shimmer
DISCOVERY IN MOTION

BtStream for Shimmer3

Firmware User Manual

Rev 0.7a

Legal Notices and Disclaimer

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1. Introduction

This document is an accompaniment to the *BtStream* Firmware v0.6.0 (or later) image for *Shimmer3*. No previous development experience is required.

Note that *BtStream* v0.7.0 is a Beta release.

BtStream firmware is a general purpose, fully configurable application to be used with the *Shimmer3* platform. As the name suggests, a *Shimmer3* programmed with *BtStream* firmware will stream data via a Bluetooth connection to a PC, mobile or other Bluetooth-enabled device.

BtStream firmware provides a complete solution, ready for use as-is for configurable data streaming and is fully compatible with the Shimmer Instrument Driver Libraries for LabVIEW and MATLAB as well as Shimmer APIs in Android and C#, and with *Multi Shimmer Sync* software applications. The source code is also openly available for any able user who may wish to modify or customise it to their own needs or, indeed, to use it as the basis for a new firmware application.

⚠ Whenever the warning symbol appears throughout this document, it denotes a new, modified or deprecated feature in v0.6.0 (or later).

2. Scope of this User Manual

The purpose of this user manual is to guide the user through the features of the *BtStream* firmware image and to provide the required instructions to configure the data streaming options and to parse the received data. The user manual does not provide an extensive explanation of the source code for the firmware.

3. Pre-Requisites

BtStream for Shimmer3 firmware can be used with a *Shimmer3* device. A Bluetooth enabled device (PC, mobile, etc.) is required to interface with *Shimmer3* and receive the streamed data.

For *Shimmer2/2r*, please see the *BtStream for Shimmer2/2r Firmware User Manual*, available for download from www.shimmersensing.com.

4. Installation

Install the *BtStream* firmware v0.7.0 firmware image (BtStream_Shimmer3_v0.7.0.txt) onto a *Shimmer3* device using the *Shimmer3 Bootstrap Loader* (*Shimmer3 BSL*) application, available on our website[1].

[1] http://www.shimmersensing.com/support/wireless-sensor-networks-download/category/21

5. Using the Firmware

To use the *BtStream* firmware, the device must first be paired with a PC, mobile or other Bluetooth-enabled device, as outlined in the *Shimmer User Manual*.

A *Shimmer3* programmed with *BtStream* firmware can be in one of three states: *Disconnected*, *Connected* or *Streaming*. When the *Shimmer3* is first powered on or reset, it is in the *Disconnected* state and will remain there until a connection is made over the Bluetooth link (i.e. by opening a serial connection).

In the *Connected* state, the *Shimmer3* can process various commands to configure its sensors and sampling parameters, set calibration parameters, send configuration settings back to the "host" (PC, mobile or other) and start sampling. When a command to start sampling is received, the *Shimmer3* goes into the *Streaming* state and starts sampling data from its sensors and sending that data over the Bluetooth link. This continues until a command to stop logging is received, whereupon the *Shimmer3* returns to the *Connected* state. Closing the serial connection will put the *Shimmer3* in the *Disconnected* state.

When the *Shimmer3* is in the *Connected* or *Streaming* states, there can be active communication between the *Shimmer3* and the host over the Bluetooth serial connection. Packets of bytes are sent in both directions and these can consist of commands, responses or data.

The first byte of every packet received by the *Shimmer3* or the host is an identifier, telling the receiver what action to carry out or how to interpret the subsequent bytes. The full list of identifiers that are used to interface with the *BtStream* application, can be found in the header file, *Shimmer.h*, which can be found in the Appendix in Section 7.1 of this document (most recent version available in our *Shimmer3* repository on Github[2].)

For every packet that the *Shimmer3* receives, it sends an acknowledgement message (ACK_COMMAND_PROCESSED) back to the host, to acknowledge receipt of the command.

5.1. Set Commands

The "SET" commands are used to set the values of all of the configurable parameters:

- Enabled sensors.
- Sampling rate.
- Accelerometer, gyroscope, magnetometer range.
- Accelerometer, gyroscope, magnetometer data rate.
- Battery monitoring.
- Calibration parameters for Accelerometers, Gyroscope, Magnetometer.
- Blink LED.

The packets sent between the *Shimmer3* and the PC for a SET command are shown in Figure 5-1.

[2] https://github.com/ShimmerResearch/shimmer3.

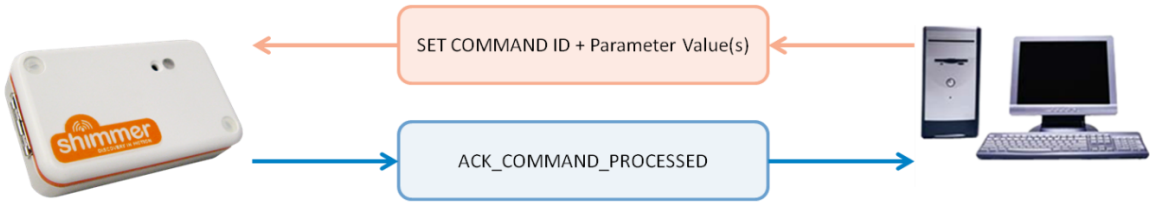


Figure 5-1 Packets sent for SET commands

These commands require that further data be received by the *Shimmer3* after the identifier byte. e.g. the SET_SAMPLING_RATE_COMMAND identifier must be followed by a one-byte value representing the sampling rate that the *Shimmer3* is to use. Another example is the SET_A_ACCEL_CALIBRATION_COMMAND identifier, which must be followed by 21 bytes representing the accelerometer calibration parameters.

5.2. Get Commands

The "GET" commands are requests for information and require that the *Shimmer3* sends data back to the host. The packets sent between the *Shimmer3* and the PC for a SET command are shown in Figure 5-2.

