Studio software.

15.7 Technical Specifications

- The accelerometer range is $\pm 58.8\,\mathrm{m/s^2}$ (6 g) (optionally $\pm 19.6\,\mathrm{m/s^2}$ (2 g)).
- Accelerometers have a typical noise density of $1.3\,\mathrm{mm/s^2/\sqrt{Hz}}$.
- The X and Y axis gyros have a range of ± 34.9 rad/s (2000 dps)
- The Z axis gyro has a range of ± 26.8 rad/s (1500 dps)
- The X and Y axis gyros have a typical noise density of 0.81 mrad/s/$\sqrt{\mathrm{Hz}}$
- The Z axis gyro have a typical noise density of 2.2 mrad/s/$\sqrt{\mathrm{Hz}}$
- Magnetometers have a range of ± 6 Gauss
- The magnetometers have a typical noise density is 160 nT/$\sqrt{\mathrm{Hz}}$
- Positive X is pointing from the monitor toward the connector. Positive Y is pointing left of X looking top down at the monitor. Z is pointing up out of the top of the case. Angular velocity sign is defined according to a right hand rule. A counterclockwise rotation about the Z axis looking from the +Z direction is positive.

15.8 LED Reference

15.8.1 Status Codes and LED Colors/Patterns

The LEDs on the access points and movement monitors provide important information about the operating state of the hardware, including error statuses. The tables below list the LED patterns associated with these states and can be useful in troubleshooting issues encountered with the hardware.

15.8.2 Movement Monitor LED Reference

Movement monitors contain a RGB LED capable of outputting a wide array of colors to the user to indicate its current state. The following colors are used: white (○), red (●), yellow (●), green (●), cyan (●), blue (●), magenta (●), and led off (_). In the off state the LED will appear as a non illuminated white dot in the corner of the monitor opposite the docking connector. All LED patterns are output on a repeating cycle which may vary in period depending on the pattern. In all cases the last color listed will stay constant until the pattern repeats. For example "●_●_" will blink yellow twice and then stay off until the pattern repeats.

State	LED Pattern
Startup (boot loader)	
Startup wait (5 sec)	●
Failed to load firmware	●
Boot loader mode	○
Firmware	
Reset mode	○_
Docked mode (transition)	●_
Docked mode (bulk charging)	●●(fast)
Docked mode (trickle charging)	●●(slow)
Docked mode (full charge)	●
Docked mode (bad cable connection)	●_●
Error mode: default	●_●_
Error mode: configuration	●_●_●_
Error mode: system	●_●_●_●_
Error mode: data buffer	●_●_●_●_●_
Error mode: SD buffer	●_●_●_●_●_●_
Error mode: SD I/O	●_●_●_●_●_●_●_
Card is full	●_
Run mode (transition)	●
Run mode (battery level indication off)	●_
Run mode (battery level 4/4)	●_●_●_●_
Run mode (battery level 3/4)	●_●_●_
Run mode (battery level 2/4)	●_●_
Run mode (battery level 1/4)	●_
Powering off	●_
Wireless Streaming Debug LED Modes	
Normal	●_
CPU out of cycles	●_●_
Missed an access point time packet	●_●_

16 Access Point Reference

16.1 Drivers

Drivers are provided as part of the library distribution and Motion Studio. Instructions for installing drivers are provide in the “Hardware Driver Installation” section of this document.

16.2 Firmware Updates

Updating the movement monitor firmware should be done using the Motion Studio software.

16.3 Mounting and Placement

The antennas of the access point are located directly behind the black plastic face of the access point. The access point(s) should be aimed such that this face is in the approximate direction of the area where the movement monitors will be used.

16.4 Single vs. Dual

With the wide range of wireless environments it is not always possible to provide a reliable channel of communication between any two nodes. Using two access points per set of up to six movement monitors is one method of improving reliability by utilizing spacial diversity. In this mode a movement monitor can hop between access points depending on which one has a better signal path. For large spaces or with spaces that have obstacles that may block wireless signals this mode of operation is recommended. Configuration of a system in this mode is transparent to the user and is automatically selected when there is enough access points available for the given number of movement monitors. Using multiple access points requires them to all have a synchronization cable connected between them.

