Motion Studio User's Guide

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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 an access point into the your computer.
4. Plug the docking stations or monitor cables into your computer.
5. Dock the movement monitors into their docking stations or attach them to their cables. You should see the light on the monitors turn blue.
6. Open Motion Studio, and click on the "Setup" button. Choose your desired recording mode, and click "Finish".
7. Undock or unplug 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 monitor.
    b) Press the "Stream" button in the toolbar. You can view live data streaming in the strip chart.
    c) Press the "Record" button to start recording data.
    d) Note: It is recommended that you wait for the monitor clocks to fully synchronize before recording. The first time they are configured for streaming after being "off", the clocks may take a up two minutes to fully synchronize. During this period, the recording dialog may indicate dropped samples.

9. Logging modes

    a) Undock the monitors from their docking stations or cables. They will start recording within a few moments.
    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.

3   System Overview

The APDM movement monitoring system allows the user to record data from numerous monitors; each integrating a complement of various sensors. The system can be configured in 3 recording modes allowing for a wide rage of applications. Some movement monitors will be limited to a subset of these modes allowing for a lower cost solution. The modes of operation are low power logging, synchronized logging, and synchronized streaming. 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 usage environment. There are a number of options for mounting the monitors on subjects using a selection of straps.

The Opalmovement 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.

3.3   Docking Station

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

3.4   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.

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

3.5   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 devices 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   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.

4.1   Low Power Logging

All movement monitor variations are able to be configured for low power logging. The main difference with this mode to the other two is that there is no wireless communications. The system in this mode can be configured to run for longer periods of time which might be better for non clinical environments. Since the mode does not use any wireless synchronization each movement monitor will collect data independently and potentially at different rates due to clock drift. This mode is recommended when tight correlation of data between multiple movement monitors is not needed.

4.2   Synchronized Logging

Synchronized logging gives the user the ability to collect data with multiple movement monitors and tightly correlate the individual recordings. The synchronization is archived using the wireless communication between the devices. In this mode up to 32 nodes can be synchronized to sample data at the same time and with corresponding time stamps. Only Emeralds and Opals are able to use this mode.

4.3   Synchronized Streaming and Logging

In the synchronized streaming mode access points attached to a PC collect data transmitted wirelessly from the movement monitors. The 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.

5 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: In order to use the 64-bit version of Motion Studio, you also need to have the 64-bit Java JRE installed. Sun Microsystems does not currently make it easy to download the 64 bit version of the JRE for Windows probably because it can cause problems with other installed software such as web browsers. If you don't have the 64-bit JRE installed, the 32-bit version of Motion Studio will work.

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

6   Hardware Driver Installation

6.1   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.

6.2   Windows XP (x32)

6.2.1   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"

6.2.2   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"

6.2.3   Monitor Cable

1. Plug the monitor cable 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 the "MotionStudio/drivers/apdm_device_cable_driver" folder
10. Click "Ok"
11. Click "Next"
12. If Windows prompts you about the driver not being signed, click 'Continue Anyway'
13. Click "Finish"

6.2.4   Docking Station

1. Copy the file "MotionStudio/drivers/ftd2xx.dll" to the folder located at "C:/Windows/system32". This step is only necessary if you do not have monitor cables.
2. Plug the docking station into your computer.
3. The "Welcome to the Found New Hardware Wizard" dialog will popup
4. Select "No, not this time"
5. Click "Next"
6. Check "Install from a list or specific location" and click "Next"
7. Uncheck "Search removable media"
8. Check "Include this location in the search"
9. Click the "Browse" button and navigate to the "MotionStudio/drivers/apdm_docking_station_drivers" folder
10. Click "Ok" and Click "Next"
11. If Windows prompts you about the driver not being signed, click 'Continue Anyway'
12. Click "Finish"

6.3   Windows Vista (x32/x64)

6.3.1   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"

6.3.2 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.

6.3.3 Monitor Cable

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_device_cable_driver" 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.

6.3.4 Docking Station

1. Copy the file "MotionStudio/drivers/ftd2xx.dll" to the folder located at "C:/Windows/system32". This step is only necessary if you do not have monitor cables.
2. Plug the access point into your computer.
3. A "Found New Hardware" dialog will pop-up.

4. Select the "Locate and install driver software" option
5. Select "I don't have the disc. Show me other options".
6. Select "Browse my computer for driver software".
7. Click on the "Browse" button and navigate to the "MotionStudio/drivers/apdm_docking_station_drivers" folder.
8. Check "Include Subfolders".
9. Click "Next".
10. A warning message will be presented indicating that "Windows cannot verify the publisher of this driver software".
11. Click "Install this driver software anyway".
12. Close the confirmation dialog.

6.4   Windows 7 (x32/x64)

6.4.1   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.

6.4.2   Monitor Cable

1. Plug the monitor cable 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 "TTL232R-3V3" with a yellow exclamation point next to

it.

