# Motion Driver 6.12 – Features User Guide

# Table of Contents

# 1 Revision History

| Revision Date | Revision | Description |
|---|---|---|
| 06/27/2014 | 1.0 | Initial Release |
| 05/05/2015 | 1.1 | Updated for MD 6/12 Release |

## 2 Purpose

Motion Driver is an embedded software stack of the sensor driver layer that easily configures and leverages many of the features of the InvenSense motion tracking solutions. The motion devices supported are MPU6050/MPU6500/MPU9150/MPU9250. Many of the features of the hardware and the on board Digital Motion Processor (DMP) are encapsulated into modular APIs which can be used and referenced.

Motion Driver is designed as a solution which can be easily ported to most MCUs. With the release of the Motion Driver 6.12 it includes a 9-axis solution for ARM MCUs and the TI-MSP430. 6-axis only solutions should continue to reference the Motion Driver 5.1.2 for easier understanding of the software.

This document details the various features of MD6.12. It will go into details on the Motion Processor Library algorithm (MPL), the Digital Motion Processor features (DMP), and the MPU hardware capabilities.

## 3 Before you start

Please read the Motion Driver 6.12 Getting Started Guide. It is recommended that customers bring up the Motion Driver 6.12 on one of the ported platforms (TI-MSP430 or IAR for ARM) so they can immediately see the features.

## 4 The DMP features

The DMP is a fast, low power, programmable, embedded lightweight processor in the MPU devices. It is design to offload functionality, like sensor fusion and gesture recognition, from the MCU to save overall power in the system.

The DMP has many features which can be dynamically turned off and on at run-time. Individual feature can also be disabled while leaving others running. All DMP data is outputted to the FIFO except for pedometer. The DMP can also be programmed to generate an interrupt via gesture or if data ready. For details on flashing and enabling the DMP please read the porting guide.

- 3 Axis Low Power Quaternions – gyro only quaternions. This feature when enabled will integrate the gyro data at 200Hz while outputting the sensor fusion data to the FIFO at the user requested rate. The 200Hz integration will allow for more accurate sensor fusion data. In MD6, if this feature is enabled, the driver will push the 3-axis quaternion into the MPL library and the MPL will handle the accel and compass integrations.
- 6 Axis Low Power Quaternions – gyro and accel quaternions. Similar to the 3-axis LPQ, integrates the accel and gyro at 200Hz sampling rates will outputting to the FIFO at the user requested rates. The 3-axis LPQ and 6-axis LPQ are mutually exclusive and should not be run concurrently. If enabled the 6-axis quaternions can be pushed into the MPL library and the MPL will handle the compass integration for 9-axis.
- Orientation Gesture Recognition – Uses sensor data to detect is there is a change in device orientation from portrait, landscape, reverse portrait, and reverse orientation. Very much dependent on the orientation matrix.
- Tap Gesture Recognition - multi-directional tap detection on the device. This feature will let users know on which axis position or negative a tap is detected on. It can detect multi-taps up to 4. APIs exist to configure this feature's threshold, dead time, and tap counts.
- Pedometer Gesture Recognition – simple pedometer providing step count and timestamp. This feature is automatically enabled but is not triggered until there is 5 seconds of continuous steps

detected. After 5 seconds the count and timestamp will start and the data can be read out from the DMP memory.

- DMP Interrupt – interrupts can be configured to generate either when there is sensor data ready which is the FIFO output rate, or when a tap or orientation gesture is detected.

# 5 The MPL

The Motion Driver 6.12 contains a binary library which contains InvenSense proprietary algorithms for sensor fusion and dynamic calibration. The MD 6.12 driver pushes the sensor data into the MPL and the MPL will handle the 9-axis sensor fusion including the compass integration.

MPL features are configured before enabling the MPL library. They can be dynamically turned off and on through API calls into the MPL.

