SH-2 Reference Manual

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1.0 Introduction

The SH-2 is CEVA's Hillcrest Labs business unit's turnkey sensor hub software solution. The SH-2 connects to various motion and environmental sensors, collects data from them, processes that data and provides the results to a host processor.

1.1 Intended Audience

This document is intended for application developers implementing products that use the SH-2.

1.2 Scope

This document describes the features of the SH-2, how they work, how to use them and the application programming interface (API) for the SH-2. This document assumes the reader is already familiar with Hillcrest's MotionEngine.

1.3 Revision History

Revision	Date	Description
1.5		
1.4	5/20/2019	Mark FRS block read errors codes as deprecated. Update FRS write response status codes. Document UART reset command. Update ME Calibration command to support On Table Cal control. Clarify output of accelerometer sensor in section 6.5.9. Added Interactive calibration feature. Clarified minimum periods and on/off sensors in section 5.4.1. Correct default format for UART output in section 4.3.23. Add new Clear DCD command to RVC mode in section 3.1.4.4.
1.3	12/12/2017	Added simple command usage. Added Bootloader command usage and product ID request. Removed support for block reads from FRS read requests. Added Simple Calibration Configuration records.
1.2	05/19/2017	Clarified Tare command usage, added description of Tare application to AR/VR Stabilized Rotation Vectors and Gyro-Integrated Rotation Vector. Clarified FRS Read "BUSY" status behavior. Fix bad references. Added language clarifying interaction between Gyro-Integrated Rotation Vector and other fusion outputs. Clarified SHTP channels in 6.2.
1.1	02/16/2017	Update the default value of AR/VR Stabilization FRS record. Remove unused reference.
1.0	02/06/2017	Initial issue

Figure 1: Document History

2.0 Sensor Usage

The SH-2 connects to and manages a variety of physical sensors. It processes the outputs of the physical sensors to produce virtual sensors. Virtual sensors require data from one or more physical sensors. Figure 2 indicates which physical sensors are required for which virtual sensors. The number of physical sensors in use at any one time impacts the power consumed by the device. Using more physical sensors means consuming more power.

Virtual Sensors	Physical Sensors: accelerometer	gyroscope	magnetometer	pressure	ambient light	humidity	proximity	temperature	HRM
Raw accelerometer	X								
Acceleration	X								
Linear acceleration	X								
Gravity	X								
Raw gyroscope		X							
Gyroscope calibrated	X	X							
Gyroscope uncalibrated	X	X							
Raw magnetometer	X								
Magnetic field calibrated	X		X						
Magnetic field uncalibrated	X		X						
Rotation vector	X	X	X						
Game rotation vector	X	X							
Geomagnetic rotation vector	X		X						
Pressure				X					
Ambient light					X				
Humidity						X			
Proximity							X		
Temperature								X	
Tap detector	X								
Step detector	X								
Step counter	X								
Significant motion	X								
Stability classifier	X	X							
Shake detector	X								
Flip detector	X								
Pickup detector	X								
Stability detector	X								
Personal Activity classifier	X								
Sleep detector	X								
Tilt detector	X								
Pocket detector	X				X		X		
Circle detector	X								
Heart rate monitor	X								X
AR/VR Stabilized Rotation Vector	X	X	X						
AR/VR Stabilized Game Rotation Vector	X	X							
Gyro-Integrated Rotation Vector	X	X	X[1]						

Figure 2: Sensor Usage

[1] Magnetometer is not required when Gyro-Integrated Rotation Vector is configured with the Game Rotation Vector as its Reference Data Type (see 4.3.24).

3.0 Host Interfaces

The SH-2 communicates to the host processor through Hillcrest's Sensor Hub Transport Protocol. See [1] for details of the SHTP protocol. See [2] for details of how SH-2 uses SHTP.

3.1 UART Interface

Certain SH-2 products support a UART interface with special output formats. There are three such output formats available.

3.1.1 H-format Output Packet

The H-format packet is the default output packet format for the UART mode. This output packet provides Euler angles and acceleration values. This output packet format needs to be selected using an FRS record – see 4.3.23 for more information on the FRS record. Below is a description of the output packet layout.

Byte	Description
0	Header LSB = 0xAA
1	Header MSB = 0xAA
2	Sequence Number
3	Yaw LSB
4	Yaw MSB
5	Pitch LSB
6	Pitch MSB
7	Roll LSB
8	Roll MSB
9	X-axis acceleration LSB
10	X-axis acceleration MSB
11	Y-axis acceleration LSB
12	Y-axis acceleration MSB
13	Z-axis acceleration LSB
14	Z-axis acceleration MSB
15	Motion intent
16	Motion request
17	Reserved
18	Checksum

Figure 3: H-format Output Packet Definition

Header	16-bit packet header, always equal to 0xAAAA.
Sequence Number	Sequence number of the packet. The first packet sent after startup will have a sequence number of 0. After the 256th packet is sent the sequence number rolls over back to 0.
Yaw	16-bit angular yaw value expressed in units of centidegrees (degrees x100).
Pitch	16-bit angular pitch value expressed in units of centidegrees (degrees x100).

Roll	16-bit angular roll value expressed in units of centidegrees (degrees x100).
X-axis acceleration	16-bit acceleration value expressed in milli-gravities (gravitational constant x1000) representing the acceleration of the device in the X-direction.
Y-axis acceleration	16-bit acceleration value expressed in milli-gravities (gravitational constant x1000) representing the acceleration of the device in the Y-direction.
Z-axis acceleration	16-bit acceleration value expressed in milli-gravities (gravitational constant x1000) representing the acceleration of the device in the Z-direction.
Motion intent	A reflection of the motion intent provided to the sensor hub. See 6.4.12.1 for values.
Motion request	An enumeration of the requested motion. See 6.5.45.2 for values.
Reserved	Reserved bytes, always equal to 0x00.
Checksum	Checksum of the packet, equal to the sum of the sequence number, yaw, pitch, roll, acceleration and reserved bytes of the packet.

3.1.2 S-format Output Packet

The S-format is an alternate output packet format for the UART mode. This output packet provides heading information. Below is a description of the output packet layout:

Byte	Description
0	Header = 0xAA
1	Reserved = 0x00
2	Sequence Number
3	Angle LSB
4	Angle MSB
5	Checksum

Figure 4: S-format Output Packet Definition

Header	Packet header byte, always equal to 0xAA.
Reserved	Reserved byte, always equal to 0x00.
Sequence Number	Sequence number of the packet. The first packet sent after startup will have a sequence number of 0. After the 256th packet is sent the sequence number rolls over back to 0.
Angle	16-bit heading value expressed in units of centidegrees (degrees x100). This value has a range of -18000 to 18000 centidegrees.

Checksum	Checksum of the packet, equal to the XOR of the sequence number and angle bytes of the packet.

3.1.3 L-format Output Packet

The L-format packet is an alternate output packet format for the UART mode. This output packet format needs to be selected using an FRS record – see 4.3.23 for more information on the FRS record. Below is a description of the output packet layout.

Byte	Description
0	Header LSB = 0xAC
1	Header MSB = 0xAC
2	Sequence Number
3	Angle LSB
4	Angle MSB
5	Angular velocity LSB
6	Angular velocity MSB
7	X-axis acceleration LSB
8	X-axis acceleration MSB
9	Y-axis acceleration LSB
10	Y-axis acceleration MSB
11	Z-axis acceleration LSB
12	Z-axis acceleration MSB
13	Reserved
14	Checksum

Figure 5: L-format Output Packet Definition

Header	16-bit packet header, always equal to 0xACAC.
Sequence Number	Sequence number of the packet. The first packet sent after startup will have a sequence number of 0. After the 256^{th} packet is sent the sequence number rolls over back to 0.
Angle	16-bit heading value expressed in units of decidegrees (degrees x10). This value has a range of -1800 to 1800 decidegrees.
Angular velocity	16-bit angular velocity value expressed in units of decidegrees per second (degrees per second x10).
X-axis acceleration	16-bit acceleration value expressed in milli-gravities (gravitational constant x1000) representing the acceleration of the device in the X-direction.
Y-axis acceleration	16-bit acceleration value expressed in milli-gravities (gravitational constant x1000) representing the acceleration of the device in the Y-direction.
Z-axis acceleration	16-bit acceleration value expressed in milli-gravities (gravitational constant x1000) representing the acceleration of the device in the Z-direction.

Reserved	Reserved byte, always equal to 0x00.
Checksum	Checksum of the packet, equal to the sum of the sequence number, angle, angular velocity, and acceleration bytes of the packet.

3.1.4 UART Inputs

The UART interface accepts a limited number of input messages

3.1.4.1 Reset

The reset command is: $MIB,RESET*87

3.1.4.2 Motion Intent

There are four motion intent commands that correspond to the values in 6.4.12.1

The motion intent commands are:

$MIB,INTENT*00

$MIB,INTENT*01

$MIB,INTENT*02

$MIB,INTENT*03

3.1.4.3 Configure ME Calibration

The MotionEngine calibration enables can be set using the following command

$MIB,DYNCAL*nn where nn is an ascii hexadecimal value representing a bit mask of the calibration enables. 1 enables the calibration, 0 disable the calibration. For example, “1F” enables all the calibrations. The bit positions within the mask are used as follows:

Bit 0: accelerometer calibration enable

Bit 1: gyroscope calibration enable

Bit 2: magnetometer calibration enable

Bit 3: planar accelerometer calibration enable

Bit 4: on table calibration enable

3.1.4.4 Clear DCD and Reset

The Clear DCD and Reset command the clears the DCD from flash and from RAM and then resets the device. When the system comes out of reset, it will start fresh without any previous DCD. The command is:

$MIB,CLRDCD*00

4.0 Configuration

The SH-2 has a number of configurable options that control the overall behavior of the hub. These configuration options are stored as records in either flash or RAM. Only one record of each configuration options may be stored. Access to the configuration records is provided through reports described in section 6.3.

4.1 Flash Storage

The SH-2 can be implemented on processors with flash memory. On these systems the configuration records persist through power cycles. The configuration options may be changed at any time; however, the SH-2 must be restarted for changes to take effect. The SH-2 has a very simple flash record system (FRS) that manages reading, writing and erasing these records. The FRS implements wear leveling to reduce wear on the flash memory.

4.2 RAM Storage

The SH-2 can also be implemented on processors without flash. In these systems the configuration records are stored in RAM. They must be downloaded each time the SH-2 is started. To change configuration options, restart the SH-2 and download new options.

4.3 Records

4.3.1 Static Calibration

Static calibration data is produced by the manufacturing process for per device calibration and stored on the SH-2. There are two per device calibration records – one for the accelerometer, gyroscope and magnetometer (AGM) sensor set and one for the screen rotation accelerometer (SRA). The SH-2 uses a nominal calibration if static calibration data is not configured. The nominal calibration is built-in to the SH-2 sensor drivers. There are two nominal calibration records – one for the AGM sensor set and one for the SRA. The per device records are read/write. The nominal records are read only. The data format is proprietary to Hillcrest Labs.

4.3.2 Dynamic Calibration

Dynamic calibration is produced by MotionEngine during operation. Dynamic calibration may be stored for use following a restart to enhance MotionEngine's startup performance. The data format is proprietary to Hillcrest Labs.

4.3.3 MotionEngine Power Management and Stability Classifier

The MotionEngine power management record controls the thresholds MotionEngine uses to determine when the device is at rest and when it is in motion. The format of a MotionEngine Power Management record is shown in Figure 6. This record also configures the thresholds use by the stability classifier.

	Description			
Word	**Byte 3**	**Byte 2**	**Byte 1**	**Byte 0**
0	Delta orientation			
1	Stable threshold			
2	Reserved	Delta acceleration	Stable duration	

Figure 6: MotionEngine Power Management and Stability Classifier Record

Delta orientation	Once a device has been determined to be not moving based on the generation of ON_TABLE or IS_STABLE, delta orientation is the amount of change in device orientation required to recognize that the device is in motion. The units are radians. The delta orientation value is a signed, 2's-complement fixed point number with a Q point of 28. The default value is 0.2.
Stable threshold	The gyro output must be below this limit for the stable duration in order for an IS_STABLE notification to be generated. The units are radians per second. The stable threshold value is a signed, 2's-complement fixed point number with a Q point of 25. The default value is 1.0.
Stable duration	The amount of time in seconds that motion must be below the stable threshold before an IS_STABLE notification is generated. The default value is 3.
Delta acceleration	When using wake-on-motion, this is the amount of acceleration required for the accelerometer to determine that motion has occurred. The units are mg. The delta acceleration value is unsigned. The default value is 0.

4.3.4 Sensor Orientation

The sensor orientation record controls the rotation of the MotionEngine output coordinate system relative to the sensor's coordinate system. The rotation vector is a signed, 2's-complement fixed point number with a Q point of 30. The format of a sensor orientation record is shown in Figure 7. If the rotation vector is set to all 0's then no rotation is applied. The default values are 0 for all for values. In addition, each accelerometer, gyroscope and magnetometer has its own sensor orientation record. The sensor specific records are used to align the orientation of sensors to the system when not using per device static calibration data.

Word	Description
0	Rotation quaternion X
1	Rotation quaternion Y
2	Rotation quaternion Z

Word	Description
3	Rotation quaternion W

Figure 7: Sensor Orientation Record

4.3.5 AR/VR Stabilization

During large, fast motions the angular position output may sometimes become misaligned with the actual angular position. When the device slows or stops, angular position can be determined accurately and the angular position output updated accordingly. However, step updates to the output are undesirable in some applications. AR/VR stabilization addresses this issue by correcting angular position errors only when the device is moving.

The AR/VR stabilization record controls the thresholds MotionEngine uses to stabilize angular position. The format of an AR/VR stabilization record is shown in Figure 8. The AR/VR stabilization parameters are all unsigned, fixed point numbers. There are separate AR/VR stabilization records for the rotation vector and game rotation vector. If a record is not programmed then default values of 0 are used for all parameters.

Word	Description
0	Scaling
1	Max rotation
2	Max error
3	Stability magnitude

Figure 8: AR/VR Stabilization Record

Scaling	Scaling controls what fraction of the angular velocity can be used to correct angular position errors. The range for this parameter is 0 to 1.0. This parameter is dimensionless. The Q point is 30. A typical value is 0.2.
Max rotation	Max rotation is the maximum amount of angular correction that can be used to correct angular position errors. The settings for scaling and max rotation determine how aggressively angular errors are corrected. The range is 0 to PI. The units are radians. The Q point is 29. A typical value is 7.3 degrees or 0.127 radians.
Max error	Max error is the maximum angular error allowed to accumulate before the angular position output is updated in a single step. The units are radians. The range is 0 to PI. The Q point is 29. A typical value is 45 degrees or 0.785 radians.
Stability magnitude	Stability magnitude controls the amount of change in angular position that must occur before the angular position output is updated with a new value. The units are radians. The Q point is 29. A typical value is 0.0 degrees or 0.0 radians.

4.3.6 Significant Motion Detector Configuration

The significant motion detector has several parameters that must be configured. The configuration parameters are 32-bit integers or 32-bit signed fixed point numbers. If this record is not programmed then default values are used.

Word	Description
0	Acceleration threshold
1	Step threshold

Figure 9: Significant Motion Detector Configuration Record

Acceleration threshold — The acceleration threshold to trigger significant motion. The default value is 10.0 m/s^2. The Q point is 24.