7. Right-click on the "TTL232R-3V3" 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‿device‿cable‿driver" 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.

6.4.3 Docking Station

1. Copy the file "MotionStudio/drivers/ftd2xx.dll" to the folder located at "C:/Windows/system32". This step is only necessary if you do not have monitor cables.

2. Plug the monitor cable into your computer.

3. There may be an notification that the device driver could not be installed.

4. Click on the Windows "Start" button

5. Right-click on the "Computer" button and select "Manage"

6. Select the "Device Manager"

7. Under "Other Devices" there should be an entry for "DockingStation" with a yellow exclamation point next to it.

8. Right-click on the "DockingStation" entry and select "Update Driver Software..."

9. Select "Browse my computer for driver software"

10. Click on the "Browse" button and navigate to the "MotionStudio/drivers/apdm‿docking‿station‿drivers" folder.

11. Check "Include Subfolders"

12. Click "Next"

13. A warning message will be presented indicating that "Windows cannot verify the publisher of this driver software".

14. Click "Install this driver software anyway".

15. Close the confirmation dialog.

6.5 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
Monitor Cable:	**VID:** 0x0404	**PID:** 0x9D37

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

```
ACTION=="add", ATTRS{idVendor}=="224f", ATTRS{idProduct}=="0001", MODE:="0666"
ACTION=="add", ATTRS{idVendor}=="224f", ATTRS{idProduct}=="0002", MODE:="0666"
ACTION=="add", ATTRS{idVendor}=="0403", ATTRS{idProduct}=="9d37", MODE:="0666"
```

7 Hardware Setup

1. **Plug the access point(s) into your computer (wireless streaming mode only)**. More than one access point can be added for redundancy or to support additional Opals. A single access point can receive data from up to 6 Opals. If multiple access points are used, connect them using the 1/8" sync cable.
2. **Plug in the monitor cable(s) and/or docking station(s) to your computer.** If you run out of USB ports on your computer, you can use a powered USB 2.0 high speed hub.
3. **Plug your monitors into their cables**

8 Configuration

APDM movement monitors can be configured in a number of ways to match your needs. To open the configuration dialog: Make sure your access points, monitor cables, and docking stations are plugged into the computer and that your monitors are connected to their cables or inserted into their docks. Press the "Setup" button in the application tool bar. The configuration dialog will enable you to configure the settings of your individual monitors, in addition to system-wide settings. These options include:

8.1 Automatic Firmware Updates

Whenever you press the "Setup" 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.

8.2 System Configuration

8.2.1 Rescan Hardware

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

8.2.2 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.

8.3   Wireless Channel

Movement monitors configured in synchronized streaming and logging modes transmit data in the 2.4ghz wireless spectrum range. Channel zero corresponds to roughly 2.4000ghz, and channel 90 corresponds to roughly 2.4900ghz. The 2.4ghz spectrum has many other consumer electronic devices, such as WiFi routers, cordless phones and blue-tooth devices, that also operate in this area of the spectrum. As such, 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`

8.4   Monitor Configuration

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

8.4.1   Sensors

Enable or disable sensor types. 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. Accelerometer Range. Specifies whether the range of the accelerometer is 2g or 6g. This is approximately equal to 20 or 60 m/s2, although some sensors may have a slightly larger range before saturating. If your application does not need the full 6g range, using the 2g range will slightly improve the signal to noise ration (SNR) of your accelerometer readings.

8.4.2   Power

Turn Off When Unplugged If set, your monitor will power down when it is unplugged from the cable or removed from the docking station. This is useful if you wish to power down a single monitor and the "Spin off" feature is disabled.

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 table.

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

8.4.3 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.

8.4.4 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.

8.4.5 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.

8.5 Firmware

8.5.1 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.

8.5.2 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.

8.6   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 cables or docking stations.

8.7   Re-configuration

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.

9 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.

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

9.2 Real Time Chart

The real time chart allows you to view the data streaming from your monitors. Use the "Select Device" 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.

9.3 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.

9.4 Save Options

9.4.1 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.

9.4.2 File Name

Specify the name of the data file recorded to disk.

9.4.3 Prepend Date

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

9.5 Statistics

9.5.1 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.).

9.5.2 Dropped Samples (Total)

Displays the total number of samples dropped since the current streaming session was started. Samples may be dropped when the clocks on the monitors are still synchronizing after config-

uration. This settling time is usually under a minute, but may be extended if the monitors were cold at configuation time.

9.5.3 Dropped Samples (Recording)

Displays the total number of samples dropped in the current recording. This value is reset each time a new recording is started.

9.6 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.

10   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.

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.

10.2.1   Import Options

10.2.2   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.

10.2.3   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.

10.2.4 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.

10.2.5 Base File Name

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

10.2.6 Include Monitor ID

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

10.2.7 Prepend Date

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

Browse to the monitor, which will show up on your file system as an external storage device. Select the file that you wish to import. It will show up in your current working directory. Right click on it and select "Plot" to plot the data to the screen.