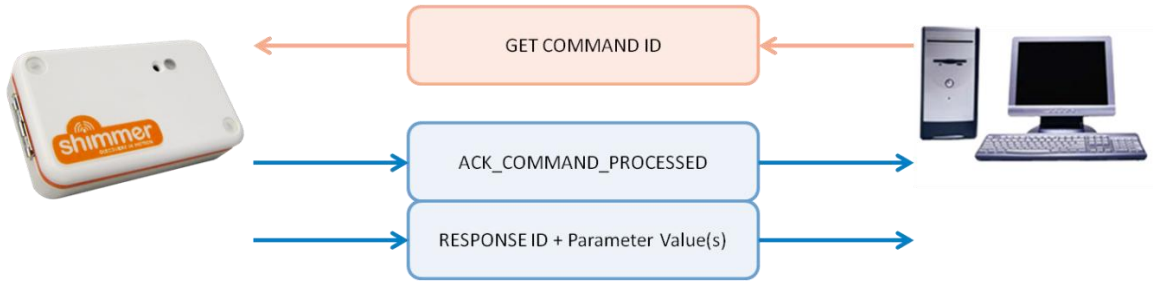


Figure 5-2 Packets sent for GET commands

On receipt of a GET command, the *Shimmer3* will send an acknowledgement message and, then, it will prepare and send a packet containing the appropriate response identifier byte, followed by the data that was requested.

For example, when the *Shimmer3* receives the GET_SAMPLING_RATE_COMMAND, it must send the current value of the sampling rate back to the host; the response packet will contain two bytes: the first byte will be the SAMPLING_RATE_REPONSE identifier and the second byte will be the sampling rate value.

Similarly, if the *Shimmer3* receives a GET_A_ACCEL_CALIBRATION_COMMAND, it will send a packet whose first byte is the A_ACCEL_CALIBRATION_RESPONSE identifier, followed by 21 bytes representing the accelerometer calibration parameters.

The INQUIRY_COMMAND

The INQUIRY_COMMAND is issued by the host when it wants to know the entire configuration of the *Shimmer3*, like what is the sampling rate, what is the buffer size, to which channel is each enabled

sensor assigned, etc. In response to this command, the *Shimmer3* will send a packet back to the host with the structure shown in Table 5-1.

Byte	0	1-2	3-6	7	8	9	10	...	x
Value	Packet Type	Sampling rate	Config Bytes 0-3	Num Chans	Buffer size	Chan1	Chan2	...	ChanX

Table 5-1 Inquiry response packet format

where the Packet Type = INQUIRY_RESPONSE and the value in the channel fields (Chan1, Chan2, ..., ChanX) indicate exactly what data from which sensor will be contained in the equivalent field of the data packet. The total number of bytes sent by the *Shimmer3* will depend on how many data channels are active (i.e. which sensors are enabled).

Signal name, byte values and datatypes

Table 5-2 lists the values in the channel contents bytes of the Inquiry response packet along with the signal names and datatypes for the equivalent sensor signals (* in the Signal Datatype column denotes MSB first; otherwise LSB first).

Signal Name	Byte Value	Signal Datatype
Low Noise Accelerometer X*	0	u12
Low Noise Accelerometer Y*	1	u12
Low Noise Accelerometer Z*	2	u12
Battery	3	u12
Wide Noise Accelerometer X*	4	i16
Wide Noise Accelerometer Y*	5	i16
Wide Noise Accelerometer Z*	6	i16
Magnetometer X*	7	i16*
Magnetometer Y*	8	i16*
Magnetometer Z*	9	i16*
Gyroscope X*	A	i16*
Gyroscope Y*	B	i16*
Gyroscope Z*	C	i16*
External ADC 7	D	u12
External ADC 6	E	u12
External ADC 15	F	u12
Internal ADC 1	10	u12
Internal ADC 12	11	u12
Internal ADC 13	12	u12
Internal ADC 14	13	u12
BMP180 Temperature*	1A	u16*
BMP180 Pressure*	1B	u24*
GSR Raw	1C	u16
ExG_ADS1292R_1_STATUS	1D	u8
ExG_ADS1292R_1_CH1_24BIT	1E	i24*
ExG_ADS1292R_1_CH2_24BIT	1F	i24*
ExG_ADS1292R_2_STATUS	20	u8
ExG_ADS1292R_2_CH1_24BIT	21	i24*
ExG_ADS1292R_2_CH2_24BIT	22	i24*

ExG_ADS1292R_1_CH1_16BIT	23	i16*
ExG_ADS1292R_1_CH2_16BIT	24	i16*
ExG_ADS1292R_2_CH1_16BIT	25	i16*
ExG_ADS1292R_2_CH2_16BIT	26	i16*
Bridge Amplifier High	27	u12
Bridge Amplifier Low	28	u12

Table 5-2 Signal names, channel contents byte values and datatypes for available sensor signals

5.3. Action Commands

There are a number of available "ACTION" commands, which do not require that parameter values be sent between the PC and the *Shimmer3* but, instead, tell the *Shimmer3* what action it is to carry out. These include the START_STREAMING_COMMAND and STOP_STREAMING_COMMAND and the TOGGLE_LED_COMMAND.

5.4. Streaming

When the START_STREAMING_COMMAND is received by the *Shimmer3*, it will send an acknowledge message back to the host and start sampling sensor data. As the sensor data is sampled, the *Shimmer3* will prepare data packets and send them to the host over Bluetooth.

The *Buffer size* parameter determines the number of samples that are sent together in a single data packet. The structure of the data packet with *Buffer size = 2* is shown in Table 5-3, where Packet Type = DATA_PACKET, *TS* denotes "Timestamp" and *Ch* denotes "Channel".