Step threshold — The number of steps required to trigger significant motion. The default value is 5. This is an unsigned integer.

4.3.7 Shake Detector Configuration

The shake detector has several parameters that must be configured. The configuration parameters are 32-bit signed integers, 32-bit signed fixed point numbers or bit fields. If this record is not programmed then default values are used.

Word	Description
0	Minimum time
1	Maximum time
2	Threshold
3	Shake count
4	Enable flags

Figure 10: Shake Detector Configuration Record

Minimum time — The minimum time in microseconds between direction changes. The default value is 50,000us.

Maximum time — The maximum time in microseconds between direction changes. The default value is 400,000us.

Threshold — The threshold in m/s^2 that must be exceeded to count as a direction change. The default value is 8.0m/s^2. The Q point is 26.

Shake count — The number of direction changes to count as a shake. The default value is 3.

Enable flags — Enable flags for shake detection on the X, Y and Z axes. 0 – disable, 1 – enable. X, Y, and Z axes are enabled by default.

Bit 0 – X axis
Bit 1 – Y axis
Bit 2 – Z axis
Bit 3:7 - reserved

4.3.8 Serial Number

The serial number record stores a 32-bit number used to identify an individual device. The format of a serial number record is shown in Figure 11.

Word	Description
0	32-bit serial number

Figure 11: Serial Number Record

4.3.9 Maximum Fusion Period

The maximum fusion period record stores the maximum fusion period allowed. The units are microseconds. If a fusion period larger than this maximum is requested then the fusion period will be set to this maximum. The fusion period check can be disabled by clearing this record or by setting the maximum to 0.

Word	Description
0	Max fusion period

Figure 12: Maximum Fusion Period Record

4.3.10 Environmental Sensor Calibration

Each environmental sensor may require calibration. The calibration parameters for the environmental sensors are offset and scale. Offset accounts for a fixed difference between the output of the sensor and the actual value. Scale accounts for the difference between how much the output of the sensor changes and how much the actual value changes. Offset and scale are both signed fixed point numbers. The Q point is different for each type of sensor. If the calibration record for a particular sensor is not programmed then default values of offset = 0 and scale = 1 are used.

Word	Description
0	Offset
1	Scale

Figure 13: Environmental Sensor Calibration Record

Offset
: The offset value is added to the output of the sensor. The Q points are:

Pressure: 20
Temperature: 7
Humidity: 8
Ambient Light: 8
Proximity: 4

Scale
: The output of the sensor is multiplied by the scale. The Q points are:

Pressure: 15
Temperature: 15
Humidity: 15
Ambient Light: 15
Proximity: 15

4.3.11 Ambient Light Sensor (ALS) Calibration

The ALS may require additional calibration parameters beyond the simple scale and offset provided to all environmental sensors. These parameters are device specific and are stored in the ALS Calibration Record.

Word	Description
0	Sensor GUID
1	Bits 7:0 – Length Bits 31:8 - Reserved
1..N	Parameters

Figure 14: ALS Calibration Record

Sensor GUID	An ID that uniquely identifies the sensor for which the calibration record was created.
Length	Length in words of the parameters section of the record.
Parameters	The calibration parameters applicable for a specific sensor. Contact Hillcrest Labs for details.

4.3.12 Proximity Sensor Calibration

The proximity sensor may require additional calibration parameters beyond the simple scale and offset provided to all environmental sensors. These parameters are device specific and are stored in the Proximity Sensor Calibration Record.

Word	Description
0	Sensor GUID
1	Bits 7:0 – Length Bits 31:8 - Reserved
1..N	Parameters

Figure 15: Proximity Sensor Calibration Record

Sensor GUID	An ID that uniquely identifies the sensor for which the calibration record was created.
Length	Length in words of the parameters section of the record.
Parameters	The calibration parameters applicable for a specific sensor. Contact Hillcrest Labs for details.

4.3.13 Flip Detector Configuration

The flip detector has several parameters that must be configured. The configuration parameters are 32-bit signed fixed point numbers. If this record is not programmed then default values are used.

Word	Description
0	Time constant
1	Angular threshold
2	Angular hysteresis

Figure 16: Flip Detector Configuration Record

Time constant	The time constant used for filtering input data. The default value is 0.4. The Q point is 20.
Angular threshold	The angle in radians, measured from a downward pointing line (i.e. line pointing toward earth) defining the maximum range to be in the down state. The default value is pi/4 (45 degrees). The Q point is 29.
Angular hysteresis	The angle in radians defining the amount of hysteresis to apply. The hysteresis region is angular threshold ± (angular hysteresis / 2). The default value is pi/90 (2 degrees). The Q point is 29.

4.3.14 Pickup Detector Configuration

The pickup detector has several parameters that must be configured. The configuration parameters are 32-bit signed fixed point numbers. If this record is not programmed then default values are used.

The pickup detector can be operated in three different modes. The first mode, "Level-to-not-level" (LNL) reports a pick-up event when the sensor hub moves from a level position to a non-level position. The second mode, "Stopped within Tilt Region" (SWTR) reports a pick-up event when the sensor hub is rotated to a given angular position and held there. The third mode reports a pick-up event when either the LNL or SWTR conditions are satisfied.

These detectors are configured independently. In Figure 17, fields are identified as belonging to the "Level-to-Not-Level" (LNL) detector or the "Stopped Within Tilt Region" (SWTR) detector.

Word	Description			
	MSB			LSB
0	Enabled detectors			
1	LNL Orientation Y		LNL Orientation X	
2	LNL Orientation W		LNL Orientation Z	
3	LNL Group Delay			
4	LNL Angular Deviation			
5	LNL Angular Hysteresis			
6	SWTR Orientation Y		SWTR Orientation X	
7	SWTR Orientation W		SWTR Orientation Z	
8	SWTR Group Delay			
9	SWTR Roll Minimum			
10	SWTR Roll Maximum			
11	SWTR Pitch Minimum			
12	SWTR Pitch Maximum			
13	SWTR Stable Acceleration			
14	SWTR Motion Acceleration			
15	SWTR Motion to Stable Duration			

Figure 17: Pickup Detector Configuration Record

Enabled Detectors	A bitmap of enabled detectors. LNL and SWTR detectors are enabled by default. Bit 0 – LNL detector Bit 1 – SWTR detector Bit 2:31 – reserved
LNL Orientation	A rotation quaternion that is applied to the input before computing what is "level". The default value is the identity quaternion. The Q point is 14.
LNL Group delay	The desired group delay in seconds. The default value is 0.4 seconds. The Q point is 20.
LNL Angular Deviation	The angle (in radians) defining much tilt there can be and still consider the device "level". The default value is pi/4 radians (45 degrees). The Q point is 29.

LNL Angular Hysteresis	The angle (in radians) defining the amount of hysteresis to apply. The entry point for level will be: angDeviation - angHysteresis/2. The exit point from level will be: angDeviation + angHysteresis/2. The default value is pi/90 radians (2 degrees). The Q point is 29.
SWTR Orientation	A rotation quaternion that is applied to the input before decomposing into roll and pitch. The default value is (0.7071, 0, 0, 0.7071) for (W,X,Y,Z). The Q point is 14.
SWTR Group Delay	The desired group delay in seconds. The default value is 0.125 seconds. The Q point is 20.
SWTR Roll Minimum	The minimum roll value (in rads) when stopped to trigger a detection. The default value is –pi/18 radians (-10 degrees). The Q point is 29.
SWTR Roll Maximum	The maximum roll value (in rads) when stopped to trigger a detection. The default value is 2.96706 radians (170 degrees). The Q point is 29.
SWTR Pitch Minimum	The minimum pitch value (in rads) when stopped to trigger a detection. The default value is –pi/3 radians (-60 degrees). The Q point is 29.
SWTR Pitch Maximum	The maximum pitch value (in rads) when stopped to trigger a detection. The default value is pi/3 radians (60 degrees). The Q point is 29.
SWTR Stable Acceleration	The largest acceleration (in m/s^2) that is allowed to indicated stopped. The default value is 1.0 m/s^2. The Q point is 24.
SWTR Motion Acceleration	The smallest acceleration (in m/s^2) that will trigger motion. The default value is 4.0 m/s^2. The Q point is 24.
SWTR Motion to Stable Duration	The amount of time allowed (in seconds) between the last detected motion and when the device is stopped. The Q point is 20. The default value is 1.0 seconds.

4.3.15 Stability Detector Configuration

The stability detector has several parameters that must be configured. The configuration parameters are 32-bit fixed point numbers. If this record is not programmed then default values are used.

Word	Description
0	Acceleration threshold
1	Duration

Figure 18: Stability Detector Configuration Record

Acceleration threshold	The acceleration in m/s^2 that must be exceeded to trigger not stable. The default value is 0.784 m/s^2. The Q point is 24. This value is signed.
Duration	The duration in microseconds that acceleration must remain below the acceleration threshold in order to declare that the device is stable. The default value is 500,000us. The Q point is 0. This value is unsigned.

4.3.16 Activity Tracker Configuration

The data format of the Activity Tracker Configuration is proprietary to Hillcrest Labs.

4.3.17 Sleep Detector Configuration

The sleep detector has several parameters that must be configured. The configuration parameters are 32-bit unsigned fixed point numbers. If this record is not programmed then default values are used.

Word	Description
0	Filter coefficient
1	Processing window
2	Categorization window
3	Calibration constant

Figure 19: Sleep Detector Configuration Record

Filter coefficient	A coefficient used to clamp low acceleration values to 0. The default value is 0.035. The Q point is 29.
Processing window	The processing window size in seconds. The default value is 10. The Q point is 0.
Categorization window	The categorization window size in number of processing windows. The default value is 6. The Q point is 0.
Calibration constant	A unitless calibration constant that tunes how small a movement triggers a hard wake. It should be tuned experimentally. The default value is 0.45. The Q point is 29.

4.3.18 Tilt Detector Configuration

The tilt detector has several parameters that must be configured. The configuration parameters are 32-bit signed fixed point numbers. If this record is not programmed then default values are used.

Word	Description
0	Processing window
1	Angular threshold

Figure 20: Tilt Detector Configuration Record

Processing window — The processing window size in seconds. The default value is 2. The Q point is 27.

Angular threshold — The cosine of the angle that defines a tilt. The default value is cos(35 degrees) = 0.81915… The Q point is 30.

4.3.19 Pocket Detector Configuration

The pocket detector has several parameters that must be configured. The configuration parameters are 32-bit signed fixed point numbers. If this record is not programmed then default values are used.

Word	Description			
	MSB			LSB
0	Orientation Y		Orientation X	
1	Orientation W		Orientation Z	
2	Orientation Group Delay			
3	Angular Ghost Group Delay			
4	Near threshold			
5	Dark threshold			
6	Level threshold			
7	Inverted threshold			
8	Straight threshold			
9	Linear motion threshold			
10	Angular motion threshold			
11	Motion timeout			
12	Opaque adjacency debounce time			

Figure 21: Pocket Detector Configuration Record

Orientation — A rotation quaternion that is applied to the input before pocket determination. The default value is the identity quaternion. The Q point is 14.

Orientation Group Delay — The desired group delay of the orientation filter in seconds. The Q point is 20.

Angular Ghost Group Delay — The desired group delay of the angular ghost filter in seconds. The Q point is 20.

Near Threshold	The threshold below which values are considered near. The default value is 3 cm. The Q point is 0.
Dark Threshold	The threshold below which values are considered dark. The default value is 10 lux. The Q point is 0.
Level Threshold	The threshold at which a "level" state is determined. The default value is cos(15 degrees). The Q point is 29.
Inverted Threshold	The threshold at which a "inverted" state is determined. The default value is cos(100 degrees). The Q point is 29.
Straight Threshold	The threshold at which a "straight" state is determined The default value is sin(10 degrees). The Q point is 29.
Linear Motion Threshold	The threshold at which linear motion is considered. The default value is 2 m/s^2. The Q point is 26.
Angular Motion Threshold	The threshold at which angular motion is considered. The default value is pi/3 rad/s. The Q point is 28.
Motion Timeout	The timeout for determining motion consideration. The default value is 1 second. The Q point is 20.
Opaque Adjacency Debounce Time	The debounce time for determining opaque adjacency (a near and dark state). The default value is 1 second. The Q point is 20.

4.3.20 Circle Detector Configuration

The circle detector has several parameters that must be configured. The configuration parameters are 32-bit signed fixed point numbers. If this record is not programmed then default values are used.

Word	Description
0	Acceleration threshold
1	Angular threshold
2	Revolution threshold

Figure 22: Circle Detector Configuration Record

Acceleration threshold	The threshold of acceleration change from gravity to be considered circle motion. The default value is 4 m/s^2. The Q point is 24.
Angular threshold	The threshold of angle between rotation axes. The default value is 0. The Q point is 30.
Revolution threshold	The threshold for revolutions in radians. The default value is 3pi. The Q point is 25.

4.3.21 User Record

There is a record available for the user to store data. The data must be stored as words. The user record should be limited to 64 words.

Word	Description
0	User defined
…	
n	

Figure 23: User Record

4.3.22 MotionEngine Time Source Selection

MotionEngine needs to know how to determine the amount of time between two samples from gyroscope. There are two methods for determining the sample time. The first method is to use the period that the gyroscope is set to. The second method is to use the sample timestamps provided by the system clock from the chip on which the sensor hub library is operating. If the system clock is based on a crystal or an accurate oscillator (±2%) then use time stamps; otherwise use the gyroscope period.

Word	Description
0	Time source

Figure 24: Time Source Record

Time source	0 – use gyroscope period 1 – use timestamps others – reserved

4.3.23 UART Output Format Selection

Some SH-2 products support UART output. There are multiple output formats available for products operating in UART mode. This FRS record is used to select which output format to use. If this record is not present in a system, the H-format output is used by default.

Word	Description
0	UART Output Format Selection

Figure 25: UART Output Format Selection Record

UART Output Format Selection	0 – S-format Output 1 – L-format Output 2 – H-format Output others – reserved

4.3.24 Gyro-Integrated Rotation Vector

The Gyro-Integrated Rotation Vector provides high-rate, low-latency rotation vector output. It can be configured to use several different sources as a reference vector, and prediction can optionally be enabled and tuned.

Word	Description			
	MSB			LSB
0	Reserved		Reference Data Type	
1	Synchronization Interval			
2	Maximum Error			
3	Prediction Amount			
4	Alpha			
5	Beta			
6	Gamma			

Figure 26: Gyro-Integrated Rotation Vector Configuration Record

Reference Data Type	The slower fused result which is used to provide periodic corrections to the fast gyro integration process. Acceptable values are 0x0207 (6-axis Game Rotation Vector) and 0x0204 (9-axis Absolute Rotation Vector). Default value is 6-axis Game Rotation Vector (0x0207).
Reserved	Set to 0.
Synchronization Interval	Duration, in microseconds, desired between outputs of reference data type. The units are microseconds. The default value is 10000 (equivalent to 100 Hz).
Maximum Error	Maximum discrepancy, in radians, between the gyro-integrated rotation vector and the reference vector that can be used for smooth corrections. If the reference vector diverges from the gyro-integrated rotation vector by more than this amount, the gyro-integrated rotation vector will be updated in a single discontinuous step to match the reference. The units are radians. The Q-point is 29. The default value is π/6 (equivalent to 30 degrees).
Prediction amount	Amount forward in time at which prediction will be performed. The units are seconds. The Q-point is 10. Default value is 0. Set this to 0 to disable prediction.
Alpha	Unitless position prediction parameter. The Q-point is 20. Default value is 0.303072543909142
Beta	Unitless velocity prediction parameter. The Q-point is 20. Default value is 0.113295896384921
Gamma	Unitless acceleration prediction parameter. The Q-point is 20. Default value is 0.002776219713054

4.3.25 Fusion Control Record

MotionEngine needs to know if the Game Rotation Vector is to use the magnetometer for stabilization. This is a bit oriented flag word.