11 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.

11.1 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.

11.2   To import recorded data

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

11.2.1   Import Options

11.2.2   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.

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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.

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11.2.7   Prepend Date

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

Browse to the monitor, which will show up on your file system as an external storage device. Select the file that you wish to import. It 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 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.

To create a new folder or project, right-click in the Data Explorer and select "New".

12.2   Working Directory

Your current Working Directory 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.

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

12.3   Plotting

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

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 document 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.

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

- 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 it's time set since turning on (1: yes, 0: no)
    - 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 (deg C)
- **– Temperature_Derivative** Dataset containing the rate of change of temperature
    - ∗ **Units** Attribute string containing the temperature derivative units (deg 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 epoch microseconds

... Opal_zzz/

Additional fields present when raw data is also stored:

- • Opal_xxx/
    - **– 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 in MATLAB.

```
filename = 'example.h5';
idList = hdf5read(filename, '/Device_List');
groupName = ['/Opal_' num2str(idList(1))]; %Get data from the first monitor
accPath = [groupName '/Acceleration'];
fs = hdf5read(filename, [groupName '/Sample_Rate']);
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';
info = hdf5info(filename);
idList = hdf5read(filename, '/Device_List');
groupName = ['/Opal_' num2str(idList(1))];
accPath = [groupName '/Acceleration'];
fs = hdf5read(filename, [groupName '/Sample_Rate']);
fs = double(fs);
nSamples = 0;
for cGroup = 1:length(info.GroupHierarchy.Groups)
    if strcmp(info.GroupHierarchy.Groups(cGroup).Name, groupName)
        group = info.GroupHierarchy.Groups(cGroup);
        for cDataset = 1:length(group.Datasets)
            if strcmp(group.Datasets(cDataset).Name, accPath)
```

```
                nSamples = group.Datasets(cDataset).Dims(2);
            end
        end
    end
end
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 Monitor Reference

14.1 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.

14.2 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.

14.3 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.

14.4 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 device 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 device. The movement monitor should also have an adequate charge to ensure a good battery lifetime.

14.5 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.

14.6 Firmware Updates

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

14.7 Technical Specifications

[As of Feb 17, 2010]

- The accelerometer range is $\pm 58.8 \mathrm{m/s}^2$ (6g) (optionally $\pm 19.6 \mathrm{m/s}^2$ (2g)).
- Accelerometers have a typical noise density of $1.3 \mathrm{mm/s}^2 / \sqrt{\mathrm{Hz}}$).
- The X and Y axis gyros have a range of $\pm 34.9 \mathrm{rad/s} (2000 \mathrm{dps})$
- The Z axis gyro has a range of $\pm 26.8 \mathrm{rad/s} (1500 \mathrm{dps})$
- The X and Y axis gyros have a typical noise density of $0.81 \mathrm{mrad/s/} \sqrt{\mathrm{Hz}}$
- The Z axis gyro have a typical noise density of $2.2 \mathrm{mrad/s/} \sqrt{\mathrm{Hz}}$
- Magnetometers have a range of $\pm 6 \mathrm{Gauss}$
- The magnetometers have a typical noise density is $160 \mathrm{nT/} \sqrt{\mathrm{Hz}}$
- 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.

14.8   LED Reference

14.8.1   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.

14.8.2   Movement Monitor LED Reference

The 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 (charging)	🔵
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	🔵_

15 Access Point Reference

15.1 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.

15.2 Firmware Updates

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

15.3 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.

15.4 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.

15.5   LED Reference

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 wich 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	🔴_

16   Docking Station 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   LED Reference

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 Data Abort Error	🔴 _ ⚪ _ 🔴 _ ⚪ _ 🔴 _ ⚪ _
Hardware General Abort Error	🔴 _ 🔵 _ 🔴 _ 🔵 _ 🔴 _ 🔵 _
Hardware Prefetch Abort Error	🔴 _ 🟡 _ 🔴 _ 🟡 _ 🔴 _ 🟡 _
Hardware Undef Abort Error	🔴 _ 🟣 _ 🔴 _ 🟣 _ 🔴 _ 🟣 _

16.3   Power

- If running a single docking station, it can be powered from:
    - a USB cable plugged into a dedicated USB port on your computer

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- **–** 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

17 Troubleshooting

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

Q: When streaming, Motion Studio indicates that I am dropping data.
A: It is recommended that you wait for the monitor clocks to fully synchronize before recording. The first time they are configured for streaming after being "off", the clocks may take a up two minutes to fully synchronize. During this period, the recording dialog may indicate dropped samples.

Q: My monitor flashes red, and plugging it back into the cable does not fix the problem
A: If you have any data saved on the monitor from using it in logging mode, first back up the data using from you operating system's file explorer import the data with Motion Studio using the "Tools→Import Raw Data" feature. Next, from the "Setup" dialog, select the monitor in the "Select Device" 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.

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