16.5 LED Reference

Access points contain a RGB LED capable of outputting a wide array of colors to the user to indicate its current state. The following colors are used: white (○), red (●), yellow (●), green (●), cyan (●), blue (●), magenta (●), and led off (_). All LED patterns are output on a repeating

cycle which may vary in period depending on the pattern. In all cases the last color listed will stay constant until the pattern repeats. For example "●_●_" will blink yellow twice and then stay off until the pattern repeats.

State	LED Pattern
Access point is powered on and is not receiving data from any monitors	●
Access point is receiving data from all monitors and there is no excessive latency for any of the monitors	●_
Access point is receiving data from all monitors but there is excessive latency (¿3s) in one or more monitors. The latency is, however, decreasing (improving). This usually indicates that one or more monitors was temporarily obstructed and is now catching up.	●●
Access point is receiving data from all monitors but there is excessive latency (¿3s) in one or more monitors which is increasing (getting worse). This usually indicates that one or more monitors is obstructed and is having trouble transmitting its data.	●●
Access point is receiving data from one or more, but not all, of the movement monitors	●_
Access point is receiving data from one or more monitors that it is not expecting to receive data (e.g. there is a monitor configured on another computer system streaming data)	●●(fast)

17 Docking Station Reference

17.1 Drivers

Drivers are provided as part of the library distribution and Motion Studio. Instructions for installing drivers are provide in the “Hardware Driver Installation” section of this document.

17.2 LED Reference

Docking stations contain a RGB LED capable of outputting a wide array of colors to the user to indicate its current state. The following colors are used: white (○), red (●), yellow (●), green (●), cyan (●), blue (●), magenta (●), and led off (_). All LED patterns are output on a repeating cycle which may vary in period depending on the pattern. In all cases the last color listed will stay constant until the pattern repeats. For example “●_●_” will blink yellow twice and then stay off until the pattern repeats.

State	LED Pattern
OK	●
Powered off, USB suspended, or booloader pause	●
OK, but USB not enumerated	●
Power problem. Need to plug in external power or USB power.	●_
Docked, SD unavailable on host	●_●
Docked, SD card mounted on host	●
SD card read-access in progress	●_
USB error	●
Error	●_
Error: SD card mounting error	●_●_
Error: in-dock USB hub problem	●_●_●_
Bootloader mode	●
Updating firmware	○
Hardware Error -DA	●_○_●_○_●_○_
Hardware Error - GA	●_●_●_●_●_●_
Hardware Error - PA	●_●_●_●_●_●_
Hardware Error - UA	●_●_●_●_●_●_

17.3 Power

- If running a single docking station, it can be powered from:
  - a USB cable plugged into a dedicated USB port on your computer
  - a USB cable plugged into a a powered USB hub
  - a USB cable plugged into a wall adapter (charging only)
  - the external AC adapter (charging only)
- If running a chain of 2 or more docking stations:
  - For data transfer, both USB and external AC power are required. If a power-related error occurs, then the docking station will blink yellow until external or power is plugged in.
  - if only charging is required, the external AC power must be used

18 Troubleshooting

Q: When I dock my monitor into its station, it flashes alternately red and blue.
A: This is an indication of a poor connection. Try to re-dock your monitor and make sure the docking station is securely plugged into your computer.

Q: My monitor flashes red (and possibly yellow), and docking/undocking it does not fix the problem
A: If you have any data saved on the monitor from using it in logging mode, first attempt to back up the data using from you operating system's file explorer or Motion Studio's Import Manager. Next, from the Configuration dialog, select the monitor in the "Select Monitor" combo box and click on the "Re-flash Default Firmware" button. This will reset the monitor to its original state.

APDM is pleased to assist you with any questions you may have about our software or about the use of the technology for your application.

Please contact us at:
email: info@apdm.com
telephone: 888-988-APDM (2736)