Word	Description
0	Flags

Figure 27: Fusion Control Record

Bit 0 - Enable Mag Stabilized Game Rotation Vector	0 – False 1 – True
	others – reserved

4.3.26 Simple Calibration Configuration

The simple calibration process requires several sensor specific configuration parameters as well as some process specific configuration parameters. These parameters can be set using the Simple Calibration Configuration record. In addition, SH-2 and the SH-2 sensor drivers have built-in nominal parameters that are used if the Simple Calibration Configuration record is empty. Contact Hillcrest for further details on the use of this record.

4.3.27 Configuration Records Summary

A list of all the configuration records is shown in Figure 28.

Record ID	Description
0x7979	Static calibration – AGM
0x4D4D	Nominal calibration – AGM
0x8A8A	Static calibration – SRA
0x4E4E	Nominal calibration - SRA
0x1F1F	Dynamic calibration
0xD3E2	MotionEngine power management
0x2D3E	System orientation
0x2D41	Primary accelerometer orientation
0x2D43	Screen rotation accelerometer orientation
0x2D46	Gyroscope orientation
0x2D4C	Magnetometer orientation
0x3E2D	AR/VR stabilization – rotation vector
0x3E2E	AR/VR stabilization – game rotation vector
0xC274	Significant Motion detector configuration
0x7D7D	Shake detector configuration
0xD7D7	Maximum fusion period
0x4B4B	Serial number
0x39AF	Environmental sensor - Pressure calibration
0x4D20	Environmental sensor - Temperature calibration
0x1AC9	Environmental sensor - Humidity calibration
0x39B1	Environmental sensor - Ambient light calibration
0x4DA2	Environmental sensor - Proximity calibration

Record ID	Description
0xD401	ALS Calibration
0xD402	Proximity Sensor Calibration
0x1B2A	Pickup detector configuration
0xFC94	Flip detector configuration
0xED85	Stability detector configuration
0xED88	Activity Tracker configuration
0xED87	Sleep detector configuration
0xED89	Tilt detector configuration
0xEF27	Pocket detector configuration
0xEE51	Circle detector configuration
0x74B4	User record
0xD403	MotionEngine Time Source Selection
0xA1A1	UART Output Format Selection
0xA1A2	Gyro-Integrated Rotation Vector configuration
0xA1A3	Fusion Control Flags
0xA1A4	Simple Calibration Configuration
0XA1A5	Nominal Simple Calibration Configuration

Figure 28: Configuration Records

4.3.28 Version Information

Version information is retrieved by using the HCOMM Product ID Request message.

5.0 Operation

5.1 Sensor Metadata

Each sensor has a set of static metadata associated with it. This metadata provides information about the sensor's capabilities and limitations. The metadata available for each sensor is

- Vendor ID
- Sensor driver version
- Sensor-specific metadata
- Name string
- Maximum range
- Minimum period
- Batch buffer reserved count
- Maximum batch buffer count
- Resolution
- Power
- Bytes used in batch buffer for one sample
- Q point 1 – applies to sensor output
- Q point 2 – applies to sensor bias or sensor accuracy unless otherwise noted.

The metadata for each sensor is retrieved by performing an FRS read operation. The FRS record ID for each sensor is listed in Figure 29.

Record ID	Description
0xE301	Raw accelerometer
0xE302	Accelerometer
0xE303	Linear acceleration
0xE304	Gravity
0xE305	Raw gyroscope
0xE306	Gyroscope calibrated
0xE307	Gyroscope uncalibrated
0xE308	Raw magnetometer
0xE309	Magnetic field calibrated
0xE30A	Magnetic field uncalibrated
0xE30B	Rotation vector
0xE30C	Game rotation vector
0xE30D	Geomagnetic rotation vector
0xE30E	Pressure
0xE30F	Ambient light
0xE310	Humidity
0xE311	Proximity
0xE312	Temperature
0xE313	Tap detector
0xE314	Step detector
0xE315	Step counter
0xE316	Significant motion
0xE317	Stability classifier
0xE318	Shake detector
0xE319	Flip detector

Record ID	Description
0xE31A	Pickup detector
0xE31B	Stability detector
0xE31C	Personal Activity classifier
0xE31D	Sleep detector
0xE31E	Tilt detector
0xE31F	Pocket detector
0xE320	Circle detector
0xE321	Heart Rate Monitor
0xE322	ARVR Stabilized Rotation Vector
0xE323	ARVR Stabilized Game Rotation Vector
0xE324	Gyro-integrated Rotation Vector
0xE325	Motion Request

Figure 29: Metadata Records

The format of the metadata records is shown in Figure 30 and Figure 26.

Word	Description			
	MSB			LSB
0	Version			
1	Range			
2	Resolution			
3	Revision = 3		Power	
4	Minimum period			
5	FIFO reserved count		FIFO max count	
6	Vendor ID length		Batch buffer bytes	
7	Q point 2		Q point 1	
8	Q point 3		Sensor-Specific Metadata Length	
9	Sensor-Specific metadata			
…	…			
9 + Sensor-Specific Metadata Length	Vendor ID			
…	…			
N	Vendor ID			

Figure 30: Metadata Record Format – Revision 3

Word	Description			
	MSB			LSB
0	Version			
1	Range			
2	Resolution			
3	Revision = 4		Power	
4	Minimum period			
5	FIFO reserved count		FIFO max count	

Word	Description			
	MSB			LSB
6	Vendor ID length		Batch buffer bytes	
7	Q point 2		Q point 1	
8	Q point 3		Sensor-Specific Metadata Length	
9	Maximum period			
10	Sensor-Specific metadata			
…	…			
10 + Sensor-Specific Metadata Length	Vendor ID			
…	…			
N	Vendor ID			

Figure 31: Metadata Record Format – Revision 4

Version	Identifies the physical sensor/driver/fusion versions for a given sensor. The elements within this field are updated when a component changes in a manner that affects the output of the sensor. LSB – ME version Byte 1 – MH version Byte 2 – SH version MSB – 0x00
Range	The range of the sensor. The format is unsigned fixed point. The units and Q point are the same as those used in the sensor's input report.
Resolution	The resolution of the sensor. The format is unsigned fixed point. The units and Q point are the same as those used in the sensor's input report.
Power	The power used by the sensor in mA when operating. The format is unsigned fixed point. The Q point is 10.
Revision	Indicates the revision of the metadata record.
Minimum period	An unsigned integer indicating the minimum operating period in microseconds of the sensor.
FIFO max count	The maximum number of samples that can be stored in the batch buffer.
FIFO reserved count	The number entries reserved in the batch FIFO for this sensor
Batch buffer bytes	The number of bytes used in the batch buffer to store one entry.

Vendor ID length	The length of the vendor ID in bytes.
Q point 1	A signed 16-bit integer indicating the Q point of the sensor data fields.
Q point 2	A signed 16-bit integer indicating the Q point of the sensor bias or accuracy fields. This field is applicable only to sensors that have bias or accuracy outputs as well as data outputs.
Sensor-Specific Metadata length	An unsigned 16-bit integer indicating how many bytes are used for sensor-specific metadata. 0 if there is no additional metadata. This value must be a multiple of four.
Q point 3	A signed 16-bit integer indicating the Q point of the sensor data change sensitivity.
Maximum period	An unsigned integer indicating the maximum operating period in microseconds of the sensor.
Sensor-Specific Metadata	Some sensors expose additional information (e.g. Personal activity classifier exposes a bitmap representing the set of supported classification states). This area is used for such information. This field is padded with zeroes if the length is not a multiple of four.
Vendor ID	The vendor ID is a character string that lists the vendor name and part number. It is null terminated. The first byte starts in the LSB of the first word. This field is padded with zeroes if the length of the vendor ID is not a multiple of four.

5.1.1 Sensor-Specific Metadata

Sensors may need to expose more detailed information than the basic set of fields above. The format of these sensors' Sensor-specific Metadata is described here.

5.1.1.1 Personal Activity Classifier Metadata (0xE31C)

The sensor-specific metadata length is 4.

The sensor-specific metadata is structured as shown in Figure 32.

	Description							
Byte	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
0	…	…	…	…	…	…	Classification 1 supported	Classification 0 supported
1	…	…	…	…	…	…	…	…
2	…	…	…	…	…	…	…	…
3	Reserved	Classification 30 supported	…	…	…	…	…	…

Figure 32: Personal Activity Classifier Sensor-Specific Metadata.

5.2 Input Reports

The SH-2 returns sensor data to the host via input reports. Each sensor has its own input report. Input reports are sent at a rate specified by the host. This rate may either be synchronous to the sensor's operating rate or asynchronous. Input reports may also be requested by the host at any time. The SH-2may also be configured to send input reports only if thresholds are exceeded. Each sensor has its own set of thresholds. If a threshold is configured then the SH-2 will send reports at the requested rate only if the sensor output exceeds the threshold.

Sensor data is sent to the host on either the "Wakeup" SHTP channel or the "Normal" SHTP channel, depending on whether a sensor has been configured as a wakeup sensor or not (see [2]).

The Gyro-integrated Rotation Vector is reported on a separate "gyroRV" SHTP channel to facilitate traffic prioritization and other optimizations.

Input reports are also used to send configuration responses to the host. Configuration input reports will be sent on the SHTP "control" channel (see [2]).

5.3 Output Reports

Output reports are used to send configuration information to the SH-2.

5.4 Feature Reports

Sensor operation is controlled through feature reports. Setting a feature report for a sensor causes operation of that sensor to change to comply with the settings in the feature report. Getting a feature report returns the current operation configuration of the sensor. The operations that can be controlled by feature reports are described in the following sections. These descriptions provide an overview of how to control sensor operation. In cases where specific field in feature reports are mentioned see section 6.0 for detailed information about those fields.

5.4.1 Rate Control

Sensor operating rate is controlled through the report interval field. When set to zero the sensor is off. When set to a non-zero value the sensor generates reports at that interval or more frequently. If the sensor cannot operate as quickly as requested, it will operate at its minimum interval, if possible. Input reports are generated at the operating rate of the sensors.

When it is active, the Gyro-Integrated Rotation Vector (6.5.44) may cause a reduction in both the nominal and actual reporting periods for fusion outputs for given requested periods. For example, a 400 Hz Game Rotation Vector may drop to 100 Hz to permit full-speed operation of the Gyro-Integrated Rotation Vector.

Some sensors have maximum operating periods. Setting the interval to a value larger than the maximum operation period results in the sensor operating at its maximum period.

Some sensors are either on or off. Setting the interval to any non-zero value turns the sensor on. The on/off sensors are:

- Motion Request

5.4.2 Threshold Control

Each sensor has a configurable reporting threshold used to determine if an input report should be sent or not. The reporting threshold is set using the change sensitivity field. Change sensitivities are either absolute or relative. Absolute sensitivities are evaluated to determine if the current output values exceed the change sensitivity. Relative sensitivities are evaluated to determine if the current output has changed relative to the previous output by an amount that exceeds the change sensitivity.

5.4.3 Batch Operation

Batching causes the sensor to buffer its input reports until they can be sent. There are two batch buffers. The first buffer is a circular buffer. When the SH-2 in on, reports are sent based on a delay interval or when the buffer is full. When the SH-2 is asleep, reports are queued in the buffer until the buffer is full. New sensor reports then overwrite the oldest reports in the buffer. When the SH-2 is turned on the reports in the buffer are sent.

The second buffer is a wake-on-full buffer. When the SH-2 is on or asleep, reports are sent based on a delay interval or when the buffer is full. When the SH-2 is asleep, reports are queued in the buffer until the buffer is full. When the buffer is full, the SH-2 wakes the AP and sends the reports.

In cases where reports are sent when the buffer is full, they are sent soon enough to prevent the buffer from actually overflowing. Thus, no reports are lost.

5.5 Sensor Triggering

Sensors report events based on trigger modes. The trigger modes are:

- Continuous – events are reported continuously at the report interval
- On-change – events are reported only if the sensor's output has changed. In addition, events are reported no more frequently than once every report interval
- One-shot – a single event is reported and then the sensor turns off
- Special – reporting requirements are explained in the section on that sensor's report
- Wake-up – When the sensor has a report to send, it can wake the host in order to send the report. i.e. it can cause the system to exit sleep mode.
- Always-on – The sensor remains on, even during periods of sleep

The trigger mode for each sensor, except the significant motion detector, can be configured as continuous, on-change or special. The trigger mode for the significant motion detector is always one-shot. In addition, sensors can be configured to wake up the application processor. The trigger mode and wake-up capability for each sensor when configured for an Android system is shown in Figure 33.

Note the interaction between "wake-up" and "always-on." A sensor may be configured as always-on, but not wakeup. In this mode, the sensor will continue to run and log data to the non-wakeup batch buffer while the hub is asleep. When a (different) wakeup sensor triggers, the buffered data from all sensors is delivered. Thus, the host will get the data from the wakeup sensor and then the backlog of data from the non-wakeup, but always-on sensors. It is generally not useful to configure a sensor as "wake-up" but not "always-on."

Output	continuous	on-change	one-shot	special	wake-up	always-on
Raw accelerometer	X					
Acceleration	X					
Linear acceleration	X					
Gravity	X					
Raw gyroscope	X					
Gyroscope calibrated	X					
Gyroscope uncalibrated	X					
Raw magnetometer	X					
Magnetic field calibrated	X					
Magnetic field uncalibrated	X					
Rotation vector	X					
Game rotation vector	X					
Geomagnetic rotation vector	X					
ARVR-Stabilized Rotation vector	X					
ARVR-Stabilized Game rotation vector	X					
Pressure	X					
Ambient light		X				
Humidity		X				
Proximity		X			X	
Temperature		X				
SAR						
Tap detector				X		
Step detector				X		
Step counter		X				X
Significant motion			X		X	
Stability classifier		X				
Shake detector				X	X	
Flip detector				X	X	
Pickup detector				X	X	
Stability detector		X				
Personal Activity Classifier		X				
Sleep detector		X			X	
Tilt detector				X	X	
Pocket Detector		X			X	
Circle detector				X	X	

Figure 33: Sensor Trigger Modes

5.6 Interactive Calibration

Gyroscope outputs are sensitive to changes in temperature. To account for output changes due to temperature, the temperature of the gyroscope must be monitored and the gyroscope's response to temperature changes must be measured and compensated for. This compensation requires detecting when the device is not in motion. The sensor hub performs this detection automatically; however, for some systems, performance can be improved by providing the sensor hub with information about the intended motion of the device. These systems include ones in which the sensor hub may be rotating slowly at a constant rate and ones in which the device is stationary but the sensor hub may be vibrating.

In addition to receiving information about the device's motion, the sensor hub can indicate when a stop will be valuable and how long a stop should be.