## 5.1 Algorithms

| MPL Algorithm | Description |
|---|---|
| Gyro Calibration (Fast No Motion) | Run-time calibration routine. Once a no motion state is detected the gyro calibration will trigger. Calibration will complete within .5 seconds of no motion state detection. |
| Gyro Temperature Compensation | After each gyro calibration, the MPL will record the internal temperature. After several data points the MPL will be able to build a multi-point temperature slope for the gyro and apply it along with the calibration biases. This will compensate for gyro drift due to temperature. |
| Compass Calibration | Run-time hard iron compass calibration for MPU9150 and MPU9250. MPL reads and builds the magnetic field environment around the device. Once enough data is present the compass offset can be applied and 9-axis quaternions can be generated.<br><br>If you are in an environment with unstable magnetic field the compass will not get calibrated. If compass is not calibrated the quaternions will only use 6-axis.<br><br>Figure 8 motions on the device will quicken the calibration. |
| Mag Disturbance Rejection | After calibration the MPL library will keep track of the magnetic field and if there is an anomy detected, the MPL library will reject the compass data and switch back to 6-axis fusion.<br><br>After a magnetic disturbance is detected, the MPL library will continue to check the compass data every 5 seconds. At each check if the disturbance is no longer there, it will switch back to 9-axis fusion…otherwise it will continue to reject the data. |
| Fusion 3 Axis | gyro angle quaternions |

| | |
|---|---|
| Fusion 6 Axis | Gyro and accel quaternions |
| Fusion 9 Axis | Gyro, accel, and compass quaternions |

### 5.2 Sensor Data

Many other types of data can be derived from the quaternion data. These conversions to the other data types outside the 3 main sensors are provided in the Motion Driver 6.12. With MD6.12, users will be able to get the following data -

- Compass – magnetic field data in micro tesla on each axis
- Gyro – X, Y, Z axis rotational acceleration data in degrees per second
- Accel – X, Y, Z axis linear acceleration data in Gees
- Heading – 360 degrees from North with Y+ axis as the pointer
- Rotational Matrix – linear math 9 element matrix representation
- Euler Angles – Pitch, roll, yaw based in degrees with frame reference
- Quaternions – sensor fused w, x, y, z rotational angles
- Linear Acceleration – linear acceleration in body frame coordinates
- Gravity Vector – Which access gravity effects

The python client which comes with the release package can be used to display the different types of data above.

## 6 MPU Hardware Features

The Motion Driver 6.12 has some specific algorithms for the hardware of the MPU devices. The python client can be used to manually trigger these algorithms for users to see how it works

- Factory Calibration – example of how to calibrate the accel and gyroscope at the factory line. It is highly recommended that the accel is calibrated. Before calibration you must orient your device in a specific orientation. This particular algorithm requires that the device be placed still with the Z+ axis upwards against gravity. Once triggered the biases are obtained and can be applied either to the Hardware Offset registers or the MPL library. Biases need to be saved in flash memory so can be reapplied after on/off.
- Factory Self Test – Factory Tool based on InvenSense Hardware Self Test algorithm to provide go/no go test of the MEMS sensors
- Saving and Loading Sensor States – APIs on saving the sensor states to flash memory. This includes the calibration data for each sensor and also the temperature compensation data. Users can use this as an example of how to save the sensor data into their flash or EEPROM.
- Low Power Accel Mode – Only for MPU6500 and MPU9250. This is an accel only duty cycle mode for lower power. There are multiple samplings users can select from 1Hz up to 640Hz.
- Low Power Motion Interrupt Mode – Only for MPU6500 and MPU9250. Sets the MPU device into a low power accel mode in which if a motion is detected it will generate an interrupt to the MCU for the MCU to wake up and continue processing. The threshold for motion is configurable.
- Dynamically change sensor ODR – MD 6.12 will contain APIs on how to change the output data rates of the sensors as well as how to turn sensors off and on
- Register dump – a dump of all register values