Byte	0	1 - 2	3 - 4	5 - 6	...	(x-1) - x	(x+1) - (x+2)	(x+3) - (x+4)	(x+5) - (x+6)	...	(2x-1) - 2x
Value	Packet Type	TS	Ch1	Ch2	...	ChX	TS	Ch1	Ch2	...	ChX
		Sample 1					Sample 2				

Table 5-3 Data packet structure (Buffer size =2)

If *Buffer size* were equal to 1, then the data packet would contain only one timestamp and one sample from each channel (i.e. the bytes denoted "Sample 1" in Table 5-3. If *Buffer size* were any integer value greater than 1, then subsequent timestamps and sample values for each channel would be appended at the end of the packet until the number of samples equals the buffer size.

Sensor data will continue to be sampled and streamed until a STOP_STREAMING_COMMAND is received by the *Shimmer3*.

By default, the application will sample low noise accelerometer, gyroscope, magnetometer and battery voltage at a rate of 51.2 Hz, with the gyroscope range set to +/- 500 dps and the magnetometer range set to +/-1.3 Ga, and the data will be sent using a data buffer of size 1.

5.5. Configuration

Configuration via Bluetooth

The recommended method of writing the calibration parameters to a Shimmer device, programmed with *BtStream* firmware is to connect via the *ShimmerCapture* software application, which can be downloaded from the Shimmer website[3] and use the graphical interface to configure the device via a Bluetooth connection. Alternatively, the 'SET' and 'GET' commands, described previously, may be used via any of the Shimmer APIs/IDs, which can be downloaded from www.shimmersensing.com or via custom software developed by the user.

Configuration via UART

⚠ Configuration via UART is a new feature introduced in v0.6.0 (or later)..

Configuration parameters can be written directly to the non-volatile memory (infomem) on the Shimmer3 via the UART interface, using a *Shimmer Dock* or *Consensys Base*.

To write the configuration parameters via UART, the following must be specified:

- the memory address of the first byte.
- the number of bytes to be written.
- the values to be written to the relevant bytes.

Please refer to the Section 7.2 in the Appendices of this document for a description of infomem contents. Please refer to the source code of *BtStream* for details for the UART commands.

[3] www.shimmersensing.com/support/wireless-sensor-networks-download/category/21

5.6. BtStream firmware LED indicators

The *Shimmer3* has five LEDs in two locations: lower location A (green, yellow[4] and red); upper location B (green , blue), as shown in Figure 5-3.

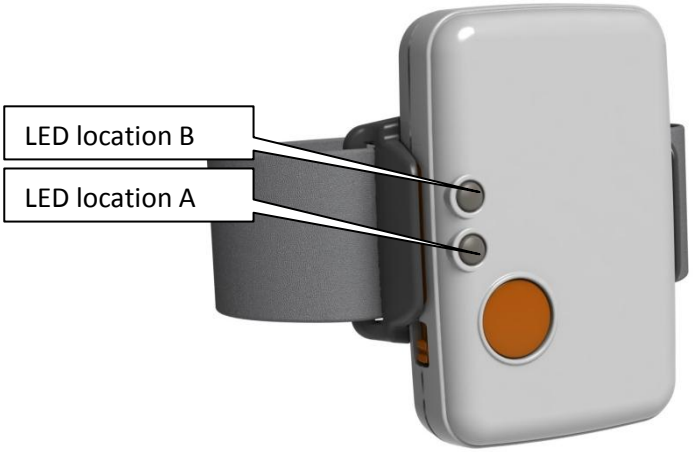


Figure 5-3 Shimmer3 LED Locations

The LEDs in Location A are used to indicate battery charge status, as outlined in Table 5-4.

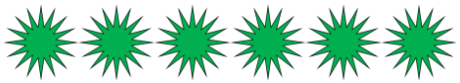
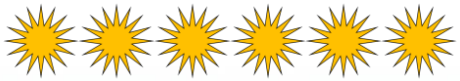
		LED Pattern	Description
Docked or in Multi Charger	Full Charge		Green Solid ON
	Charging		Yellow Solid ON
Undocked	Full Charge		Green 0.1s ON/5s OFF
	Medium Charge		Yellow 0.1s ON/5s OFF
	Low Charge		Red 0.1s ON/5s OFF

Table 5-4 BtStream Battery Charge Status Indication

[4] Note that what is referred to as the yellow LED may appear orange to some users.

The LEDs in Location B are used to indicate operation status, as outlined in Table 5-5.

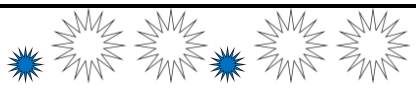
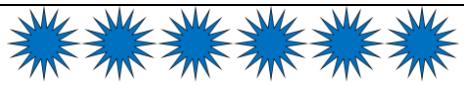
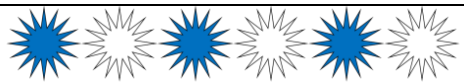
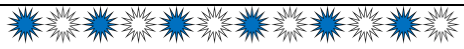
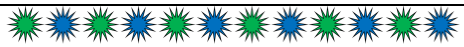
		LED Pattern	Description
Docked or Undocked	Standby		Blue 0.1s ON/2s OFF
	Connected		Blue Solid ON
	Streaming		Blue 1s ON / 1s OFF
	Configuring		Blue 0.1s ON/ 0.1s OFF
	Error		0.1s Blue/0.1s Green

Table 5-5 BtStream Operation Status Indication

6. Further resources

There are sample python scripts available on https://github.com/ShimmerResearch/shimmer3 or from support@shimmersensing.com which will help to get new users up to speed with interfacing with a *Shimmer3* running *BtStream*. The *README.txt* document accompanying the scripts describes what each script does and, also, outlines how to bind the MAC address of the *Shimmer3* to an RFCOMM port in Linux, in order to allow serial connections over Bluetooth.

7. Appendices

7.1. Bluetooth latency

Delays due to Bluetooth transmission should be taken into account when streaming data, particularly if the data is to be synchronised on the receiver side. Our lab tests have shown up to 100 ms of latency with considerable variation (> 50 ms). These measures result from multiple FIFOs in the data path, as expected in wireless data acquisition systems using conventional computing devices for the data end-points. Actual performance is strongly impacted by end-point system configuration and load.

7.2. Infomem Contents

⚠ The information in this section applies to *BtStream Firmware v0.6.0* (or later), only.

The configuration and calibration parameter values are stored by the *Shimmer3* in the Infomem, which is the part of the *Shimmer3* memory that survives a reset or power cycle but is overwritten when the *Shimmer3* is reprogrammed. The format of the configuration data stored in Infomem is as follows:

Infomem Byte	Contents
0 - 1	Sampling rate
2	Buffer size
3 - 5	Selected sensors
6 - 9	Config bytes (Allows for 56 individual boolean settings)
10 - 29	ExG configuration bytes
30	Bluetooth Communication baud rate
31 - 33	Derived Channels
34 - 54	Low Noise Accelerometer calibration values
55 - 75	Gyroscope calibration values
76 - 96	Magnetometer calibration values
97 - 117	Wide Range Accelerometer calibration values
118 - 127	Reserved for future use
128 - 129	MPL sensors
130 - 132	MPL config bytes
133 - 153	MPL Accelerometer calibration values
154 - 174	MPL Magnetometer calibration values
175 - 186	MPL Gyroscope calibration values
187 - 229	SD Logging configuration parameters
230	Infomem contents changed flags
256 - 381	Slave Node IDs

Table 7-1 Infomem layout overview.

Selected Sensors - Infomem Bytes 3 to 5

The *Selected sensors* bytes have a single bit assigned to each sensor as follows:

	Bit	Property
Infomem Byte 3	7	Low Noise Accelerometer.
	6	Gyroscope.
	5	Magnetometer.
	4	ExG1_24BIT.
	3	ExG2_24BIT.
	2	GSR.
	1	External Expansion ADC Channel 7.
	0	External Expansion ADC Channel 6.
Infomem Byte 4	7	Bridge Amplifer.
	6	Not yet assigned.
	5	Battery Monitor.
	4	Wide Range Accelerometer.
	3	External Expansion ADC Channel 15.
	2	Internal Expansion ADC Channel 1.
	1	Internal Expansion ADC Channel 12.
	0	Internal Expansion ADC Channel 13.
Infomem Byte 5	7	Internal Expansion ADC Channel 14.
	6	MPU9150 Accelerometer.
	5	MPU9150 Magnetometer.
	4	ExG1_16BIT.
	3	ExG2_16BIT.
	2	BMP180 Pressure.
	1	BMP180 Temperature.
	0	MSP430 Temperature.

Table 7-2 Selected Sensor Bytes

Sensor Config Bytes - Infomem Bytes 6 to 9

The *Sensor Config bytes* contain the following parameters:

Infomem Byte 6 - Config Setup Byte 0	
Bits 7 – 4	Wide Range (LSM303DLHC) Accelerometer Data Rate.
Bits 3 – 2	Wide Range (LSM303DLHC) Accelerometer Range.
Bit 1	Wide Range (LSM303DLHC) Accelerometer Low Power Mode.
Bit 0	Wide Range (LSM303DLHC) Accelerometer High Resolution Mode.
Infomem Byte 7 - Config Setup Byte 1	
Bits 7 – 0	MPU9150 Data Rate.
Infomem Byte 8 - Config Setup Byte 2	
Bits 7 – 5	(LSM303DLHC) Magnetometer Range.
Bits 4 – 2	(LSM303DLHC) Magnetometer Data Rate.
Bit 1 - 0	MPU9150 Gyroscope Range.
Infomem Byte 9 - Config Setup Byte 3	
Bits 7 – 6	MPU9150 Accelerometer Range.

Bits 5 – 4	BMP180 Pressure Resolution.
Bit 3 - 1	GSR Range
Bit 0	Internal Expansion Power Enable

Table 7-3 Sensor Config bytes

ExG Configuration Bytes - Infomem Bytes 10 to 29

These bytes store the configuration bytes which are sent to the *ECG/EMG Expansion Board* if one is connected and enabled. For detailed information on these bytes please refer to either the *ECG User Guide* or the *EMG User Guide - both of* which are available for download from the members section of the Shimmer website.

BT Communication Baud Rate - Infomem Byte 30

This byte stores the baud rate at which the Shimmer's microcontroller communicates with the on-board Bluetooth module and consequently, back to a base device. There are 11 allowable options, as listed in Table 7-4:

Value (decimal)	Baud
0	115200 (default)
1	1200
2	2400
3	4800
4	9600
5	19200
6	38400
7	57600
8	230400
9	460800
10	921600

Table 7-4 BT Communication Baud Rate byte options

Derived Channels - Infomem Bytes 31 to 34

These bytes contain flags to indicate the type of peripheral that is attached to the analog channels. These bytes have no explicit function in firmware and are included to allow software applications, like *Consensys*, to correctly label the data. In custom applications, they may be used as the developer sees fit.

Calibration Parameters - Infomem Bytes 34 to 117

The calibration parameters for the inertial measurement units (accelerometer, gyroscope and magnetometer) consist of a three-element offset bias vector, a three-element sensitivity vector and

a 3x3-element alignment matrix[5]. The structure of these values when they are sent to/from the *Shimmer3* and stored in Infomem is as follows:

- Each of the 3 offset bias vector values are stored as 16-bit signed integers (big endian) and are contained in bytes 0-5.
- Each of the 3 sensitivity vector values are stored as 16-bit signed integers (big endian) and are contained in bytes 6-11.
- Each of the 9 alignment matrix values are stored as 8-bit signed integers and are contained in bytes 12-20.

MPL Parameters - Infomem Bytes 118 to 186

These bytes are not relevant for *BtStream* firmware.

SD Logging - Experiment parameters - Infomem Bytes 187 to 229

These bytes are not relevant for *BtStream* firmware.

Infomem contents changed flags - Infomem Byte 230

This byte os not relevant for *BtStream* firmware.

Slave Node IDs - Infomem Bytes 256 - 381

These bytes are not relevant for *BtStream* firmware.

7.3. Shimmer.h file

```
/*
 * Copyright (c) 2013, Shimmer Research, Ltd.
 * All rights reserved
 *
 * Redistribution and use in source and binary forms, with or without
 * modification, are permitted provided that the following conditions are
 * met:
 *
 *     * Redistributions of source code must retain the above copyright
 *       notice, this list of conditions and the following disclaimer.
 *     * Redistributions in binary form must reproduce the above
 *       copyright notice, this list of conditions and the following
 *       disclaimer in the documentation and/or other materials provided
 *       with the distribution.
 *     * Neither the name of Shimmer Research, Ltd. nor the names of its
 *       contributors may be used to endorse or promote products derived
 *       from this software without specific prior written permission.
 *     * You may not use or distribute this Software or any derivative works
 *       in any form for commercial purposes with the exception of commercial
 *       purposes when used in conjunction with Shimmer products purchased
 *       from Shimmer or their designated agent or with permission from
 *       Shimmer.
 *       Examples of commercial purposes would be running business
 *       operations, licensing, leasing, or selling the Software, or
 *       distributing the Software for use with commercial products.
 *
```

[5] For a more detailed description of IMU calibration parameters, refer to the *Shimmer 9DoF Calibration User Manual* and the *Shimmer IMU User Guide*.

```
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 * "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT
 * LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR
 * A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT
 * OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL,
 * SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT
 * LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE,
 * DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY
 * THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
 * (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE
 * OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
 *
 * @author Mike Healy
 * @date December, 2013
 */


#ifndef SHIMMER_H
#define SHIMMER_H

//these are defined in the Makefile for BtStream (TinyOS)
#define DEVICE_VER      3     //Represents shimmer3
#define FW_IDENTIFIER   1     //Two byte firmware identifier number
#define FW_VER_MAJOR    0     //Major version number: 0-65535
#define FW_VER_MINOR    6     //Minor version number: 0-255
#define FW_VER_REL      0     //Release candidate version number: 0-255


// Packet Types
#define DATA_PACKET                                     0x00
#define INQUIRY_COMMAND                                 0x01
#define INQUIRY_RESPONSE                                0x02
#define GET_SAMPLING_RATE_COMMAND                       0x03
#define SAMPLING_RATE_RESPONSE                          0x04
#define SET_SAMPLING_RATE_COMMAND                       0x05
#define TOGGLE_LED_COMMAND                              0x06
#define START_STREAMING_COMMAND                         0x07  //maintain
compatibility with Shimmer2/2r BtStream
#define SET_SENSORS_COMMAND                             0x08
#define SET_LSM303DLHC_ACCEL_RANGE_COMMAND              0x09
#define LSM303DLHC_ACCEL_RANGE_RESPONSE                 0x0A
#define GET_LSM303DLHC_ACCEL_RANGE_COMMAND              0x0B
#define SET_CONFIG_SETUP_BYTES_COMMAND                  0x0E
#define CONFIG_SETUP_BYTES_RESPONSE                     0x0F
#define GET_CONFIG_SETUP_BYTES_COMMAND                  0x10
#define SET_A_ACCEL_CALIBRATION_COMMAND                 0x11
#define A_ACCEL_CALIBRATION_RESPONSE                    0x12
#define GET_A_ACCEL_CALIBRATION_COMMAND                 0x13
#define SET_MPU9150_GYRO_CALIBRATION_COMMAND            0x14
#define MPU9150_GYRO_CALIBRATION_RESPONSE               0x15
#define GET_MPU9150_GYRO_CALIBRATION_COMMAND            0x16
#define SET_LSM303DLHC_MAG_CALIBRATION_COMMAND          0x17
#define LSM303DLHC_MAG_CALIBRATION_RESPONSE             0x18
#define GET_LSM303DLHC_MAG_CALIBRATION_COMMAND          0x19
#define SET_LSM303DLHC_ACCEL_CALIBRATION_COMMAND        0x1A
#define LSM303DLHC_ACCEL_CALIBRATION_RESPONSE           0x1B
#define GET_LSM303DLHC_ACCEL_CALIBRATION_COMMAND        0x1C
#define STOP_STREAMING_COMMAND                          0x20  //maintain
compatibility with Shimmer2/2r BtStream
#define SET_GSR_RANGE_COMMAND                           0x21
#define GSR_RANGE_RESPONSE                              0x22
#define GET_GSR_RANGE_COMMAND                           0x23
#define DEPRECATED_GET_DEVICE_VERSION_COMMAND           0x24  //maintain
compatibility with Shimmer2/2r BtStream
                                                              //deprecated because
0x24 ('$' ASCII) as a command
```

```
                                                    //is problematic if
remote config is enabled in
                                                    //RN42 Bluetooth
module. Replaced with 0x3F command
#define DEVICE_VERSION_RESPONSE                     0x25  //maintain
compatibility with Shimmer2/2r BtStream
#define GET_ALL_CALIBRATION_COMMAND                 0x2C
#define ALL_CALIBRATION_RESPONSE                    0x2D
#define GET_FW_VERSION_COMMAND                      0x2E  //maintain
compatibility with Shimmer2/2r BtStream
#define FW_VERSION_RESPONSE                         0x2F  //maintain
compatibility with Shimmer2/2r BtStream
#define SET_CHARGE_STATUS_LED_COMMAND               0x30
#define CHARGE_STATUS_LED_RESPONSE                  0x31
#define GET_CHARGE_STATUS_LED_COMMAND               0x32
#define BUFFER_SIZE_RESPONSE                        0x35
#define GET_BUFFER_SIZE_COMMAND                     0x36
#define SET_LSM303DLHC_MAG_GAIN_COMMAND             0x37
#define LSM303DLHC_MAG_GAIN_RESPONSE                0x38
#define GET_LSM303DLHC_MAG_GAIN_COMMAND             0x39
#define SET_LSM303DLHC_MAG_SAMPLING_RATE_COMMAND    0x3A
#define LSM303DLHC_MAG_SAMPLING_RATE_RESPONSE       0x3B
#define GET_LSM303DLHC_MAG_SAMPLING_RATE_COMMAND    0x3C
#define UNIQUE_SERIAL_RESPONSE                      0x3D
#define GET_UNIQUE_SERIAL_COMMAND                   0x3E
#define GET_DEVICE_VERSION_COMMAND                  0x3F
#define SET_LSM303DLHC_ACCEL_SAMPLING_RATE_COMMAND  0x40
#define LSM303DLHC_ACCEL_SAMPLING_RATE_RESPONSE     0x41
#define GET_LSM303DLHC_ACCEL_SAMPLING_RATE_COMMAND  0x42
#define SET_LSM303DLHC_ACCEL_LPMODE_COMMAND         0x43
#define LSM303DLHC_ACCEL_LPMODE_RESPONSE            0x44
#define GET_LSM303DLHC_ACCEL_LPMODE_COMMAND         0x45
#define SET_LSM303DLHC_ACCEL_HRMODE_COMMAND         0x46
#define LSM303DLHC_ACCEL_HRMODE_RESPONSE            0x47
#define GET_LSM303DLHC_ACCEL_HRMODE_COMMAND         0x48
#define SET_MPU9150_GYRO_RANGE_COMMAND              0x49
#define MPU9150_GYRO_RANGE_RESPONSE                 0x4A
#define GET_MPU9150_GYRO_RANGE_COMMAND              0x4B
#define SET_MPU9150_SAMPLING_RATE_COMMAND           0x4C
#define MPU9150_SAMPLING_RATE_RESPONSE              0x4D
#define GET_MPU9150_SAMPLING_RATE_COMMAND           0x4E
#define SET_MPU9150_ACCEL_RANGE_COMMAND             0x4F
#define MPU9150_ACCEL_RANGE_RESPONSE                0x50
#define GET_MPU9150_ACCEL_RANGE_COMMAND             0x51
#define SET_BMP180_PRES_OVERSAMPLING_RATIO_COMMAND  0x52
#define BMP180_PRES_OVERSAMPLING_RATIO_RESPONSE     0x53
#define GET_BMP180_PRES_OVERSAMPLING_RATIO_COMMAND  0x54
#define BMP180_CALIBRATION_COEFFICIENTS_RESPONSE    0x58
#define GET_BMP180_CALIBRATION_COEFFICIENTS_COMMAND 0x59
#define RESET_TO_DEFAULT_CONFIGURATION_COMMAND      0x5A
#define RESET_CALIBRATION_VALUE_COMMAND             0x5B
#define MPU9150_MAG_SENS_ADJ_VALS_RESPONSE          0x5C
#define GET_MPU9150_MAG_SENS_ADJ_VALS_COMMAND       0x5D
#define SET_INTERNAL_EXP_POWER_ENABLE_COMMAND       0x5E
#define INTERNAL_EXP_POWER_ENABLE_RESPONSE          0x5F
#define GET_INTERNAL_EXP_POWER_ENABLE_COMMAND       0x60
#define SET_EXG_REGS_COMMAND                        0x61
#define EXG_REGS_RESPONSE                           0x62
#define GET_EXG_REGS_COMMAND                        0x63
#define DAUGHTER_CARD_ID_RESPONSE                   0x65
#define GET_DAUGHTER_CARD_ID_COMMAND                0x66
#define SET_DAUGHTER_CARD_MEM_COMMAND               0x67
#define DAUGHTER_CARD_MEM_RESPONSE                  0x68
#define GET_DAUGHTER_CARD_MEM_COMMAND               0x69
#define SET_BT_COMMS_BAUD_RATE                      0x6A     //11 allowable
options: 0=115.2K(default), 1=1200, 2=2400, 3=4800,
```

```
                                                                    //4=9600, 5=19.2K,
6=38.4K, 7=57.6K, 8=230.4K, 9=460.8K, 10=921.6K
                                                                    //Need to disconnect
BT connection before change is active
#define BT_COMMS_BAUD_RATE_RESPONSE                 0x6B
#define GET_BT_COMMS_BAUD_RATE                      0x6C
#define SET_DERIVED_CHANNEL_BYTES                   0x6D
#define DERIVED_CHANNEL_BYTES_RESPONSE              0x6E
#define GET_DERIVED_CHANNEL_BYTES                   0x6F
//0x70 to 0x87 and 0xE0 reserved for Log+Stream
#define ACK_COMMAND_PROCESSED                       0xFF


//SENSORS0
#define SENSOR_A_ACCEL            0x80
#define SENSOR_MPU9150_GYRO       0x40
#define SENSOR_LSM303DLHC_MAG     0x20
#define SENSOR_EXG1_24BIT         0x10
#define SENSOR_EXG2_24BIT         0x08
#define SENSOR_GSR                0x04
#define SENSOR_EXT_A7             0x02
#define SENSOR_EXT_A6             0x01
//SENSORS1
#define SENSOR_BRIDGE_AMP         0x80     //higher priority than SENSOR_INT_A13 and
SENSOR_INT_A14
#define SENSOR_VBATT              0x20
#define SENSOR_LSM303DLHC_ACCEL   0x10
#define SENSOR_EXT_A15            0x08
#define SENSOR_INT_A1             0x04
#define SENSOR_INT_A12            0x02
#define SENSOR_INT_A13            0x01
//SENORS2
#define SENSOR_INT_A14            0x80
#define SENSOR_MPU9150_ACCEL      0x40
#define SENSOR_MPU9150_MAG        0x20
#define SENSOR_EXG1_16BIT         0x10
#define SENSOR_EXG2_16BIT         0x08
#define SENSOR_BMP180_PRESSURE    0x04


#define MAX_COMMAND_ARG_SIZE      131   //maximum number of arguments for any
command sent
                                        //(daughter card mem write)
#define RESPONSE_PACKET_SIZE      131   //biggest possibly required  (daughter card
mem read + 1 byte for ack)
#define MAX_NUM_CHANNELS          28    //3xanalogAccel + 3xdigiGyro + 3xdigiMag +
                                        //3xLSM303DLHCAccel + 3xMPU9150Accel +

3xMPU9150MAG +
                                        //BMP180TEMP + BMP180PRESS + batteryVoltage

+
                                        //3xexternalADC + 4xinternalADC
#define DATA_PACKET_SIZE          66    //3 + (MAX_NUM_CHANNELS * 2) + 1 + 6 (+1 as
BMP180
                                        //pressure requires 3 bytes, +6 for 4 (3

byte) ExG
                                        //channels plus 2 status bytes instead of
                                        //4xinternalADC)


// Channel contents
#define X_A_ACCEL                       0x00
#define Y_A_ACCEL                       0x01
#define Z_A_ACCEL                       0x02
#define VBATT                           0x03
#define X_LSM303DLHC_ACCEL              0x04
#define Y_LSM303DLHC_ACCEL              0x05
#define Z_LSM303DLHC_ACCEL              0x06
```

```
#define X_LSM303DLHC_MAG                0x07
#define Y_LSM303DLHC_MAG                0x08
#define Z_LSM303DLHC_MAG                0x09
#define X_MPU9150_GYRO                  0x0A
#define Y_MPU9150_GYRO                  0x0B
#define Z_MPU9150_GYRO                  0x0C
#define EXTERNAL_ADC_7                  0x0D
#define EXTERNAL_ADC_6                  0x0E
#define EXTERNAL_ADC_15                 0x0F
#define INTERNAL_ADC_1                  0x10
#define INTERNAL_ADC_12                 0x11
#define INTERNAL_ADC_13                 0x12
#define INTERNAL_ADC_14                 0x13
#define X_MPU9150_ACCEL                 0x14
#define Y_MPU9150_ACCEL                 0x15
#define Z_MPU9150_ACCEL                 0x16
#define X_MPU9150_MAG                   0x17
#define Y_MPU9150_MAG                   0x18
#define Z_MPU9150_MAG                   0x19
#define BMP180_TEMP                     0x1A
#define BMP180_PRESSURE                 0x1B
#define GSR_RAW                         0x1C
#define EXG_ADS1292R_1_STATUS           0x1D
#define EXG_ADS1292R_1_CH1_24BIT        0x1E
#define EXG_ADS1292R_1_CH2_24BIT        0x1F
#define EXG_ADS1292R_2_STATUS           0x20
#define EXG_ADS1292R_2_CH1_24BIT        0x21
#define EXG_ADS1292R_2_CH2_24BIT        0x22
#define EXG_ADS1292R_1_CH1_16BIT        0x23
#define EXG_ADS1292R_1_CH2_16BIT        0x24
#define EXG_ADS1292R_2_CH1_16BIT        0x25
#define EXG_ADS1292R_2_CH2_16BIT        0x26
#define BRIDGE_AMP_HIGH                 0x27
#define BRIDGE_AMP_LOW                  0x28


// Infomem contents
#define NV_NUM_SETTINGS_BYTES           34
#define NV_NUM_CALIBRATION_BYTES        84
#define NV_TOTAL_NUM_CONFIG_BYTES       118

#define NV_SAMPLING_RATE                0
#define NV_BUFFER_SIZE                  2
#define NV_SENSORS0                     3
#define NV_SENSORS1                     4
#define NV_SENSORS2                     5
#define NV_CONFIG_SETUP_BYTE0           6
#define NV_CONFIG_SETUP_BYTE1           7
#define NV_CONFIG_SETUP_BYTE2           8
#define NV_CONFIG_SETUP_BYTE3           9
#define NV_EXG_ADS1292R_1_CONFIG1       10
#define NV_EXG_ADS1292R_1_CONFIG2       11
#define NV_EXG_ADS1292R_1_LOFF          12
#define NV_EXG_ADS1292R_1_CH1SET        13
#define NV_EXG_ADS1292R_1_CH2SET        14
#define NV_EXG_ADS1292R_1_RLD_SENS      15
#define NV_EXG_ADS1292R_1_LOFF_SENS     16
#define NV_EXG_ADS1292R_1_LOFF_STAT     17
#define NV_EXG_ADS1292R_1_RESP1         18
#define NV_EXG_ADS1292R_1_RESP2         19
#define NV_EXG_ADS1292R_2_CONFIG1       20
#define NV_EXG_ADS1292R_2_CONFIG2       21
#define NV_EXG_ADS1292R_2_LOFF          22
#define NV_EXG_ADS1292R_2_CH1SET        23
#define NV_EXG_ADS1292R_2_CH2SET        24
#define NV_EXG_ADS1292R_2_RLD_SENS      25
#define NV_EXG_ADS1292R_2_LOFF_SENS     26
```

```
#define NV_EXG_ADS1292R_2_LOFF_STAT       27
#define NV_EXG_ADS1292R_2_RESP1           28
#define NV_EXG_ADS1292R_2_RESP2           29
#define NV_BT_COMMS_BAUD_RATE             30
#define NV_DERIVED_CHANNEL_BYTE_0         31
#define NV_DERIVED_CHANNEL_BYTE_1         32
#define NV_DERIVED_CHANNEL_BYTE_2         33
#define NV_A_ACCEL_CALIBRATION            34
#define NV_MPU9150_GYRO_CALIBRATION       55
#define NV_LSM303DLHC_MAG_CALIBRATION     76
#define NV_LSM303DLHC_ACCEL_CALIBRATION   97


//Config byte masks
//Config Byte0
#define LSM303DLHC_ACCEL_SAMPLING_RATE          0xF0
#define LSM303DLHC_ACCEL_RANGE                  0x0C
#define LSM303DLHC_ACCEL_LOW_POWER_MODE         0x02
#define LSM303DLHC_ACCEL_HIGH_RESOLUTION_MODE   0x01
//Config Byte1
//MPU9150_SAMPLING_RATE                         0xFF
//Config Byte2
#define LSM303DLHC_MAG_GAIN                     0xE0
#define LSM303DLHC_MAG_SAMPLING_RATE            0x1C
#define MPU9150_GYRO_RANGE                      0x03
//Config Byte3
#define MPU9150_ACCEL_RANGE                     0xC0
#define BMP180_PRESSURE_RESOLUTION              0x30
#define GSR_RANGE                               0x0E
#define INT_EXP_POWER_ENABLE                    0x01


//ADC initialisation mask
#define MASK_A_ACCEL      0x0001
#define MASK_VBATT        0x0002
#define MASK_EXT_A7       0x0004
#define MASK_EXT_A6       0x0008
#define MASK_EXT_A15      0x0010
#define MASK_INT_A1       0x0020
#define MASK_INT_A12      0x0040
#define MASK_INT_A13      0x0080
#define MASK_INT_A14      0x0100
#define MASK_GSR          0x0020   //uses ADC1
#define MASK_BRIDGE_AMP   0x0180   //uses ADC13 and ADC14


//LSM303DLHC Accel Range
//Corresponds to the FS field of the LSM303DLHC's CTRL_REG4_A register
//and the AFS_SEL field of the MPU9150's ACCEL_CONFIG register
#define ACCEL_2G     0x00
#define ACCEL_4G     0x01
#define ACCEL_8G     0x02
#define ACCEL_16G    0x03

//LSM303DLHC Accel Sampling Rate
//Corresponds to the ODR field of the LSM303DLHC's CTRL_REG1_A register
#define LSM303DLHC_ACCEL_POWER_DOWN 0x00
#define LSM303DLHC_ACCEL_1HZ        0x01
#define LSM303DLHC_ACCEL_10HZ       0x02
#define LSM303DLHC_ACCEL_25HZ       0x03
#define LSM303DLHC_ACCEL_50HZ       0x04
#define LSM303DLHC_ACCEL_100HZ      0x05
#define LSM303DLHC_ACCEL_200HZ      0x06
#define LSM303DLHC_ACCEL_400HZ      0x07
#define LSM303DLHC_ACCEL_1_620KHZ   0x08 //1.620kHz in Low-power mode only
#define LSM303DLHC_ACCEL_1_344kHz   0x09 //1.344kHz in normal mode, 5.376kHz in
low-power mode
```

```
//LSM303DLHC Mag gain
#define LSM303DLHC_MAG_1_3G          0x01 //+/-1.3 Gauss
#define LSM303DLHC_MAG_1_9G          0x02 //+/-1.9 Gauss
#define LSM303DLHC_MAG_2_5G          0x03 //+/-2.5 Gauss
#define LSM303DLHC_MAG_4_0G          0x04 //+/-4.0 Gauss
#define LSM303DLHC_MAG_4_7G          0x05 //+/-4.7 Gauss
#define LSM303DLHC_MAG_5_6G          0x06 //+/-5.6 Gauss
#define LSM303DLHC_MAG_8_1G          0x07 //+/-8.1 Gauss

//LSM303DLHC Mag sampling rate
#define LSM303DLHC_MAG_0_75HZ        0x00 //0.75 Hz
#define LSM303DLHC_MAG_1_5HZ         0x01 //1.5 Hz
#define LSM303DLHC_MAG_3HZ           0x02 //3.0 Hz
#define LSM303DLHC_MAG_7_5HZ         0x03 //7.5 Hz
#define LSM303DLHC_MAG_15HZ          0x04 //15 Hz
#define LSM303DLHC_MAG_30HZ          0x05 //30 Hz
#define LSM303DLHC_MAG_75HZ          0x06 //75 Hz
#define LSM303DLHC_MAG_220HZ         0x07 //220 Hz

//MPU9150 Gyro range
#define MPU9150_GYRO_250DPS          0x00 //+/-250 dps
#define MPU9150_GYRO_500DPS          0x01 //+/-500 dps
#define MPU9150_GYRO_1000DPS         0x02 //+/-1000 dps
#define MPU9150_GYRO_2000DPS         0x03 //+/-2000 dps

//BMP Pressure oversampling ratio
#define BMP180_OSS_1                 0x00
#define BMP180_OSS_2                 0x01
#define BMP180_OSS_4                 0x02
#define BMP180_OSS_8                 0x03

//BtStream specific extension to range values
#define GSR_AUTORANGE                0x04

//UART definitions
//Command names
#define UART_RXBUF_START             0
#define UART_RXBUF_CMD               1
#define UART_RXBUF_LEN               2
#define UART_RXBUF_COMP              3
#define UART_RXBUF_PROP              4     //data in rxbuf starts from byte 3
#define UART_RXBUF_DATA              5     //data in rxbuf starts from byte 3
#define UART_DATA_LEN_MAX            138   //max case: '$' + get + length +
comp_shimmer+ prop_infomem
#define UART_RSP_PACKET_SIZE         138   //+ info_len + info_loc*2 + 128bytes data
+ crc*2 = 138

//Commands
#define UART_SET                     0x01
#define UART_RESPONSE                0x02
#define UART_GET                     0x03
#define UART_BAD_CMD_RESPONSE        0xFC
#define UART_BAD_ARG_RESPONSE        0xFD
#define UART_BAD_CRC_RESPONSE        0xFE
#define UART_ACK_RESPONSE            0xFF

//Components names
#define UART_COMP_SHIMMER            0x01
#define UART_COMP_BAT                0x02  //this is seen as a sensor
#define UART_COMP_DAUGHTER_CARD      0x03

//Property names
#define UART_PROP_MAC                0x02
#define UART_PROP_VER                0x03
#define UART_PROP_INFOMEM            0x06
#define UART_PROP_VALUE              0x02
```

```
#define UART_PROP_CARD_ID           0x02
#define UART_PROP_CARD_MEM          0x03


#endif
```

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