To find out when the sensor hub needs to stop, enable the Motion Request report in 6.5.45 or monitor the motion request field in the RVC output of **Error! Reference source not found.**.

To notify the sensor hub of the device's motion use the Interactive Calibration Request described in 3.1.4.2 or 6.4.12. The motion intent notifications may be sent even if the motion requests are not being monitored.

6.0 Report Descriptions

6.1 Report ID Convention

The report ID is shown as byte 0 in the reports defined throughout the following sections.

6.2 Summary

The following table summarizes all the reports in use with SH-2. Direction is relative to the host (e.g. "write" indicates transmission of data from host to hub).

SHTP Channel	Direction	Report ID	Description
SH-2 Control	W	0xFE	Get Feature Request
SH-2 Control	W	0xFD	Set Feature Command
SH-2 Control	W	0xFC	Get Feature Response
Wakeup/Normal	R	0xFB	Base Timestamp
Wakeup/Normal	R	0xFA	Timestamp Rebase
SH-2 Control	W	0xF9	Product ID Request
SH-2 Control	R	0xF8	Product ID Response
SH-2 Control	W	0xF7	FRS Write Request
SH-2 Control	W	0xF6	FRS Write Data
SH-2 Control	W	0xF5	FRS Write Response
SH-2 Control	W	0xF4	FRS Read Request
SH-2 Control	R	0xF3	FRS Read Response
SH-2 Control	W	0xF2	Command Request
SH-2 Control	R	0xF1	Command Response
Wakeup/Normal	R	0x01	Accelerometer
Wakeup/Normal	R	0x02	Gyroscope
Wakeup/Normal	R	0x03	Magnetic Field
Wakeup/Normal	R	0x04	Linear Acceleration
Wakeup/Normal	R	0x05	Rotation Vector
Wakeup/Normal	R	0x06	Gravity
Wakeup/Normal	R	0x07	Uncalibrated Gyroscope
Wakeup/Normal	R	0x08	Game Rotation Vector
Wakeup/Normal	R	0x09	Geomagnetic Rotation Vector
Wakeup/Normal	R	0x0A	Pressure
Wakeup/Normal	R	0x0B	Ambient Light
Wakeup/Normal	R	0x0C	Humidity
Wakeup/Normal	R	0x0D	Proximity
Wakeup/Normal	R	0x0E	Temperature
Wakeup/Normal	R	0x0F	Uncalibrated Magnetic Field
Wakeup/Normal	R	0x10	Tap Detector
Wakeup/Normal	R	0x11	Step Counter
Wakeup/Normal	R	0x12	Significant Motion
Wakeup/Normal	R	0x13	Stability Classifier
Wakeup/Normal	R	0x14	Raw Accelerometer
Wakeup/Normal	R	0x15	Raw Gyroscope
Wakeup/Normal	R	0x16	Raw Magnetometer

SHTP Channel	Direction	Report ID	Description
Wakeup/Normal	R	0x17	SAR
Wakeup/Normal	R	0x18	Step Detector
Wakeup/Normal	R	0x19	Shake Detector
Wakeup/Normal	R	0x1A	Flip Detector
Wakeup/Normal	R	0x1B	Pickup Detector
Wakeup/Normal	R	0x1C	Stability Detector
Wakeup/Normal	R	0x1E	Personal Activity Classifier
Wakeup/Normal	R	0x1F	Sleep Detector
Wakeup/Normal	R	0x20	Tilt Detector
Wakeup/Normal	R	0x21	Pocket Detector
Wakeup/Normal	R	0x22	Circle Detector
Wakeup/Normal	R	0x23	Heart Rate Monitor
Wakeup/Normal	R	0x28	ARVR-Stabilized Rotation Vector
Wakeup/Normal	R	0x29	ARVR-Stabilized Game Rotation Vector

Figure 34: Report ID List

6.3 Configuration Reports

Configuration reports are read and written using messages. These messages are described in the following sections. Some configuration reports are used to collect information. Some configuration reports are used to read and write configuration records.

6.3.1 Product ID Request (0xF9)

The product ID request is used to request product ID information from the FSP3xx.

Byte	Description
0	Report ID = 0xF9
1	Reserved

Figure 35: Product ID Request

6.3.2 Product ID Response (0xF8)

The product ID response returns product ID information about the FSP3xx.

Byte	Description
0	Report ID = 0xF8
1	Reset Cause
2	SW Version Major
3	SW Version Minor
4	SW Part Number LSB
5	SW Part Number …
6	SW Part Number …
7	SW Part Number MSB
8	SW Build Number LSB
9	SW Build Number …

Byte	Description
10	SW Build Number …
11	SW Build Number MSB
12	SW Version Patch LSB
13	SW Version Patch MSB
14	Reserved
15	Reserved

Figure 36: Product ID Response

Reset Cause: The last cause of the processor reset. Only reported for the overall system ID. Subsystem Product IDs will report Not Applicable.

0 – Not Applicable
1 – Power On Reset
2 – Internal System Reset
3 – Watchdog Timeout
4 – External Reset
5 – Other

SW Version: software version major (8 bits).minor (8 bits).patch (16 bits)

SW Part Number: 32-bit value representing the software part number

SW Build Number: 32-bit software build number

6.3.3 FRS Write Request (0xF7)

The FRS write request is used to initiate writing an FRS record.

Byte	Description
0	Report ID = 0xF7
1	Reserved
2	Length LSB
3	Length MSB
4	FRS Type LSB
5	FRS Type MSB

Figure 37: FRS Write Request

Length: length in 32-bit words of the record to be written. If the length is set to 0 then the record is erased.

FRS Type: FRS record type (see Figure 28)

6.3.4 FRS Write Data Request (0xF6)

The FRS write data request is sent to write data to the record indicated by a previous write request. Only one FRS operation may be in progress at any one time.

Byte	Description
0	Report ID = 0xF6
1	Reserved

Byte	Description
2	Offset LSB
3	Offset MSB
4	Data0 LSB
5	Data0 …
6	Data0 …
7	Data0 MSB
8	Data1 LSB
9	Data1 …
10	Data1 …
11	Data1 MSB

Figure 38: FRS Write Data Request

Offset: offset, in 32-bit words, from the beginning of the record indicating where in the record the data is to be written

Data0/1: 32-bit words of data to be written to the FRS record

The offset field is used to detect missing or put of order write data requests. When writing a record, the write data requests must be supplied in order, with both data0 and data1 fields used. If the record contains an odd number of words then the final write data request must use data0.

6.3.5 FRS Write Response (0xF5)

The write response report indicates the status of a write operation.

Byte	Description
0	Report ID = 0xF5
1	Status/Error
2	Word Offset LSB
3	Word Offset MSB

Figure 39: FRS Write Response

Status/Error:
0 – word(s) received
1 – unrecognized FRS type
2 – busy
3 – write completed
4 – write mode entered or ready
5 – write failed
6 – data received while not in write mode
7 – invalid length
8 – record valid (the complete record passed internal validation checks)
9 – record invalid (the complete record failed internal validation checks)
10 – device error (DFU flash memory device unavailable) - deprecated
11 – record is read only
12 – unable to write record. FRS memory is full

12-255 – reserved

Word Offset: the number of words offset from the beginning of the record for the last word of data written to the FRS record.

An FRS write response is generated for each write request or write data request.

6.3.6 FRS Read Request (0xF4)

The FRS read request is used to retrieve an FRS record from the FSP3xx. Only one FRS operation may be in progress at a time. If a Read Request is issued before the first read operation is complete, it will be responded to with a Read Response indicating BUSY and then it will complete the already in-progress read operation.

Byte	Description
0	Report ID = 0xF4
1	Reserved
2	Reserved
3	Reserved
4	FRS Type LSB
5	FRS Type MSB
6	Reserved
7	Reserved

Figure 40: FRS Read Request

FRS Type: FRS record type to read (see Figure 28)

6.3.7 FRS Read Response (0xF3)

The FRS read response report is used to return the contents of an FRS record. Once a read request has been received, the FSP3xx generates read responses until the request record or portion of a record is returned. Only one FRS operation may be in progress at a time.

Byte	Description	
0	Report ID = 0xF3	
1	Data Length (bits 7:4)	Status (bits 3:0)
2	Word Offset LSB	
3	Word Offset MSB	
4	Data0 LSB	
5	Data0 …	
6	Data0 …	
7	Data0 MSB	
8	Data1 LSB	
9	Data1 …	
10	Data1 …	
11	Data1 MSB	
12	FRS Type LSB	
13	FRS Type MSB	
14	Reserved	
15	Reserved	

Figure 41: FRS Read Response

Data Length: the number of data words contained within the message.

Status:
0 – no error
1 – unrecognized FRS type
2 – busy
3 – read record completed
4 – deprecated
5 – record empty
6 – deprecated
7 – deprecated
8 – device error (DFU flash memory device unavailable)
9-15 – reserved

Word Offset: the number of words offset from the beginning of the record

Data0/1: between 0 and 2 32-bit words of data from and FRS record. If only 1 word is present then it will be in the data0 field.

FRS Type: indicates to which type of FRS record the data belongs (see Section 4.0)

6.3.8 Command Request (0xF2)

The command request is used to ask the SH-2 to perform some special operation or report some special data that is not part of normal sensor operation.

Byte	Description
0	Report ID = 0xF2
1	Sequence number
2	Command
3	P0
4	P1
5	P2
6	P3
7	P4
8	P5
9	P6
10	P7
11	P8

Figure 42: Command Request

Sequence number: A monotonically incrementing uint8_t that rolls over. It is used to detect missing commands and to synchronize responses

Command: A unit8_t in the range of 1-127 indicating the command. 0 and 128-255 are reserved.

P0 – P9: A set of command-specific parameters. The interpretation of these parameters is defined for each command.

6.3.9 Command Response (0xF1)

The command response is used to report the results of some special operation or some special data that is not part of normal sensor operation.

Byte	Description
0	Report ID = 0xF1
1	Sequence number
2	Command
3	Command sequence number
4	Response sequence number
5	R0
6	R1
7	R2
8	R3
9	R4
10	R5
11	R6
12	R7
13	R8
14	R9
15	R10

Figure 43: Command Response

Sequence number	A monotonically incrementing uint8_t that rolls over. It is used to detect missing responses
Command	A unit8_t indicating the command being responded to. A value of with the most significant bit set indicates that the response was autonomously generated and is not associated with a command request. Bits 6-0 indicate the command that the response corresponds to. That is, bits 6-0 identify how to interpret the response.
Command sequence number	The sequence number from the command request for which the response was returned. It is used to synchronize commands and responses. This field is set to 0 for unsolicited responses.
Response sequence number	Some commands may require multiple responses. This is a monotonically incrementing uint8_t that counts responses within a group of responses to a single request. It may rollover. It restarts at 0 with each new response group. A response group may consist of only one response.
R0 – R10	A set of response values. The interpretation of these values is specific to the response for each command.

6.4 Commands

A set of commands has been defined to support a variety of operations on the sensor hub. For each command id, a Command Message and associated Response message are usually defined. (A few cases define only a command or only a response.) The definitions of the command and response formats for each command id are defined in the following sections.

The following table summarizes the command identifiers defined to date:

Id	Name	Description
1	Errors	Command and Response to access error queue. See section 6.4.1
2	Counter	Command and Response to access counters. See section 6.4.2
3	Tare	Command and Response to operate on tare. See section 6.4.3
4	Initialize	Reinitialize sensor hub components. See section 6.4.4
5	Reserved	ID 5 is not currently in use. It is reserved for future use.
6	DCD	Command to save DCD. See section 6.4.5
7	ME CAL	Command and Response to configure ME Calibration. See section 6.4.6
8	Reserved	Deprecated.
9	DCD Save	Command to configure periodic saving of DCD. See section 6.4.5
10	Oscillator	Command to retrieve the oscillator type used in the clock system. See section 6.4.8.
11	Clear DCD and Reset	Command to clear the in-memory DCD state and perform a chip reset. See section 6.4.9.
12	Calibration	Commands to control the simple calibration process. See section 6.4.10.
13	Bootloader	Command to issue queries and commands to the bootloader. See section 6.4.11.
14	Interactive Calibration	Command to send the Motion Intent to the sensor hub. See section 6.4.12.

Figure 44: Command Identifiers

6.4.1 Report Errors (0x01)

The SH-2 maintains a queue of errors. The report error command is used to retrieve values from this queue. The usage of parameters and response values is shown below. The report error command may generate multiple responses. The SH-2 will send as many responses as necessary to send all the errors in its queue. Every error response ends with a response with the error source set to 255, indicating that there are no more errors to report.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See section 6.3.8.
2	Command	0x01 – report all errors in the error queue
3	P0	The severity of errors to report. Errors of this severity and higher will be reported. 0 – highest priority.
4	P1	Reserved
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 45: Report Errors Command

Byte	Name	Description
0	Report ID	0xF1- Command Response
1	Sequence Number	See Section 6.3.9
2	Command	0x01 – report all errors in the error queue
3	Command Sequence Number	See Section 6.3.9
4	Response Sequence Number	See Section 6.3.9
5	R0	Severity – the severity of the error currently being reported
6	R1	Error sequence number. A monotonically incrementing uin8_t that counts all the errors generated for the reported severity. It may rollover.
7	R2	Error source. 0 – reserved, 1 – MotionEngine, 2 – MotionHub, 3 – SensorHub, 4 – Chip level executable, 5-254 reserved. 255 – no error to report.
8	R3	Error. See library API
9	R4	Error module. See library API
10	R5	Error code. See library API
11	R6	Reserved
12	R7	Reserved
13	R8	Reserved
14	R9	Reserved
15	R10	Reserved

Figure 46: Report Errors Response

6.4.2 Counter Commands (0x02)

Counter commands are specified with a command byte of 2. Sub-commands are specified by the P0 byte.

6.4.2.1 Get Counts (0x00)

Retrieve the number of times a specified sensor has produced samples, and what has been done with those samples.

Offered = Number of samples produced by underlying data source.

On = Number of “Offered” samples while this sensor was requested by host.

Accepted = Number of “On” samples that passed decimation filter.

Attempted = Number of “Accepted” samples that passed threshold requirements and had transmission to the host attempted.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x02 – Counter command
3	P0	0x00 – Sub-command: get counts
4	P1	Sensor ID

Byte	Name	Description
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 47: Get Counts Command

These counts are returned in a pair of responses. The response sequence number (0 or 1) indicates the types of counts it contains.

Byte	Name	Description
0	Report ID	0xF1- Command Response
1	Sequence Number	See Section 6.3.9
2	Command	0x02 – Counter command
3	Command Sequence Number	See 6.3.9
4	Response Sequence Number	See 6.3.9
5	R0	Sensor ID
6	R1	Status (0= invalid sensor requested, 1=valid sensor requested)
7	R2	Reserved
8	R3	Count Offered (Sequence Number=0) Count On (Sequence Number=1) LSB
9	R4	Count Offered (SN=0) Count On (SN=1) …
10	R5	Count Offered (SN=0) Count On (SN=1) ….
11	R6	Count Offered (SN=0) Count On (SN=1) MSB
12	R7	Count Accepted (SN=0) Count Attempted (SN=1) LSB
13	R8	Count Accepted (SN=0) Count Attempted (SN=1) …
14	R9	Count Accepted (SN=0) Count Attempted (SN=1) ….
15	R10	Count Accepted (SN=0) Count Attempted (SN=1) MSB

Figure 48: Get Counts Response

6.4.2.2 Clear Counts (0x01)

Clear all counters for a given sensor to 0.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x02 – Counter command
3	P0	0x01 – Sub-command: clear counts
4	P1	Sensor ID
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved

Byte	Name	Description
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 49: Clear Counts Command

6.4.3 Tare (0x03)

Tare commands are specified with a Command byte of 3. Sub-commands are specified by the P0 byte.

6.4.3.1 Tare Now (0x00)

This command instructs SH-2 to perform a tare operation along one or more axis. Currently the following axes are supported:

P1 = 0x07: (X,Y, Z). This tares with rotation around all axes. This will reorient all motion outputs (e.g. accelerometer, gyroscope, magnetometer, rotation vectors).

P1 = 0x04: (Z): This will tare with a rotation around Z, which changes the heading, but not the tilt. The Z axis will be defined by the current reorientation.

If P2 is 0 (Rotation Vector) or 2 (Geomagnetic Rotation Vector), then this will reorient all motion outputs.

If P2 is 1 (Gaming Rotation Vector), then this will only tare the Gaming Rotation Vector. A Z-axis Gaming Rotation tare cannot be persistent, because the Gaming Rotation Vector has no absolute reference for heading.

If P2 is 3, 4, or 5 (Gyro-Integrated Rotation Vector, ARVR-Stabilized Rotation Vector, ARVR-Stabilized Game Rotation Vector), then the tare will be performed on the underlying rotation vector (Rotation Vector or Game Rotation Vector). The derived vector will be immediately updated to match the value of the underlying rotation vector at this time.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x03 – Tare command
3	P0	0x00 – Subcommand: Perform Tare now
4	P1	Bitmap of axes to tare: Bit 0= X, Bit 1= Y, Bit 2= Z
5	P2	Rotation Vector to use as basis for tare. 0: Rotation Vector 1: Gaming Rotation Vector 2: Geomagnetic Rotation Vector 3: Gyro-Integrated Rotation Vector 4: ARVR-Stabilized Rotation Vector 5: ARVR-Stabilized Game Rotation Vector
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved

Byte	Name	Description
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 50: Tare Now Command

6.4.3.2 Persist Tare (0x01)

This command instructs SH-2 to persist the results of the last tare operation to flash for use at the next system restart. These results are stored in the master Sensor Orientation configuration record, individual sensor orientation records are not modified. Note that this only persists the tare applied to rotation vector and geomagnetic rotation vector.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x03 – Tare command
3	P0	0x01 – Persist Tare
4	P1	Reserved
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 51: Persist Tare Command

6.4.3.3 Set Reorientation (0x02)

This command instructs SH-2 to set the current run-time sensor reorientation. Note that this does not replace any persistent tare settings in the master Sensor Orientation configuration record. Persistent tare settings must be cleared by deleting the Sensor Orientation configuration record.

To clear the current tare, set P1-P8 to 0x00.

The rotation vector is a signed, 16-bit 2's-complement fixed point number with a Q-point of 14.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x03 – Tare Command
3	P0	0x02 – Set Reorientation
4	P1	Rotation quaternion X LSB
5	P2	Rotation quaternion X MSB
6	P3	Rotation quaternion Y LSB
7	P4	Rotation quaternion Y MSB
8	P5	Rotation quaternion Z LSB

Byte	Name	Description
9	P6	Rotation quaternion Z MSB
10	P7	Rotation quaternion W LSB
11	P8	Rotation quaternion W MSB

Figure 52: Set Reorientation Command

6.4.4 Initialization (0x04)

The initialize command requests that the sensor hub reinitialize itself or one of its subsystems. The response is sent unsolicited if the sensor hub itself resets.

6.4.4.1 Initialize Command

This command is sent by the host to re-initialize the sensor hub (or one of its subsystems.)

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x04 – Initialize command
3	P0	Subsystem
4	P1	Reserved
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 53: Initialize Command

The subsystem field indicates which component of the sensor hub should be reinitialized:

Value	Subsystem	Description
0	None	No Operation.
1	SensorHub	Reinitialize the entire sensor hub.
Others	Reserved	Reserved

Figure 54: Initialize Command Subsystems

6.4.4.2 Initialize Response

The sensor hub responds to the Initialize command with an Initialize Response. In the case where the sensor hub reinitializes itself, this response is unsolicited. An unsolicited response is also generated after startup.

Byte	Name	Description
0	Report ID	0xF1- Command Response
1	Sequence Number	See Section 6.3.9
2	Command	0x04 – Initialize, 0x84 – Initialize (unsolicited)

Byte	Name	Description
3	Command Sequence Number	See 6.3.9
4	Response Sequence Number	See 6.3.9
5	R0	Status (0 – successful. 1 – Operation failed)
6	R1	Subsystem
7	R2	Reserved
8	R3	Reserved
9	R4	Reserved
10	R5	Reserved
11	R6	Reserved
12	R7	Reserved
13	R8	Reserved
14	R9	Reserved
15	R10	Reserved

Figure 55: Initialize Response

6.4.5 Save DCD (0x06)

The Save DCD command requests that the sensor hub save the current DCD. Upon completion, a Save DCD Response will be sent.

6.4.5.1 Save DCD Command

This command is sent by the host to save the DCD.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x06 – Save DCD Command
3	P0	Reserved
4	P1	Reserved
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 56: Save DCD Command

6.4.5.2 Save DCD Response

The sensor hub responds to the Save DCD command with a Save DCD Response containing a success/failure status.

Byte	Name	Description
0	Report ID	0xF1- Command Response

Byte	Name	Description
1	Sequence Number	See Section 6.3.9
2	Command	0x06 – Save DCD
3	Command Sequence Number	See 6.3.9
4	Response Sequence Number	See 6.3.9
5	R0	Status (0 – success. Non Zero – Operation failed)
6	R1	Reserved
7	R2	Reserved
8	R3	Reserved
9	R4	Reserved
10	R5	Reserved
11	R6	Reserved
12	R7	Reserved
13	R8	Reserved
14	R9	Reserved
15	R10	Reserved

Figure 57: Save DCD Response

6.4.6 ME Calibration Commands (0x07)

The ME Calibration command requests tell the sensor hub to enable/disable the accelerometer, gyro and magnetometer calibration routines and can read back the enable/disable state of each of these routines.

6.4.6.1 Configure ME Calibration Command

This command is sent by the host to configure the ME calibration of the accelerometer, gyro and magnetometer giving the host the ability to control when calibration is performed.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x07 – ME Calibration Command
3	P0	Accel Cal Enable (1 – enabled, 0 – disabled)
4	P1	Gyro Cal Enable (1 – enabled, 0 – disabled)
5	P2	Mag Cal Enable (1 – enabled, 0 – disabled)
6	P3	0x00 – Subcommand: Configure ME Calibration
7	P4	Planar Accel Cal Enable (1 – enabled, 0 – disabled)
8	P5	On Table Cal Enable (1 – enabled, 0 – disabled)
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 58: Configure ME Calibration Command

6.4.6.2 Get ME Calibration Command

This command is sent by the host to request the enable/disable state of the accelerometer, gyro and magnetometer calibration routines.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x07 – ME Calibration Command
3	P0	Reserved
4	P1	Reserved
5	P2	Reserved
6	P3	0x01 – Subcommand: Get ME Calibration
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 59: Get ME Calibration Command

6.4.6.3 ME Calibration Response

The sensor hub responds to the Configure ME Calibration command with a Configure ME Calibration Response containing a success/failure status and the enable/disable state of the accelerometer, gyro and magnetometer calibration routines.

Byte	Name	Description
0	Report ID	0xF1- Command Response
1	Sequence Number	See Section 6.3.9
2	Command	0x07 – Configure ME Calibration
3	Command Sequence Number	See 6.3.9
4	Response Sequence Number	See 6.3.9
5	R0	Status (0 – success. Non Zero – Operation failed)
6	R1	Accel Cal Enable (1 – enabled, 0 – disabled)
7	R2	Gyro Cal Enable (1 – enabled, 0 – disabled)
8	R3	Mag Cal Enable (1 – enabled, 0 – disabled)
9	R4	Planar Accel Cal Enable (1 – enabled, 0 – disabled)
10	R5	On Table Cal Enable (1 – enabled, 0 – disabled)
11	R6	Reserved
12	R7	Reserved
13	R8	Reserved
14	R9	Reserved
15	R10	Reserved

Figure 60: Configure ME Calibration Response

6.4.7 Configure Periodic DCD Save (0x09)

The Configure Periodic DCD Save command configures the automatic saving of DCD. There is no response to this command. This command does not inhibit the Save DCD command.

6.4.7.1 Configure Periodic DCD Save Command

This command is sent by the host to enable or disable the saving of DCD on a periodic basis.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x09– Configure DCD Save Command
3	P0	0x00 – Enable Periodic DCD Save 0x01 – Disable Periodic DCD Save
4	P1	Reserved
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 61: Configure Periodic Save DCD Command

6.4.8 Get Oscillator Type (0x0A)

The Get Oscillator Type command is used to get information about the oscillator type used in the clock system of the SH-2.

6.4.8.1 Get Oscillator Type Command

This command is sent by the host to request information about the clock system of the SH-2.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x0A – Get Oscillator Type Command
3	P0	Reserved
4	P1	Reserved
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 62: Get Oscillator Type Command

6.4.8.2 Get Oscillator Type Response

The sensor hub responds to the Get Oscillator Type command with a Get Oscillator Type Response containing the oscillator type used by the SH-2 clock system.

Byte	Name	Description
0	Report ID	0xF1- Command Response
1	Sequence Number	See Section 6.3.9
2	Command	0x0A – Get Oscillator Type Command
3	Command Sequence Number	See 6.3.9
4	Response Sequence Number	See 6.3.9
5	R0	Oscillator Type (0 – internal Oscillator, 1 – external crystal, 2 – external clock)
6	R1	Reserved
7	R2	Reserved
8	R3	Reserved
9	R4	Reserved
10	R5	Reserved
11	R6	Reserved
12	R7	Reserved
13	R8	Reserved
14	R9	Reserved
15	R10	Reserved

Figure 63: Get Oscillator Type Response

6.4.9 Clear DCD and Reset (0x0B)

The sensor hub stores updated Dynamic Calibration Data to RAM frequently. At non-power-up reset, the hub will persist the last-stored DCD from RAM to FRS. In order to prevent this from happening (e.g. if one desires to fully clear DCD state), this command performs an atomic clear-DCD (from RAM) and system reset.

The recommended sequence for completely resetting DCD state is:

1. Reset hub (via pin toggle, reset command, or Clear DCD and Reset Command)
2. Delete flash copy of DCD via FRS: see 6.3.3.
3. Issue Clear DCD and Reset Command.

6.4.9.1 Clear DCD and Reset Command

Clear any copy of DCD stored in RAM and perform a chip reset immediately. No response is sent for this command, though the hub will report an unsolicited Initialization Response as in a standard reset (see 6.4.4.2).

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.

Byte	Name	Description
2	Command	0x0B – Clear DCD and Reset
3	P0	Reserved
4	P1	Reserved
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 64: Clear DCD and Reset Command

6.4.10 Simple Calibration Commands (0x0C)

The sensor hub has the ability to perform a self-calibration using a 180-degree motion provided by the user. The user will start the calibration, wait for a signal to move, rotate the sensor hub 180 degrees, and then indicate the motion has been completed. On successful completion, the sensor hub will store the new calibration to FRS. The sensor hub will not reset after a self-calibration – the user must reset the sensor hub after self-calibration for the new calibration to take effect.

6.4.10.1 Start Calibration Command (0x00)

The Start Calibration Command is used to initiate a turntable self-calibration process. The Calibration Interval is a 4-byte interval in microseconds that the calibration should run at. This interval should be set to whatever rate the sensor hub is expected to run at after calibration. The default Calibration Interval is 10000 microseconds.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x0C – Turntable Calibration
3	P0	0x00 – Start Calibration
4	P1	Calibration Interval LSB
5	P2	Calibration Interval
6	P3	Calibration Interval
7	P4	Calibration Interval MSB
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 65: Start Calibration Request

Once the user sends a Start Calibration Request, they should wait for a matching Start Calibration Response before starting the motion.

Byte	Name	Description
0	Report ID	0xF1- Command Response
1	Sequence Number	See Section 6.3.9
2	Command	0x0C – Turntable Calibration
3	Command Sequence Number	See 6.3.9
4	Response Sequence Number	See 6.3.9
5	R0	0x00 – Start Calibration
6	R1	Reserved
7	R2	Reserved
8	R3	Reserved
9	R4	Reserved
10	R5	Reserved
11	R6	Reserved
12	R7	Reserved
13	R8	Reserved
14	R9	Reserved
15	R10	Reserved

Figure 66: Start Calibration Response

6.4.10.2 Finish Calibration Command (0x01)

Once the user has completed the calibration motion, they send the Finish Calibration Request. This informs the sensor hub that motion is complete and that it should now compute the calibration data.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x0C – Turntable Calibration
3	P0	0x01 – Finish Calibration
4	P1	Reserved
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 67: Finish Calibration Request

When the calibration data has been computed and saved to the FRS system, a Finish Calibration Response will be sent. Or if the calibration failed, a Finish Calibration Response will still be sent with the error code of the calibration failure stored in the R1 byte. The FinishCalibration Status is given by:

0 - Success.

1 - No gyro offset.

2 - No stationary detection.

3 - Rotation outside of specification.

4 - Gyro offset outside of specification.

5 - Accelerometer offset outside of specification.

6 - Gyro gain outside of specification.

7 - Gyro period outside of specification.

8 - Gyro sample drops outside of specification.

Byte	Name	Description
0	Report ID	0xF1- Command Response
1	Sequence Number	See Section 6.3.9
2	Command	0x0C – Turntable Calibration
3	Command Sequence Number	See 6.3.9
4	Response Sequence Number	See 6.3.9
5	R0	0x01 – Finish Calibration
6	R1	Calibration Status
7	R2	Reserved
8	R3	Reserved
9	R4	Reserved
10	R5	Reserved
11	R6	Reserved
12	R7	Reserved
13	R8	Reserved
14	R9	Reserved
15	R10	Reserved

Figure 68: Finish Calibration Response

6.4.11 Bootloader Commands (0x0D)

Bootloader commands are specified with a command byte of 13. Sub-commands are specified by the P0 byte.

6.4.11.1 Bootloader Operating Mode Request (0x00)

The bootloader operating mode request is used to request various operating modes of the FSP200 bootloader.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.

Byte	Name	Description
2	Command	0x0D – Bootloader command
3	P0	0x00 – Sub-command: Bootloader Operating Mode Request
4	P1	Bootloader Operating Mode ID
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 69: Bootloader Operating Mode Request

Operating Mode ID:	0 – Reset to bootloader Mode 1 – Upgrade Application Mode; upgrade the application image in flash. 2 – Validate Image Mode; validate an application image without updating the flash 3 – Launch Application; launch the application image in flash.

6.4.11.2 Bootloader Status Request (0x01)

Request product ID information about the FSP200 bootloader.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x0D – Bootloader command
3	P0	0x01 – Sub-command: Bootloader Status Request
4	P1	Reserved
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 70: Bootloader Status Request

The application will respond with a Bootloader Status Response

Byte	Name	Description
0	Report ID	0xF1- Command Response
1	Sequence Number	See Section 6.3.9
2	Command	0x0D – Bootloader command
3	Command Sequence Number	See 6.3.9

Byte	Name	Description
4	Response Sequence Number	See 6.3.9
5	R0	0x01 – Sub-command: Bootloader Status Response
6	R1	Bootloader Operating Mode ID
7	R2	Reserved
8	R3	Bootloader Status LSB
9	R4	Bootloader Status …
10	R5	Bootloader Status …
11	R6	Bootloader Status MSB
12	R7	Bootloader Error Codes LSB
13	R8	Bootloader Error Codes …
14	R9	Bootloader Error Codes …
15	R10	Bootloader Error Codes MSB

Figure 71: Bootloader Status Response

Bitmask	Status Code
0x00000000	No status
0x00000001	Normal application launch
0x00000002	Launch bootloader
0x00000004	Upgrade operation started
0x00000008	Validate operation started
0x00000010	Internal application valid
0x00000020	Internal application not valid
0x00000040	DFU image valid
0x00000080	DFU image invalid
0x40000000	Error occurred
0x80000000	Source of DFU status

Figure 72: Bootloader Status Flags

Value	Error
0x00	No error
0x01	Unexpected command received
0x02	Invalid internal application
0x03	Flash erase error
0x04	Flash write error
0x05	Flash lock error
0x06	Flash overflow
0x07	Invalid DFU image type
0x08	Invalid DFU image size
0x09	Invalid DFU image version
0x0A	Incompatible hardware
0x0B	Invalid encryption type
0x0C	Invalid encryption key
0x0D	DFU image length mismatch
0x0E	Invalid application size in DFU image
0x0F	Invalid application CRC in DFU image

Value	Error
0x10	Invalid DFU image CRC
0x11	Invalid data payload length in request message
0x12	Invalid data offset in request message

Figure 73: Bootloader Error Codes

6.4.12 Interactive Calibration (0x0E)

The interactive calibration feature requires that the sensor hub be told of the device's intended motion. The Interactive Calibration Request is used to do this.

6.4.12.1 Interactive Calibration Request

This request notifies the sensor hub of the intended motion.

Byte	Name	Description
0	Report ID	0xF2 – Command Request
1	Sequence Number	See Section 6.3.8.
2	Command	0x0E – Interactive Calibration command
3	P0	Motion intent
4	P1	Reserved
5	P2	Reserved
6	P3	Reserved
7	P4	Reserved
8	P5	Reserved
9	P6	Reserved
10	P7	Reserved
11	P8	Reserved

Figure 74: Interactive Calibration Request

The motion intent field of the request is an enumeration. The valid values are listed in Figure 75.

Value	Description
0	FME_MOBILE_MOTION_INTENT_UNKNOWN – this is the initial state assumed by the sensor hub
1	FME_MOBILE_MOTION_INTENT_STATIONARY_WITHOUT_VIBRATION
2	FME_MOBILE_MOTION_INTENT_STATIONARY_WITH_VIBRATION
3	FME_MOBILE_MOTION_INTENT_IN_MOTION
4:255	Reserved

Figure 75: Motion Intent

6.5 Sensor Reports

Sensor feature reports are used to control and configure sensors, and to retrieve sensor configuration. Sensor input reports are used to send sensor data to the host.

The sensor input reports use fixed point formats for their data fields. Some sensors report both the sensor data output and either the sensor bias or the sensor accuracy. For sensors that have both types of outputs, the Q point of each type of output may be different. The default Q point for each type is provided in the following sections about the reports for each sensor. For SH-2 systems using revision 1 or later of the sensor metadata record, the Q points are provided in the metadata record. If there is a difference between the Q point listed below and that of the metadata record, the metadata record takes precedence.

6.5.1 Common Fields

The sensor feature and input reports have a number of fields in common across many sensors. These common fields and their meaning are listed in Figure 76. Fields that are specific to a sensor are explained in that sensors report.

Field	Description
Report ID	Report ID
Sequence number	8-bit unsigned integer used to track reports. The sequence number increments once for each report sent. Gaps in the sequence numbers indicate missing or dropped reports.
Report Interval	32-bit unsigned integer representing the interval in microseconds between asynchronous input reports
Batch Interval	32-bit unsigned integer controlling the maximum delay (in microseconds) between the time that a sensor is sampled and the time that its data can be reported. The value 0 is reserved for "do not delay" and the value 0xFFFFFFFF is reserved for "never trigger delivery on the basis of elapsed time"
Feature flags	A bit field that enables various features for a sensor. Bit 0: change sensitivity type. 0 – absolute 1 – relative Bit 1: change sensitivity enable 0 – disabled 1 – enabled Bit 2: wake-up enable 0 – disabled 1 – enabled Bit 3: always-on enable (run sensor while hub is in "sleep" mode) 0 – disabled 1 – enabled Bit 4: reserved Bit 5: reserved Bit 6: reserved Bit 7: reserved
Change sensitivity absolute	16-bit signed fixed-point integer representing the value a sensor output must exceed in order to trigger another input report.
Change sensitivity relative	16-bit signed fixed-point integer representing the amount by which a sensor output must change from the previous input report in order to trigger another input report.
Sensor-Specific Configuration word	32-bit field available for use by sensors requiring additional configuration options.

Field	Description
Status	Bits 1:0 – indicate the status of a sensor. 0 – Unreliable 1 – Accuracy low 2 – Accuracy medium 3 – Accuracy high Bits 7:2 – Delay upper bits: 6 most-significant bits of report delay. See blow.
Delay LSB	8 least-significant bits of report delay. Units are 100 us.

Figure 76: Common Report Fields

6.5.2 Common Dynamic Feature Report

All sensors use the same format for a feature report. This format is shown in Figure 77.

Byte	Description	Read/Write
0	Feature Report ID	R
1	Feature flags	R/W
2	Change sensitivity [absolute I relative] LSB	R/W
3	Change sensitivity [absolute I relative] MSB	R/W
4	Report Interval LSB	R/W
5	Report Interval	R/W
6	Report Interval	R/W
7	Report Interval MSB	R/W
8	Batch Interval LSB	R/W
9	Batch Interval	R/W
10	Batch Interval	R/W
11	Batch Interval MSB	R/W
12	Sensor-specific configuration word LSB	R/W
13	Sensor-specific configuration word	R/W
14	Sensor-specific configuration word	R/W
15	Sensor-specific configuration word MSB	R/W

Figure 77: Common Feature Report

The type of change sensitivity may be either absolute or relative. The units of change sensitivity are normally the same as that of the input reports. The Q point of the change sensitivity is normally the same as that of the input reports. Any variations from this normal arrangement are explained in the individual sensor's report section. For some sensors the change sensitivity is redefined to have a meaning that is applicable to that particular sensor. In these cases use of the change sensitivity field is explained in the feature report section for that sensor.

6.5.3 Get Feature Request (0xFE)

Get-Feature requests are issued by sending the following report to SH-2. These are sent on the SH-2 control channel from host to hub.

Byte	Description
0	Report ID=0xFE
1	Feature Report ID

Figure 78: Get Feature Request (0xFE)

“Feature Report ID” is set to the ID of the feature report that is to be obtained. For example, to request the Raw Accelerometer feature report, the bytes 0xFE 0x14 would be sent to SH-2. SH-2 will respond by sending a Get Feature Response (6.5.5) at some point in the future.

6.5.4 Set Feature Command (0xFD)

Set-Feature commands are issued by prefixing the full feature report with 0xFD. These are sent on the SH-2 control channel from host to hub.

Byte	Description
0	Report ID = 0xFD
1	Feature Report ID
2	Feature flags
3	Change sensitivity [absolute I relative] LSB
4	Change sensitivity [absolute I relative] MSB
5	Report Interval LSB
6	Report Interval
7	Report Interval
8	Report Interval MSB
9	Batch Interval LSB
10	Batch Interval
11	Batch Interval
12	Batch Interval MSB
13	Sensor-specific configuration word LSB
14	Sensor-specific configuration word
15	Sensor-specific configuration word
16	Sensor-specific configuration word MSB

Figure 79: Set Feature Command (0xFD)

6.5.5 Get Feature Response (0xFC)

SH-2 will respond to Get Feature Requests (6.5.3) by sending a Get Feature Response on the control channel. These are the full feature report that was requested, prefixed with 0xFC.

Note that SH-2 protocol version 1.0.1 and higher will send Get Feature Response messages unsolicited if a sensor’s rate changes (e.g. due to change in the rate of a related sensor).

Byte	Description
0	Report ID = 0xFC
1	Feature Report ID
2	Feature flags
3	Change sensitivity [absolute I relative] LSB
4	Change sensitivity [absolute I relative] MSB
5	Report Interval LSB
6	Report Interval
7	Report Interval
8	Report Interval MSB
9	Batch Interval LSB

Byte	Description
10	Batch Interval
11	Batch Interval
12	Batch Interval MSB
13	Sensor-specific configuration word LSB
14	Sensor-specific configuration word
15	Sensor-specific configuration word
16	Sensor-specific configuration word MSB

Figure 80: Get Feature Response (0xFC)

6.5.6 Force Sensor Flush (0xF0)

This is sent from the host to the hub to trigger a flush of outstanding data from a given sensor (e.g. before its batch settings would require it). The hub may report data for other sensors as well. Each of these will result in the transmission of a corresponding Flush Complete report (6.5.7) to the host.

Byte	Description
0	Report ID=0xF0
1	Sensor ID

Figure 81: Force Sensor Flush (0xF0)

6.5.7 Flush Completed (0xEF)

Report that all data from a given sensor, as of the corresponding Force Sensor flush () has been transmitted.

Byte	Description
0	Report ID=0xEF
1	Sensor ID

Figure 82: Flush Completed (0xEF)

6.5.8 Raw Accelerometer (0x14)

The accelerometer sensor reports raw readings from the physical accelerometer MEMS sensor. The units are ADCs. Interpretation of the reported values is sensor dependent. The report ID is 0x14.

6.5.8.1 Feature Report

The change sensitivity is applied to each axis independently.

6.5.8.2 Input Report

Byte	Description
0	Report ID = 0x14
1	Sequence number
2	Status
3	Delay
4	Accelerometer Axis X LSB
5	Accelerometer Axis X MSB

Byte	Description
6	Accelerometer Axis Y LSB
7	Accelerometer Axis Y MSB
8	Accelerometer Axis Z LSB
9	Accelerometer Axis Z MSB
10	Reserved
11	Reserved
12	Timestamp LSB
13	…
14	…
15	Timestamp MSB

Figure 83: Raw Accelerometer Input Report

The timestamp field is a uint32_t. It is the time that the sample was taken as measured by a timer running on the hub. The units are microseconds.

6.5.9 Accelerometer (0x01)

The accelerometer sensor reports the acceleration of the device, including gravity. The total acceleration of the device is the vector sum of the X, Y and Z axes accelerations. The units are m/s^2. The Q point is 8. The report ID is 0x01.

6.5.9.1 Feature Report

The change sensitivity is applied to each axis independently.

6.5.9.2 Input Report

Byte	Description
0	Report ID = 0x01
1	Sequence number
2	Status
3	Delay
4	Accelerometer Axis X LSB
5	Accelerometer Axis X MSB
6	Accelerometer Axis Y LSB
7	Accelerometer Axis Y MSB
8	Accelerometer Axis Z LSB
9	Accelerometer Axis Z MSB

Figure 84: Accelerometer Input Report

6.5.10 Linear Acceleration (0x04)

The linear acceleration sensor reports the acceleration of the device minus gravity. The units are m/s^2. The Q point is 8. The report ID is 0x04.

6.5.10.1 Feature Report

The change sensitivity is applied to each axis independently.

6.5.10.2 Input Report

Byte	Description
0	Report ID = 0x04
1	Sequence number
2	Status
3	Delay
4	Linear acceleration Axis X LSB
5	Linear acceleration Axis X MSB
6	Linear acceleration Axis Y LSB
7	Linear acceleration Axis Y MSB
8	Linear acceleration Axis Z LSB
9	Linear acceleration Axis Z MSB

Figure 85: Linear Acceleration Input Report

6.5.11 Gravity (0x06)

The gravity sensor reports gravity in the device's coordinate frame. The units are m/s^2. The Q point is 8. The report ID is 0x06.

6.5.11.1 Feature Report

The change sensitivity is applied to each axis independently.

6.5.11.2 Input Report

Byte	Description
0	Report ID = 0x06
1	Sequence number
2	Status
3	Delay
4	Gravity Axis X LSB
5	Gravity Axis X MSB
6	Gravity Axis Y LSB
7	Gravity Axis Y MSB
8	Gravity Axis Z LSB
9	Gravity Axis Z MSB

Figure 86: Gravity Input Report

6.5.12 Raw Gyroscope (0x15)

The gyroscope sensor reports raw readings from the physical gyroscope MEMS sensor. The units are ADCs. Interpretation of the reported values is sensor dependent. The report ID is 0x15.

6.5.12.1 Feature Report

The change sensitivity is applied to each axis independently.

6.5.12.2 Input Report

Byte	Description
0	Report ID = 0x15
1	Sequence number
2	Status
3	Delay
4	Gyroscope Axis X LSB
5	Gyroscope Axis X MSB
6	Gyroscope Axis Y LSB
7	Gyroscope Axis Y MSB
8	Gyroscope Axis Z LSB
9	Gyroscope Axis Z MSB
10	Gyroscope temperature LSB
11	Gyroscope temperature MSB
12	Timestamp LSB
13	…
14	…
15	Timestamp MSB

Figure 87: Raw Gyroscope Input Report

The timestamp field is a uint32_t. It is the time that the sample was taken as measured by a timer running on the hub. The units are microseconds.

6.5.13 Gyroscope Calibrated (0x02)

The gyroscope calibrated sensor reports drift-compensated rotational velocity. The units are rad/s. The Q point is 9. The report ID is 0x02.

6.5.13.1 Feature Report

The change sensitivity is applied to each axis independently.

6.5.13.2 Input Report

Byte	Description
0	Report ID = 0x02
1	Sequence number
2	Status
3	Delay
4	Gyroscope calibrated Axis X LSB
5	Gyroscope calibrated Axis X MSB
6	Gyroscope calibrated Axis Y LSB
7	Gyroscope calibrated Axis Y MSB
8	Gyroscope calibrated Axis Z LSB
9	Gyroscope calibrated Axis Z MSB

Figure 88: Gyroscope Calibrated Input Report

6.5.14 Gyroscope Uncalibrated (0x07)

The gyroscope uncalibrated sensor reports rotational velocity without drift compensation. An estimate of drift is also reported. The units for both values are rad/s. The Q point for both values is 9. The report ID is 0x07.

6.5.14.1 Feature Report

The change sensitivity is applied to each uncalibrated axis independently. The change sensitivity does not apply to the bias fields.

6.5.14.2 Input Report

Byte	Description
0	Report ID = 0x07
1	Sequence number
2	Status
3	Delay
4	Gyroscope uncalibrated Axis X LSB
5	Gyroscope uncalibrated Axis X MSB
6	Gyroscope uncalibrated Axis Y LSB
7	Gyroscope uncalibrated Axis Y MSB
8	Gyroscope uncalibrated Axis Z LSB
9	Gyroscope uncalibrated Axis Z MSB
10	Gyroscope uncalibrated bias Axis X LSB
11	Gyroscope uncalibrated bias Axis X MSB
12	Gyroscope uncalibrated bias Axis Y LSB
13	Gyroscope uncalibrated bias Axis Y MSB
14	Gyroscope uncalibrated bias Axis Z LSB
15	Gyroscope uncalibrated bias Axis Z MSB

Figure 89: Gyroscope Uncalibrated Input Report

6.5.15 Raw Magnetometer (0x16)

The magnetometer sensor reports raw readings from the physical magnetometer sensor. The units are ADCs. Interpretation of the reported values is sensor dependent. The report ID is 0x16.

6.5.15.1 Feature Report

The change sensitivity is applied to each axis independently.

6.5.15.2 Input Report

Byte	Description
0	Report ID = 0x16
1	Sequence number
2	Status
3	Delay

Byte	Description
4	Magnetometer Axis X LSB
5	Magnetometer Axis X MSB
6	Magnetometer Axis Y LSB
7	Magnetometer Axis Y MSB
8	Magnetometer Axis Z LSB
9	Magnetometer Axis Z MSB
10	Reserved
11	Reserved
12	Timestamp LSB
13	…
14	…
15	Timestamp MSB

Figure 90: Raw Magnetometer Input Report

The timestamp field is a uint32_t. It is the time that the sample was taken as measured by a timer running on the hub. The units are microseconds.

6.5.16 Magnetic Field Calibrated (0x03)

The magnetic field calibrated sensor reports the geomagnetic field calibrated for hard and soft iron effects such that the vector is aligned with the declination and heading of Earth's magnetic field. The units are uTesla. The Q point is 4. The report ID is 0x03.

6.5.16.1 Feature Report

The change sensitivity is applied to each axis independently.

6.5.16.2 Input Report

Byte	Description
0	Report ID = 0x03
1	Sequence number
2	Status
3	Delay
4	Magnetic Field calibrated Axis X LSB
5	Magnetic Field calibrated Axis X MSB
6	Magnetic Field calibrated Axis Y LSB
7	Magnetic Field calibrated Axis Y MSB
8	Magnetic Field calibrated Axis Z LSB
9	Magnetic Field calibrated Axis Z MSB

Figure 91: Magnetic Field Calibrated Input Report

6.5.17 Magnetic Field Uncalibrated (0x0F)

The magnetic field uncalibrated sensor reports the geomagnetic field calibrated for soft iron effects only. Estimates for the hard iron bias are also reported. The units for both values are uTesla. The Q point for both values is 4. The report ID is 0x0F.

6.5.17.1 Feature Report

The change sensitivity is applied to each uncalibrated axis independently. The change sensitivity does not apply to the hard iron bias fields.

6.5.17.2 Input Report

Byte	Description
0	Report ID = 0x0F
1	Sequence number
2	Status
3	Delay
4	Magnetic Field uncalibrated Axis X LSB
5	Magnetic Field uncalibrated Axis X MSB
6	Magnetic Field uncalibrated Axis Y LSB
7	Magnetic Field uncalibrated Axis Y MSB
6	Magnetic Field uncalibrated Axis Z LSB
9	Magnetic Field uncalibrated Axis Z MSB
10	Magnetic Field uncalibrated hard iron bias Axis X LSB
11	Magnetic Field uncalibrated hard iron bias Axis X MSB
12	Magnetic Field uncalibrated hard iron bias Axis Y LSB
13	Magnetic Field uncalibrated hard iron bias Axis Y MSB
14	Magnetic Field uncalibrated hard iron bias Axis Z LSB
15	Magnetic Field uncalibrated hard iron bias Axis Z MSB

Figure 92: Magnetic Field Uncalibrated Input Report

6.5.18 Rotation Vector (0x05)

The rotation vector sensor reports the orientation of the device. The format of the rotation vector is a unit quaternion. The Q point is 14. In addition, an estimate of the heading accuracy is reported. The units for the accuracy estimate are radians. The Q point is 12. The report ID is 0x05.

6.5.18.1 Feature Report

The change sensitivity is applied to the angular difference between two rotation vectors. The units for change sensitivity are radians. The change sensitivity is unsigned and the Q point is 13.

6.5.18.2 Input Report

Byte	Description
0	Report ID = 0x05
1	Sequence number
2	Status
3	Delay
4	Unit quaternion i component LSB
5	Unit quaternion i component MSB

Byte	Description
6	Unit quaternion j component LSB
7	Unit quaternion j component MSB
8	Unit quaternion k component LSB
9	Unit quaternion k component MSB
10	Unit quaternion real component LSB
11	Unit quaternion real component MSB
12	Accuracy estimate LSB
13	Accuracy estimate MSB

Figure 93: Rotation Vector Input Report

6.5.19 Game Rotation Vector (0x08)

The rotation vector sensor reports the orientation of the device. The format of the rotation vector is a unit quaternion. The Q point is 14. The report ID is 0x08.

6.5.19.1 Feature Report

The change sensitivity is applied to the angular difference between two rotation vectors. The units for change sensitivity are radians. The change sensitivity is unsigned and the Q point is 13.

6.5.19.2 Input Report

Byte	Description
0	Report ID = 0x08
1	Sequence number
2	Status
3	Delay
4	Unit quaternion i component LSB
5	Unit quaternion i component MSB
6	Unit quaternion j component LSB
7	Unit quaternion j component MSB
8	Unit quaternion k component LSB
9	Unit quaternion k component MSB
10	Unit quaternion real component LSB
11	Unit quaternion real component MSB

Figure 94: Game Rotation Vector Input Report

6.5.20 Geomagnetic Rotation Vector (0x09)

The geomagnetic rotation vector sensor reports the orientation of the device. The format of the rotation vector is a unit quaternion. The Q point is 14. In addition, an estimate of the heading accuracy is reported. The units for the accuracy estimate are radians. The Q point is 12. The report ID is 0x09.

6.5.20.1 Feature Report

The change sensitivity is applied to the angular difference between two rotation vectors. The units for change sensitivity are radians. The change sensitivity is unsigned and the Q point is 13.

6.5.20.2 Input Report

Byte	Description
0	Report ID = 0x09
1	Sequence number
2	Status
3	Delay
4	Unit quaternion i component LSB
5	Unit quaternion i component MSB
6	Unit quaternion j component LSB
7	Unit quaternion j component MSB
8	Unit quaternion k component LSB
9	Unit quaternion k component MSB
10	Unit quaternion real component LSB
11	Unit quaternion real component MSB
12	Accuracy estimate LSB
13	Accuracy estimate MSB

Figure 95: Geomagnetic Rotation Vector Input Report

6.5.21 Pressure (0x0A)

The pressures sensor reports atmospheric pressure. The units are hectopascals. The Q point is 20. The report ID is 0x0A.

6.5.21.1 Feature Report

The Q point of the change sensitivity is 6.

6.5.21.2 Input Report

Byte	Description
0	Report ID = 0x0A
1	Sequence number
2	Status
3	Delay
4	Atmospheric pressure LSB
6	…
6	…
7	Atmospheric pressure MSB

Figure 96: Pressure Sensor Input Report

6.5.22 Ambient Light (0x0B)

The ambient light sensor reports the measures the amount of light entering the sensor. The units are lux. The Q point is 8. The report ID is 0x0B.

6.5.22.1 Feature Report

The Q point of the change sensitivity is 6.

6.5.22.2 Input Report

Byte	Description
0	Report ID = 0x0B
1	Sequence number
2	Status
3	Delay
4	Ambient light LSB
5	…
6	…
7	Ambient light MSB

Figure 97: Ambient Light Sensor Input Report

6.5.23 Humidity (0x0C)

The humidity sensor reports relative humidity in the ambient air. The units are percent. The Q point is 8. The report ID is 0x0C.

6.5.23.1 Feature Report

No special remarks.

6.5.23.2 Input Report

Byte	Description
0	Report ID = 0x0C
1	Sequence number
2	Status
3	Delay
4	Relative humidity LSB
5	Relative humidity MSB

Figure 98: Humidity Sensor Input Report

6.5.24 Proximity (0x0D)

The proximity sensor reports distance from the device. The units are centimeters. The Q point is 4. The report ID is 0x0D.

6.5.24.1 Feature Report

The change sensitivity is applied to each axis independently.

6.5.24.2 Input Report

Byte	Description
0	Report ID = 0x0D
1	Sequence number
2	Status
3	Delay
4	Distance LSB
5	Distance MSB

Figure 99: Proximity Sensor Input Report

6.5.25 Temperature (0x0E)

The temperature sensor reports ambient temperature. The units are °C. The Q point is 7. The report ID is 0x0E.

6.5.25.1 Feature Report

No special remarks.

6.5.25.2 Input Report

Byte	Description
0	Report ID = 0x0E
1	Sequence number
2	Status
3	Delay
4	Temperature LSB
5	Temperature MSB

Figure 100: Temperature Sensor Input Report

6.5.26 Reserved (0x17)

6.5.27 Tap Detector (0x10)

The tap detector reports single and double taps. The report ID is 0x10.

6.5.27.1 Feature Report

The change sensitivity should be set to 0 for the tap detector.

6.5.27.2 Input Report

Byte	Description
0	Report ID = 0x10
1	Sequence number
2	Status
3	Delay

Byte	Description
4	Taps detected

Figure 101: Tap Detector Input Report

Taps detected

Bit field.
Indicates single and double taps along each axis. The direction flag is not valid if a tap was not detected along the associated axis. The direction flag means that if a tap was detected and the direction flag is set then the tap was along the positive given axis towards the origin. For example, if the positive Z axis is pointing out of the face of a device and the user taps on the face of the device then the Z axis tap and direction flags will both be set. If a tap is detected, it may be either a single or a double tap.

Bit 0 – X axis tap.
Bit 1 – X axis positive tap
Bit 2 – Y axis tap
Bit 3 – Y axis positive tap
Bit 4 – Z axis tap
Bit 5 – Z axis positive tap
Bit 6 – double tap
Bit 7 – reserved

6.5.28 Step Detector (0x18)

The step detector reports steps detected. Each report indicates a single step. The report ID is 0x18.

6.5.28.1 Feature Report

The change sensitivity should be set to 0 for the step detector.

6.5.28.2 Input Report

Byte	Description
0	Report ID = 0x18
1	Sequence number
2	Status
3	Delay
4	Detect latency LSB
5	…
6	…
7	Detect latency MSB

Figure 102: Step Detector Input Report

Detect latency

The delay in microseconds from The time from when the step occurred until the time the step was detected and reported.

6.5.29 Step Counter (0x11)

The step counter reports steps counted. The units are steps. The value is unsigned. The Q point is 0. The report ID is 0x11. The step counter will wake the host at least once before the steps field wraps around to a previously reported value.

6.5.29.1 Feature Report

No special remarks.

6.5.29.2 Input Report

Byte	Description
0	Report ID = 0x11
1	Sequence number
2	Status
3	Delay
4	Detect latency LSB
5	…
6	…
7	Detect latency MSB
8	Steps LSB
9	Steps MSB
10	Reserved
11	Reserved

Figure 103: Step Counter Input Report

Detect latency	The delay in microseconds from the time from when the last step being counted occurred until the time the step count was reported.
Steps	The number of steps counted. This is a normally incrementing count of the number of steps taken by the user. This field may decrement of motions previously reported as steps are determined not to be steps. This field rolls over.

6.5.30 Significant Motion (0x12)

The significant motion detector sends a single report when it detects significant motion. It automatically turns itself off after sending its single report. The report ID is 0x12.

6.5.30.1 Feature Report

The change sensitivity should be set to 0 for the significant motion detector.

6.5.30.2 Input Report

Byte	Description
0	Report ID = 0x12

Byte	Description
1	Sequence number
2	Status
3	Delay
4	Motion LSB
5	Motion MSB

Figure 104: Significant Motion Input Report

Motion — Indicates motion being reported.
1 – significant motion detected
All other values are reserved.

6.5.31 Stability Classifier (0x13)

The stability classifier sensor reports the type of stability detected. The report ID is 0x13.

6.5.31.1 Feature Report

The change sensitivity should be set to 0 for the stability classifier sensor.

6.5.31.2 Input Report

Byte	Description
0	Report ID = 0x13
1	Sequence number
2	Status
3	Delay
4	Stability classification
5	Reserved

Figure 105: Stability Classifier Input Report

Stability Classification — Stability classification is the state of the device based on its movement.

0 – unknown
1 – on table. The hub is at rest on a stable surface with very little vibration.
2 – stationary. The hub's motion is below the stable threshold but the stable duration requirement has not been met. This output is only available when gyro calibration is enabled. See section 6.4.6 for details about enabling gyro calibration. When gyro calibration is disabled, only states 0, 1, 3 and 4 are output.
3 – stable. The hub's motion has met the stable threshold and duration requirements.
4 – motion. The hub is moving.
5 – 255 Reserved

6.5.32 Shake Detector (0x19)

The shake detector sends a report each time it detects a shake. The report ID is 0x19.

6.5.32.1 Feature Report

The change sensitivity should be set to 0 for the shake detector.

6.5.32.2 Input Report

Byte	Description
0	Report ID = 0x19
1	Sequence number
2	Status
3	Delay
4	Shake LSB
5	Shake MSB

Figure 106: Shake Detector Input Report

Shake — A bit field that indicates the axis along which that a shake was detected.

Bit 0 – X axis shake.
Bit 1 – Y axis shake
Bit 2 – Z axis shake
Bits 3-15 – Reserved

6.5.33 Flip Detector (0x1A)

The flip detector sends a report each time it detects a flip. The report ID is 0x1A.

6.5.33.1 Feature Report

The change sensitivity should be set to 0 for the flip detector.

6.5.33.2 Input Report

Byte	Description
0	Report ID = 0x1A
1	Sequence number
2	Status
3	Delay
4	Flip LSB
5	Flip MSB

Figure 107: Flip Detector Input Report

Flip — Indicates that a flip was detected.

1 – flip detected
All other values are reserved

6.5.34 Pickup Detector (0x1B)

The pickup detector sends a report each time it detects a pickup. The report ID is 0x1B.

6.5.34.1 Feature Report

The change sensitivity should be set to 0 for the pickup detector.

6.5.34.2 Input Report

Byte	Description
0	Report ID = 0x1B
1	Sequence number
2	Status
3	Delay
4	Pickup LSB
5	Pickup MSB

Figure 108: Pickup Detector Input Report

Pickup — Indicates that a pickup was detected.

1 – level to not level detected
2 – stopped within tilt region detected
3 – both level to not level and stopped within tilt region detected
All other values are reserved

6.5.35 Stability Detector (0x1C)

The stability detector sends a report each time it detects entry in or exit from a stable state. The report ID is 0x1C.

6.5.35.1 Feature Report

The change sensitivity should be set to 0 for the stability detector.

6.5.35.2 Input Report

Byte	Description
0	Report ID = 0x1C
1	Sequence number
2	Status
3	Delay
4	Stability LSB
5	Stability MSB

Figure 109: Stability Detector Input Report

Stability — Bit field.

Indicates stability detector events. A value of 1 means the event was detected.

Bit 0 – stable state entered
Bit 1 – stable state exited
All other bits are reserved

6.5.36 Personal Activity Classifier (0x1E)

6.5.36.1 Feature Report

The lower 31 bits of Sensor-Specific Configuration Word indicate which classifications are requested (bit indices correspond with the classification states enumerated in Figure 112: Activity Classification States). For example, to enable still (4), walking (6) and running (7), the host would set bits 4, 6, and 7, supplying 0x000000D0 as the Sensor-Specific Configuration Word. If any classifications are requested, the "Unknown" classification (0) will automatically be requested.

Change sensitivity is specified in percent (0-100), and is applied to the confidence of each classification. A report will be produced if any requested classification's confidence change since the last transmitted input report exceeds the specified threshold. Note that this change is not relative to the value of the confidence. For example, a 10% change threshold, when applied to a classification having original confidence of 80%, will trigger at 90% and 70%, not 88% and 72%.

The most significant bit of Sensor-Specific Configuration Word imposes the additional constraint that the most-likely-state must differ from the last reported most-likely state when set.

	Description							
Byte	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
0	…	…	…	…	…	…	Classification 1 enable	Classification 0 enable
1	…	…	…	…	…	…	…	…
2	…	…	…	…	…	…	…	…
3	MLS Change	Classification 30 enable	…	…	…	…	…	…

Figure 110: Personal Activity Classifier Feature Report.

6.5.36.2 Input Report

Byte	Description
0	Report ID = 0x1E
1	Sequence number
2	Status
3	Delay
4	Page Number + EOS
5	Most likely state
6	Classification (10 x Page Number) confidence
7	Classification (10 x Page Number) + 1 confidence

Byte	Description
8	Classification (10 x Page Number) + 2 confidence
9	Classification (10 x Page Number) + 3 confidence
10	Classification (10 x Page Number) + 4 confidence
11	Classification (10 x Page Number) + 5 confidence
12	Classification (10 x Page Number) + 6 confidence
13	Classification (10 x Page Number) + 7 confidence
14	Classification (10 x Page Number) + 8 confidence
15	Classification (10 x Page Number) + 9 confidence

Figure 111: Personal Activity Classifier Report

Page Number + EOS	MSB is set if this is the last input report for a set of classification results, MSB is clear if more input reports follow this one. 7 least-significant bits indicate page number in the event that classifications are added that exceed the length of a single input report. Results will be reported in multiple pages of no more than 10 confidence levels per page.
Most likely state	Indicates most likely current state, per Figure 112: Activity Classification States.
Classification n confidence	Confidence that the current state is (Page Number x 10) + n. Confidences range from 0 to 100, but do not add up to 100 (as activities are not mutually exclusive).

Note that the classifier may not be able to be configured to provide exactly the set of classifications requested. In this case, confidence reports for unwanted classifications may be masked (set to 0) internally by SH-2.

Note that if the personal activity classifier supports more than 10 classifications, all pages will be reported (even if no classifications were requested on that page or no confidence levels on that page exceeded the change threshold).

ID	Description
0	Unknown
1	In-Vehicle
2	On-Bicycle
3	On-Foot
4	Still
5	Tilting
6	Walking
7	Running
8	OnStairs

Figure 112: Activity Classification States

6.5.37 Sleep Detector (0x1F)

The sleep detector sends a report each time it detects a change in sleep state. The report ID is 0x1F.

6.5.37.1 Feature Report

The change sensitivity should be set to 0 for the sleep detector.

6.5.37.2 Input Report

Byte	Description
0	Report ID = 0x1F
1	Sequence number
2	Status
3	Delay
4	Sleep state
5	Reserved

Figure 113: Sleep Detector Input Report

Sleep state — Indicates the users current sleep state.

0 – hard wake
1 – soft wake
2 – light sleep
3 – deep sleep
4 – unknown
All other values are reserved

6.5.38 Tilt Detector (0x20)

The tilt detector sends a report each time it detects a tilt. The report ID is 0x20.

6.5.38.1 Feature Report

The change sensitivity should be set to 0 for the tilt detector.

6.5.38.2 Input Report

Byte	Description
0	Report ID = 0x20
1	Sequence number
2	Status
3	Delay
4	Tilt LSB
5	Tilt MSB

Figure 114: Tilt Detector Input Report

Tilt — Indicates that a tilt was detected.

1 – tilt detected
All other values are reserved

6.5.39 Pocket Detector (0x21)

The pocket detector sends a report each time it detects entry in or exit from a pocket state. The report ID is 0x21.

6.5.39.1 Feature Report

The change sensitivity should be set to 0 for the pocket detector.

6.5.39.2 Input Report

Byte	Description
0	Report ID = 0x21
1	Sequence number
2	Status
3	Delay
4	Pocket LSB
5	Pocket MSB

Figure 115: Pocket Detector Input Report

Pocket State	Bit field. Indicates pocket detector events. A value of 1 means the event was detected. Bit 0 – entered in pocket state Bit 1 – entered out of pocket state All other bits are reserved

6.5.40 Circle Detector (0x22)

The circle detector sends a report each time it detects a double circle gesture. The report ID is 0x22.

6.5.40.1 Feature Report

The change sensitivity should be set to 0 for the circle detector.

6.5.40.2 Input Report

Byte	Description
0	Report ID = 0x22
1	Sequence number
2	Status
3	Delay
4	Circle LSB
5	Circle MSB

Figure 116: Circle Detector Input Report

Circle	Indicates that a circle was detected.

1 – circle gesture detected
All other values are reserved

6.5.41 Heart Rate Monitor (0x23)

The heart rate monitor measures the user's heart rate. The report ID is 0x23. Heart rate is an unsigned 16-bit integer reported in beats per minute (bpm).

6.5.41.1 Feature Report

No special remarks.

6.5.41.2 Input Report

Byte	Description
0	Report ID = 0x23
1	Sequence number
2	Status
3	Delay
4	Heart rate LSB
5	Heart rate MSB

Figure 117: Heart Rate Monitor Input Report

6.5.42 ARVR-Stabilized Rotation Vector (0x28)

The ARVR-stabilized rotation vector sensor reports the orientation of the device. Accumulated errors are corrected while the device is in motion, which limits the appearance of discontinuities or jumps in data. The format of the rotation vector is a unit quaternion. The Q point is 14. In addition an estimate of the heading accuracy is reported. The units for the accuracy estimate are radians. The Q point is 12. The report ID is 0x28.

6.5.42.1 Feature Report

The change sensitivity is applied to the angular difference between two rotation vectors. The units for change sensitivity are radians. The change sensitivity is unsigned and the Q point is 13.

6.5.42.2 Input Report

Byte	Description
0	Report ID = 0x28
1	Sequence number
2	Status
3	Delay
4	Unit quaternion i component LSB
5	Unit quaternion i component MSB
6	Unit quaternion j component LSB
7	Unit quaternion j component MSB
8	Unit quaternion k component LSB

Byte	Description
9	Unit quaternion k component MSB
10	Unit quaternion real component LSB
11	Unit quaternion real component MSB
12	Accuracy estimate LSB
13	Accuracy estimate MSB

Figure 118: ARVR-Stabilized Rotation Vector Input Report

6.5.43 ARVR-Stabilized Game Rotation Vector (0x29)

The ARVR-Stabilized game rotation vector sensor reports the orientation of the device. Accumulated errors are corrected while the device is in motion, which limits the appearance of discontinuities or jumps in data. The format of the rotation vector is a unit quaternion. The Q point is 14. The report ID is 0x29.

6.5.43.1 Feature Report

The change sensitivity is applied to the angular difference between two rotation vectors. The units for change sensitivity are radians. The change sensitivity is unsigned and the Q point is 13.

6.5.43.2 Input Report

Byte	Description
0	Report ID = 0x29
1	Sequence number
2	Status
3	Delay
4	Unit quaternion i component LSB
5	Unit quaternion i component MSB
6	Unit quaternion j component LSB
7	Unit quaternion j component MSB
8	Unit quaternion k component LSB
9	Unit quaternion k component MSB
10	Unit quaternion real component LSB
11	Unit quaternion real component MSB

Figure 119: ARVR-Stabilized Game Rotation Vector Input Report

6.5.44 Gyro-Integrated Rotation Vector (0x2A)

The Gyro-Integrated Rotation Vector sensor reports the absolute orientation of the device as determined by integrating gyroscope data at every gyroscope sample and correcting to the more-accurate Rotation Vector periodically. This sensor can support higher data rates than the more-accurate Rotation Vector can. The format of the output report is a unit quaternion and calibrated gyroscope data. The Q point of the angular position is 14 and angular velocity is 10. The report ID is 0x2A.

6.5.44.1 Feature Report

This feature supports neither on-change nor batched operation.

While this virtual sensor is controlled (via set-feature reports) with report ID 0x2A on the common control channel, its data is delivered on the “inputGyroRv” SHTP channel, not the standard input report channels.

6.5.44.2 Input Report

Byte	Description
0	Unit quaternion i component LSB
1	Unit quaternion i component MSB
2	Unit quaternion j component LSB
3	Unit quaternion j component MSB
4	Unit quaternion k component LSB
5	Unit quaternion k component MSB
6	Unit quaternion real component LSB
7	Unit quaternion real component MSB
8	Angular velocity x component LSB
9	Angular velocity x component MSB
10	Angular velocity y component LSB
11	Angular velocity y component MSB
12	Angular velocity z component LSB
13	Angular velocity z component MSB

Figure 120: Gyro-Integrated Rotation Vector Input Report

Note that this input report *DOES NOT* contain a report ID field. This is the only type of report delivered on the “inputGyroRV” SHTP channel, so it is omitted to save transmission time.

6.5.45 Motion Request (0x2B)

The interactive calibration feature sends motion requests to the host periodically. The report ID is 0x2B.

6.5.45.1 Feature Report

The feature does not support change sensitivity.

6.5.45.2 Input Report

Byte	Description
0	Report ID = 0x2B
1	Sequence number
2	Status
3	Delay
4	Motion intent
5	Motion request

Figure 121: Motion Request Report

Motion intent	This field reflects the motion intent provided to the sensor hub. See 6.4.12.1 for values.

Motion request	An enumeration of the requested motion. Valid values are: 0 – FME_MOBILE_MOTION_REQUEST_NO_CONSTRAINT. The device may move as desired. 1 – FME_MOBILE_MOTION_REQUEST_STAY_STATIONARY_REQUIRED. The device should remain stationary to refine its calibration to a basic level. 2 – FME_MOBILE_MOTION_REQUEST_STAY_STATIONARY_OPTIONAL. The device should remain stationary to refine its calibration to a high-precision level. If high precision is not required, the device may resume motion. (DEPRECATED. Ignore this request.) 3 – FME_MOBILE_MOTION_REQUEST_NON_URGENT_STATIONARY. The device should stop when convenient to improve its calibration. 4 – FME_MOBILE_MOTION_REQUEST_URGENT_STATIONARY. The device should stop as soon as possible to improve its calibration. 5 – FME_MOBILE_MOTION_REQUEST_TIMER_STATIONARY. The device should stop when convenient to check and possibly improve its calibration.

7.0 Batching

Under SH-2, all input reports on the inputNormal and inputWakeup channels are delivered in batch format. The batch interval setting in the Common Dynamic Feature Report (6.5.2) dictates how many microseconds are allowed to elapse between the point in time where a sensor measurement is obtained and the time that it is provided to the host. A lower value results in lower data latency but higher system power consumption.

In order to comply with the Android L requirements [3], we separate wakeup sensor data from non-wakeup sensor data. Any time that a delivery is triggered, we deliver the data from the wakeup queue first before sending the data from the non-wakeup queue.

7.1 Batch queues

SH-2 maintains two batch queues, one for wake-up sensor data, the other for non-wake-up sensor data. These are sized independently and do not share memory.

Sensors are configured as wake-up by setting the wake-up bit in the "Feature Flags" field of the Common Dynamic Feature Report (6.5.2).

7.2 Batch timestamps

In order to balance the needs of transmitting high-frequency data (with low timestamp overhead) and low-frequency data (with large batch delay values), we combine the sensor report's 14-bit delay field with two additional record types: a Base Timestamp Reference and Timestamp Rebase.

1. A "Base Timestamp Reference" record is inserted at the start of each batch, giving a shared time reference between the host and the sensor hub.
2. A "Timestamp Rebase" record is inserted to extend the delay for blocks of reports which are too far from the batch's Base Timestamp Reference to be represented with the 14-bit report delay field.

Figure 122 graphically displays the relationship between the various sources of timing data.

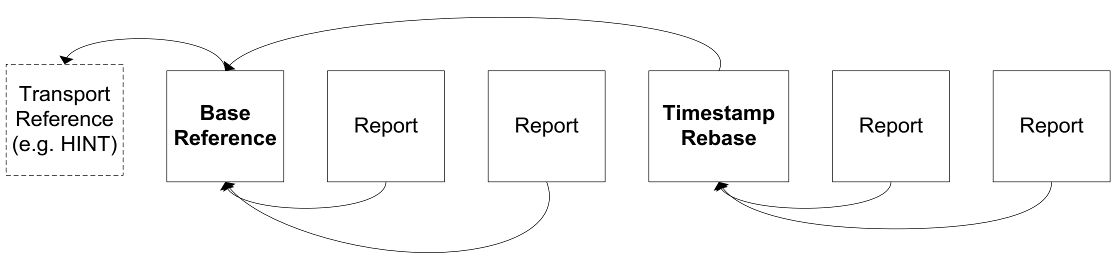

Figure 122: Timestamp Dependencies

7.2.1 Base Timestamp Reference (0xFB)

The Base Timestamp Reference provides a delta from the transport-protocol-defined reference point (the HINT assert for SHTP) and some arbitrary point in time.

Byte	Description
0	Report ID=0xFB
1	Base Delta LSB: relative to transport-defined reference point. Signed. Units are 100 microsecond ticks.
2	Base Delta
3	Base Delta
4	Base Delta MSB

Figure 123: Base Timestamp Reference Record

For example, if HINT occurs at some time t and the Base Timestamp Reference record has a value for delta of 10, the timestamps in a given batch will be relative to t – 1 ms.

The value 0x7FFFFFFF is reserved to indicate that Base Delta exceeded the maximum value that could be represented in 32 bits.

7.2.2 Timestamp Rebase (0xFA)

The 14-bit delay field of sensor input reports can represent up to 16383 100-microsecond ticks, or up to 1.64 seconds. Low frequency, batched sensor data can easily span ranges of time on the order of seconds or minutes. The Timestamp Rebase record is added to the batch's Base Timestamp Reference to derive a new base for sensor reports. Note that Rebase Delta is signed.

Byte	Description
0	Report ID=0xFA
1	Rebase Delta LSB: relative to Base Timestamp Reference. Signed. Units are 100 microsecond ticks.
2	Rebase Delta
3	Rebase Delta
4	Rebase Delta MSB

Figure 124: Timestamp Rebase Record

For example, if HINT occurs at time 5.0 seconds and the batch's Base Timestamp Base Delta is 4.0 seconds, this establishes a shared base timestamp at 1.0 seconds. If a timestamp rebase is encountered having delta 1.5 seconds, then the basis to which subsequent report delays are applied will be 2.5 (e.g. a sensor report having delay = 1.0 seconds would be timestamped as occurring at t=3.5).

8.0 References

1. Hillcrest Laboratories, 1000-3535 Sensor Hub Transport Protocol
2. Hillcrest Laboratories, 1000-3600 SH-2 SHTP Reference Manual
3. Batching: http://source.android.com/devices/sensors/batching.html

9.0 Notices

www.ceva-dsp.com

FOR MORE INFORMATION: