Biorobotics laboratory

MOUSE TREADMILL CONTROL

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Semester project description

Objectives and preliminary considerations The project consists of designing and manufacturing of a lightweight mechanism to improve roll authority at low angles of attack. After that the mechanism is tested and conclusions, with respect to the existing mechanism are drawn. A drone with morphing wings was designed and manufactured in the months before this project. The drone has wings with artificial overlapping feathers at the wing tip, which are used for roll control. The roll rate obtained at low angles of attack is too low to grant the desired high manoeuvrability as shown by [11] for a similar roll control strategy. In the first part of the project different methods are taken into account: ailerons, which are used in the aircraft industry and wing twisting, which is inspired by birds [**?**]. Those methods are simulated on XFLR5 (using VLM and 3D-Panels), after which wing twisting is chosen for implementation and testing. Wing twisting has many advantages compared to ailerons: higher roll moment [7] and higher lift to drag ratio [8]. On the other hand this technique is less used in industry and leads to an increased weight of the drone.

Mechanism design A weight of less than 20 $[g]$ is required as well as the interoperability with the pre-existing folding mechanism. Four different designs are taken into account (partial twisting, flexible components, cylindrical element and ball joints). In the end the design consisting of a lever actuated by a servo (ball joints) is chosen for implementation. This design is simple and can generate the required roll (roll control power over 2 $[\frac{\partial C_r}{\partial rad}]$ for $\alpha \leq 8°$) at low angles of attack, solving the initial problem. The folding angle ϕ is defined as the sum of the angles compared to normal sweep on the two sides.

Figure 0.1 – Roll coefficient as a function of the angle of attack for different values of twisting and folding angles. Schematics of folding configurations are added.

Testing and results The third part consists of testing the drone in the wind tunnel at different angles of attack (from 0° to 28° with steps of 4°), at three different twisting angles (0°, 5° and 10°), and with three possible wing shapes to take into account the effect of folding. Most of roll is generated with twisting at low angles of attack ($\alpha < 8°$), while at high angles folding has a greater impact (see figure 0.1).

Roll control and cost Finally a roll control algorithm for folding and twisting wing drones is presented. This is one of the most important accomplishments of this report since a study of different roll control methods on the same platform is, at the best of our knowledge, absent in literature. The cost of such a setup is discussed as well. This cost is very low, mainly due to the weight of the mechanism and to the energy consumption since the loss of aerodynamic performances during roll is small (C_d +38,98%), compared to the roll achieved ($C_r = 0.4519$ [ ]).

Contents

1 Introduction

In this section the main objectives and the state of the art for the project are presented as well as the overall structure of this report.

1.1 Motivation

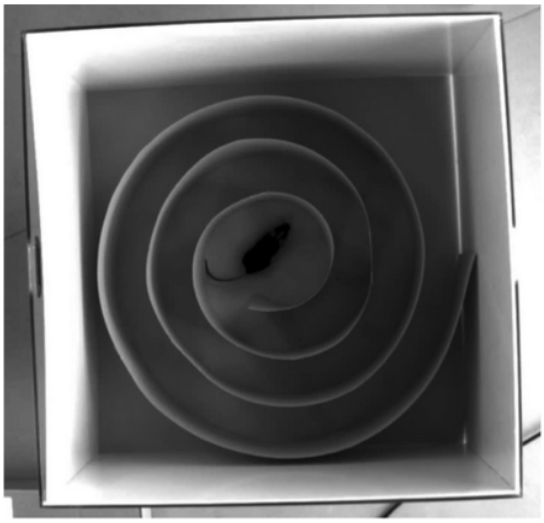

Figure 1.2 – The experimental setup used in [1].

The studies on mammal locomotion have driven more and more attention over the years, and especially experiments on mice, such as [1], have enhanced our understanding of the neuronal circuits that enable locomotion. The experimental setup in [1], on the other hand, is quite rudimental. As shown in 1.2 it only consist in a spiral maze made out cardboard. This setup comes with some advantages such as:

- Low price
- Simple to implement and use
- Untrained mice can be employed
- Free moving mouse

As well as some disadvantages:

- Impossibility to analyse the mouse gait
- The mouse movements can't be imposed

To asses these issues a new design is needed for conducting such experiments. The new platform needs to allow the control on the walking surface on which the mouse is standing in such a way that a specific speed profile can be imposed to the mouse. Moreover it must be possible to analyse the mouse gait using cameras.
For the new design inspiration is taken from some existing solutions on the market.

1.2 Requirements

First the mechanical requirements are discussed and stated. Table 1 summarizes them.

Description	**Value**	**Unit**
Dimensions of the moving surface	0.5	$[m^2]$
Course	∞	$[m]$
Maximum speed	3	$[\frac{m}{s}]$
Maximum acceleration	2	$[\frac{m}{s^2}]$
Position resolution	0.01	$[m]$
Speed resolution	0.02	$[\frac{m}{s}]$
Maximum weight	0.1	$[kg]$
Mounting time for 1 person	30	$[min]$
Maximum weight of the mouse	40	$[g]$
Length of common experiment (distance, time)	(20, 600)	($[m]$,$[s]$)

Table 1 – Summary of the requirements for the mouse treadmill platform.

The functional requirements are listed as well:

- **Closed-loop control** Once a 2D speed setpoint is chosen the speed of the surface needs to be measured and the motor control signal need to be adjusted automatically to reach the desired setpoint.
- **Speed routines** The user can define a speed routine, which needs to be executed by the treadmill. The speed routine consist in a list of 2D speed setpoints and the time interval during which the machine should execute them.
- **User interface** The user can use a Graphical user interface (GUI) on a computer to be able to use the mouse treadmill. This interface informs the user if the sensors are correctly connected and initialized, and it should give a live update of the treadmill speed.
- **Data logging** The user can save the data sent by the treadmill during the experiment for future uses.
- **Expandability of the system** The user can easily expand the system with other controllers to have other features, than the ones listed above.

1.3 Structure of the report

This report is structured as follows: an introduction is given in section 1, the system architecture and communication are explained in 2. Section 3, describes the design decisions and the components choices made .Section 5 describes the control strategy and shows some preliminary responses. Finally in section 6 the conclusion of the project is given. The code, code documentation as well as the data-sheets of the components are annexed.

2 System architecture

In this section the architecture of the system is explained and detailed. One first overview of the system is given in figure 2.3.

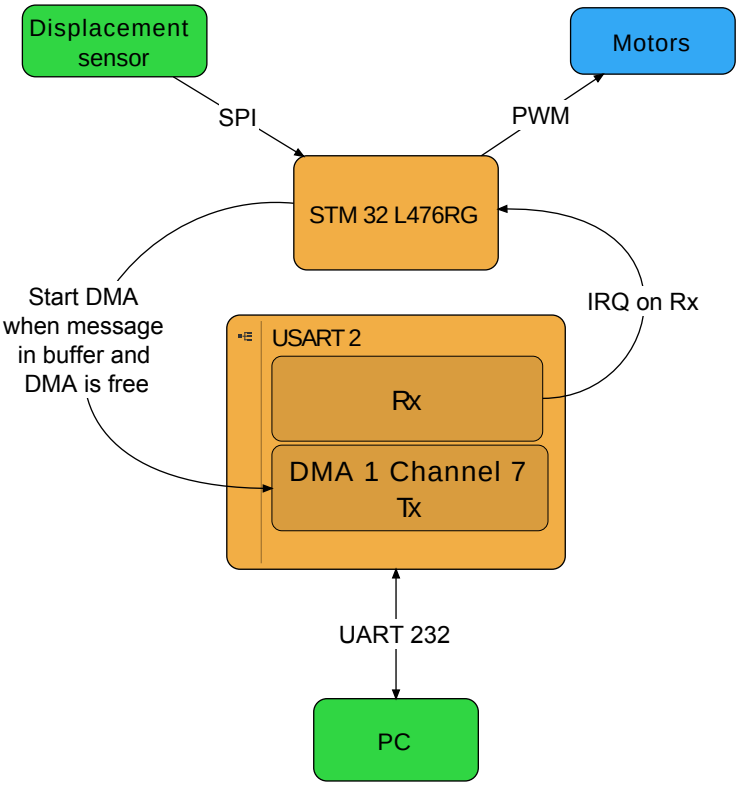

Figure 2.3 – Architecture for mouse treadmill project

The core of the system is the STM32L476RG, which can read from the sensors using the SPI interface and control the motors using the PWM. Moreover it can communicate with the computer and the GUI for data logging and to receive the inputs form the user. The communication with the computer uses the DMA capabilities of the microcontroller to free the processor from waiting for the communication to end before being able to take care of other tasks.

3 Design choices

In this section the design choices are explained and justified. First the choice of the board is analysed, then the sensors and finally the calculations for the motor dimensioning are shown.

3.1 Board

For the board choice different types are taken into account:

- **Single board computer**: In this category the raspberry pi and the odroid are taken into consideration. These boards offer powerful computers, which can be running operating systems such as Linux or Windows, which makes them interesting. Unfortunately they can't provide any accurate timing, which is needed for the motor control and PWM generation.

- **Evaluation boards**: In this category the STM32 nucleo boards as well as the arduino boards can be found. These boards allow proper timing of the signals and accurate PWM generation, but on the other hand a computer is needed for plotting and storing the data, which can't be done locally on the board due to memory restrictions and limited resources on the board.

Due to the constraints in the system the second category is consider for implementation, the STM32L476RG board is taken for the system. Table 2 summarizes the features of the board.

Description	Value	Unit
Architecture	ARM-Cortex 32-bit with FPU	–
Clock frequency	80	$[MHz]$
Flash memory	1	$[MB]$
RAM memory	128	$[KB]$
I2C interfaces	3	–
USART interfaces	5	–
SPI interfaces	3	–
DMA controller	14	–
Cost	20.58	$[CHF]$

Table 2 – STM32L476RG main features.

One of the most important feature of the board is the DMA, which enhances the performances of the CPU. The DMA is used for the UART communication with the computer. This technique frees the CPU from waiting for the UART communication to be finished, so that it can spend more time on other activities. This same solution can be, in principle, adopted for the SPI communication if a standard SPI is used. Unfortunately the timing diagrams for the sensors are not standard, thus some time needs to be "wasted" by the processor so that the sensors can keep up with the communication. Other interesting features are: the big flash memory, the good RAM memory and the low cost. One drawback is that dynamic memory allocation is not possible in such an small system to prevent stack overflow and problems during run time. This is why the size of the speed routine is limited to a given number of points. Finally the multiple serial interfaces allow the possibility to expand the system to a bigger one with more controllers involved.

3.2 Communication

For the communication with the computer the UART protocol is chosen. This choice is almost mandatory since most boards are provided with an UART to USB interface and a mini-USB connector. The STM32L476RG is no exception to this rule.

Figure 3.4 – MAVLink logo

Since the system needs to be expanded for future more complex experiments some thought is put in the choice of the messaging protocol to allow this key feature. The best solution found is MAVLink. "MAVLink is a very lightweight messaging protocol for communicating with drones"[2], one can say that the mouse treadmill is not meant to fly around, but this messaging protocol is flexible enough to be adapted to the mouse treadmill. More precisely a dialect is described in A, and summarized in table 3. Thanks to the description

file it is possible to generate libraries in different programming languages (C, Python, Java, ...) and if in the future a new message is required a additional definition can be added to the file and the libraries can be regenerated.

Despite the light weight MAVLink comes with some interesting features, such is high reliability (detects packets drops and corruption), high efficiency (only 14-bits of overhead), it can also allow up to 255 concurrent systems on the network.

Name	**Description**	**Sender**	**Receiver**
HEARTBEAT	Verifies communication	STM32	PC
SPEED_INFO	Measured speed	STM32	PC
SPEED_SETPOINT	Speed setpoint	PC	STM32
MODE_SELECTION	Changes mode	PC	STM32
MOTOR_SETPOINT	Up time of PWM duty cycle	STM32	PC
POINT_LOADED	Acknowledge for routine point loaded	STM32	PC
POINT	Information for one point of the routine	PC	STM32
ERROR	Error message	STM32	PC
RAW_SENSOR	Raw sensor values	STM32	PC

Table 3 – List and description of the MAVLink messages.

3.3 Sensor

For sensing the speed of the wheel a contactless solution is chosen. To achieve this goal a optical gaming mouse sensor is taken. Nevertheless the sensor need to come mounted on a PCB with a simple interface to reduce the time needed to design and manufacture the machine. Because of that the PMW3360 is chosen for the implentation. The working principle of the sensor is quite simple. The sensor is equipped with a LED to light a given area and a camera. The camera takes picture of the moving surface with a frequency of up to 12000 $[fps]$. Using the integrated DSP module some features are extracted form the images and, by knowing the displacement of the features, it is possible to determine how much the surface has moved on the X and Y direction. Some other useful information can be retrieved from the sensor such as :

- **Lift status** This bit in the motion register gives information about the status of the sensor and especially if the sensor detects a surface or not. This information is used to determine if the read value is valid or not.
- **Surface quality (SQUAL)** This register gives an information about how many features are detected on the surface. This value is used to verify the quality of the measurement, which is considered valid only if the number of detected feature is above a given threshold.
- **SROM ID** This value is read after the power up of the sensor to verify that the SROM

of the sensor is uploaded correctly using the SPI interface. If this value is not as expected it means that the sensor is not initialized correctly and thus might not work properly.

The performances of the sensor are summarized on table 4[1]. For more details refer to D.1.

Description	**Value**	**Unit**
High speed detection	6.3	$[\frac{m}{s}]$
High acceleration detection	490	$[\frac{m}{s^2}]$
Default resolution	5000	$[cpi]$
Resolution error of	1	$[\%]$
4 wires SPI interface	1	–
Cost	29.99	[$]

Table 4 – PMW3660 main features.

3.4 Motor

To properly dimension the motors these assumptions are taken:

1. $\eta = 1$ No losses in wheel-sphere coupling
2. No slip of the wheel on the sphere
3. Hollow sphere
4. Flat disk

The data given are:

- m_s mass of the sphere
- r_s radius of the sphere
- m_w mass of the wheel
- r_w radius of the wheel
- M_{max} maximum torque provided by the motor-gearbox
- ω_{max} maximum angular speed of the motor-gearbox
- J_m inertia of the rotor

It is therefore possible to estimate the maximum continuous acceleration and speed of the sphere.

[1] $[cpi]$ stands for counts per inch.

4 User manual for mouse treadmill software

The software is well documented in the docs folder, nevertheless some important things are pointed out in this report so that the user can more easily install and start using the mouse treadmill. The installation guide for the PC software, a user manual for the GUI, a explanation on how to write a speed routine as well as a guide on how to expand the system with new messages is provided. Note that all the provided commands and instructions are tested for MAC, mavlink is available also for LINUX and WINDOWS, the user can adapt these command to be able to install and successfully use the software on his machine.

4.1 Installation of the PC software

First python 3 needs to be installed, for that see [3]. GIT needs to be install as well. Some other python packages needs to be installed, they can be obtained using PiP. The required ones are:

- pyserial
- numpy
- json
- os
- appjar
- sys
- tqdm
- matplotlib

Make sure that pymavlink is not install. This is important since the dialect used is a standard one, but it is custom. Do not install pymavlink using PiP.

To install the software the sequent steps have to be accomplished:

1. Clone the git repository of the project using

```
$ git clone https://github.com/DidierNegretto/3DMouseTreadmill.git
```

2. Move inside the repository

```
$ cd 3DMouseTreadmill/
```

3. Make sure no previous version of pymavlink is installed

```
$ pip uninstall pymavlink
```

4. Remove the mavlink directory

```
$ rm -r -f mavlink/
```

5. Clone the mavlink repository

```
$ git clone https://github.com/mavlink/mavlink.git
```

6. Update the submodule
```
$ git submodule update --init --recursive
```
7. Copy mouse.xml file and the mouse.py files into mavlink/pymavlink/dialects/v20
8. Change directory to mavlink/
```
$ cd mavlink
```
9. Export the path to the repository so that python will find all the code it needs to run
```
$ export PYTHONPATH=‘path_to_repository/3DMouseTreadmill/‘
```
10. Change directory to pymavlink
```
$ cd pymavlink
```
11. Setup everything using the setup.py provided
```
$ python3 setup.py install --user
```

4.2 How to use the GUI

4.3 How to write a routine

An example routine is provided in MouseTreadmillPC/python/routine.py. The routine is a python dictionary containing a list of durations, setpoint_x and setpoint_y. The two setpoints define the desired speed along x and y, while the duration is the time span during which the two setpoints are applied. One should notice that the system time is discrete and increased every millisecond, moreover one should take into account the settling time for the control and the maximum acceleration provided by the motors to do a proper discretization of the desired speed profile.
A duration of 0 means that the end of the routine is reached and the routine is started again at the first point defined. A maximum of 255 points can be defined, if more points are needed the id of the point have to be changed from type uint8_t to uint16_t to allow for IDs above 255. A memory limitation is still present, but for a number of points above 1’000.

4.4 How to extend the system

5 Control

In this section the main aspect of the control are discussed as well as some results. For the closed-loop control a simple PI controller is used (see 5.2). This can be improved in future works to allow for faster and better performance control. The implementation of the controller is done in CodeSTM32/mouseDrive.c in the function void mouseDriver_control_idle(void).

5.1 Inputs/Outputs

In this section the signal definitions are described. The control diagram is shown in figure 5.5. The signals are defined as follow:

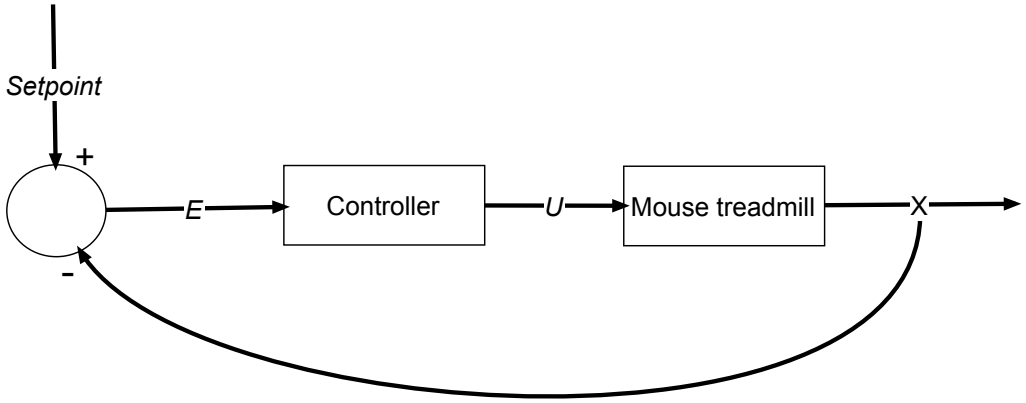

Figure 5.5 – Control diagram

- $X = \begin{bmatrix} v_x \\ v_y \end{bmatrix}$: is the measured v_x and v_y speeds. This measure is done using the optical sensors, which means that the raw values are as defined in the datasheet of the sensors (see D.1). In short words the sensor runs a navigation program, which does the correlation between two images as fast as possible and finds out of how many counts the two images are displaced in the x and y direction of the sensor, those values are then integrated up to when the motion burst is performed. Since two sensors are used, only one axis of each sensor is meaningful for the control (since the other one is always fixed). The information that can be retrieved from one sensor is the number of counts along one axis that the ball has done since the last read. This can then be translated in to meters by knowing the resolution of the sensor (which is given in counts per inch) and the relation between inches and meters. Furthermore the speed can be computed by keeping track of when the last measure is taken, and the actual time, thus knowing the dt between two measures.
- $E = \begin{bmatrix} e_x \\ e_y \end{bmatrix}$: is the error id est the difference between the setpoint and the measured speed
- $U = \begin{bmatrix} u_x \\ u_y \end{bmatrix}$: is the control signal, which is the up time of the duty cycle of the PWM signal controlling the X and Y directions. The parameters of this signal can be modified by using the PRESCALER_PWM and COUNTER_PERIOD_PWM. This two values allow for defining the frequency and number of possible values of the PWM signal.

5.2 Controller

In this section the internal structure of the controller is described. The inputs in the controller are the errors on the speed setpoint in X and Y. The control signal is defined as in equation 1.

$$U = \begin{bmatrix} u_x \\ u_y \end{bmatrix} = K * \begin{bmatrix} e_x \\ e_y \end{bmatrix} + I * \begin{bmatrix} i_x \\ i_y \end{bmatrix} \tag{1}$$

Where K and I are constant scalar values and $\begin{bmatrix} i_x \\ i_y \end{bmatrix}$ is a vector containing the sum of the errors over all the past measures where the motor signal U is not the maximum allowed. This condition is taken to avoid wind up and overshoot in the controller.
Moreover the control is done only if the measures taken are valid. Which means that the SQUAL measure is bigger than SQUAL_THRESH, the sensors are not lifted, and the PRODUCT_ID is equal 66. If those conditions are met it means that the surface quality is good, the sensor "sees" correctly the surface and the communication is done correctly. If the measures are not valid for more than MAX_MISSING_MEASURES the motors are stopped and the mode goes to STOP mode to avoid damage to the machine.

5.3 Results

In this section the results of the control are shown as well as the achieved performances in terms measures 5.3.1 and control 5.3.2.

5.3.1 Measure test

In this section a simple experiment is described and the results are shown. The experiment consist in letting the ball spin in at constant speed in one direction and measure the speed using the sensors. By doing this it is possible to analyze the noise present in the sensor and characterize it.

5.3.2 Control test

6 Conclusion

References

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A MAVLink dialect description file

```
<?xml version="1.0"?>
<mavlink>
    <version>3</version>
    <dialect>2</dialect>
    <enums>
        <enum name="MOUSE_MODE">
            <description>This enum defines the mode to be used</description>
            <entry value="0" name="MOUSE_MODE_STOP">
                <description>All motion of mouse treadmill is stopped</
                    description>
            </entry>
            <entry value="1" name="MOUSE_MODE_SPEED">
                <description>Constanst speed is applied. Speed selected by PC
                    message SPEED_SETPOINT.</description>
            </entry>
            <entry value="2" name="MOUSE_MODE_AUTO_LOAD">
                <description>Predefined speed profile is loaded</description>
            </entry>
            <entry value="3" name="MOUSE_MODE_AUTO_RUN">
                <description>Predefined speed profile is applied</description>
            </entry>
        </enum>
        <enum name="MOUSE_ERROR">
            <description>This enum defines the possible errors</description>
```

```
23          <entry value="0" name="MOTOR_ERROR">
24              <description>The motor driver flaged an error, this might be
                    due to many sources, see datasheet of motor driver.</
                    description>
25          </entry>
26          <entry value="1" name="MOTOR_LOW_SPEED">
27              <description>The speed setpoint chosen is too low to be
                    achieved.</description>
28          </entry>
29          <entry value="2" name="MOTOR_HIGH_SPEED">
30              <description>The speed setpoint chosen is too high to be
                    achieved.</description>
31          </entry>
32          <entry value="3" name="MOUSE_ROUTINE_TOO_LONG">
33              <description>More than 255 points have been defined in the
                    mouse routine.</description>
34          </entry>
35          <entry value="4" name="SENSOR_NOT_RESPONDING">
36              <description>One sensor is not responding correctly.</
                    description>
37          </entry>
38      </enum>
39          <enum name="SENSOR_ID">
40          <description>This enum defines the sensors directions</description>
41          <entry value="0" name="SENSOR_X">
42              <description>Sensor ID for X direction.</description>
43          </entry>
44          <entry value="1" name="SENSOR_Y">
45              <description>Sensor ID for Y direction.</description>
46          </entry>
47      </enum>
48  </enums>
49  <messages>
50      <message id="0" name="HEARTBEAT">
51          <description>The heartbeat message shows that a system or component
                is present and responding. Sender = STM32 Receiver = PC
52          </description>
53          <field type="uint8_t" name="mode" enum="MOUSE_MODE">Actual
                operating mode</field>
54          <field type="uint32_t" name="time">Time from boot of system</field>
55      </message>
56      <message id="1" name="SPEED_INFO">
57          <description>The message giving the actual speed of the motor.
                Sender = STM32 Receiver = PC
58          </description>
59          <field type="uint32_t" name="time_x">Time from boot of system for
                speed_x measure</field>
60          <field type="uint32_t" name="time_y">Time from boot of system for
```

```
            speed_y measure</field>
61          <field type="float" name="speed_x">Speed in x direction</field>
62          <field type="float" name="speed_y">Speed in y direction</field>
63          <field type="uint8_t" name="valid">0 if data are not valid, 1 if
               data are valid </field>
64      </message>
65       <message id="2" name="SPEED_SETPOINT">
66          <description>The message is sent to send and validate the setpoint
               sent from computer. Sender = PC/STM32 Receiver = STM32/PC
67          </description>
68          <field type="float" name="setpoint_x">Speed setpoint in x direction
               </field>
69          <field type="float" name="setpoint_y">Speed setpoint in y direction
               </field>
70      </message>
71      <message id="3" name="MODE_SELECTION">
72          <description>This message is used to select the mode of the STM32
               Sender = PC Receiver = STM32
73          </description>
74          <field type="uint8_t" name="mode" enum="MOUSE_MODE">Actual
               operating mode</field>
75      </message>
76      <message id="4" name="MOTOR_SETPOINT">
77          <description>This message defines the raw motor input values. This
               values defines the Duty_Cycle up time for PWM signals. Sender =
               STM32 Receiver = PC
78          </description>
79          <field type="uint32_t" name="time">Time from boot of system</field>
80          <field type="float" name="motor_x">Speed setpoint in x direction</
               field>
81          <field type="float" name="motor_y">Speed setpoint in y direction</
               field>
82      </message>
83      <message id="5" name="POINT_LOADED">
84          <description>This message is used to acknowledge the receipt of one
                point for auto mode Sender = STM32 Receiver = PC
85          </description>
86          <field type="uint16_t" name="point_id">Last ID of point loaded</
               field>
87      </message>
88      <message id="6" name="POINT">
89          <description>This message is used to send one point for auto mode.
               Sender = PC Receiver = STM32
90          </description>
91          <field type="uint32_t" name="duration">Time during which the
               setpoint need to be kept</field>
92          <field type="uint16_t" name="point_id">point ID</field>
93          <field type="float" name="setpoint_x">Speed setpoint in x direction
```

```
            </field>
94          <field type="float" name="setpoint_y">Speed setpoint in y direction
            </field>
95      </message>
96      <message id="7" name="ERROR">
97          <description>This message is used to send errors Sender = STM32
            Receiver = PC
98          </description>
99          <field type="uint32_t" name="time">Time from boot of system</field>
100         <field type="uint8_t" name="error" enum="MOUSE_ERROR">error ID</
            field>
101     </message>
102     <message id="8" name="RAW_SENSOR">
103             <description>This message contains raw sensor values Sender =
                STM32 Receiver = PC
104             </description>
105             <field type="uint32_t" name="time">Time from boot of system</
                field>
106             <field type="uint8_t" name="sensor_id">0 for X, 1 for Y.</field
                >
107             <field type="int16_t" name="delta_x">Displacement along sensor'
                s x in counts per inch.</field>
108                 <field type="int16_t" name="delta_y">Displacement along
                    sensor's y in counts per inch.</field>
109                 <field type="uint8_t" name="squal">Quality of the
                    surface. For white paper is around 30.</field>
110                 <field type="uint8_t" name="lift">1 if the sensor is
                    lifted (not measuring). 0 otherwise</field>
111             <field type="uint8_t" name="product_id">0x42 if the serial
                communication with the sensor works correctly.</field>
112         <field type="uint8_t" name="srom_id">0x00 if initialisation is not
            done. Other value if done correctly.</field>
113         </message>
114 </messages>
115 </mavlink>
```

B Code for STM32 NUCLEO 64 board

B.1 Main

```
1  /* USER CODE BEGIN Header */
2  /**
3   ******************************************************************************
4   * @file           : main.h
5   * @brief          : Header for main.c file.
6   *                   This file contains the common defines of the application.
7   ******************************************************************************
8   * @attention
9   *
10  * <h2><center>&copy; Copyright (c) 2019 STMicroelectronics.
```

```
11   * All rights reserved.</center></h2>
12   *
13   * This software component is licensed by ST under BSD 3-Clause license,
14   * the "License"; You may not use this file except in compliance with the
15   * License. You may obtain a copy of the License at:
16   *                        opensource.org/licenses/BSD-3-Clause
17   *
18   ******************************************************************************
19   */
20 /* USER CODE END Header */
21
22 /* Define to prevent recursive inclusion -------------------------------------*/
23 #ifndef __MAIN_H
24 #define __MAIN_H
25
26 #ifdef __cplusplus
27 extern "C" {
28 #endif
29
30 /* Includes
       ------------------------------------------------------------------
       */
31 #include "stm32l4xx_hal.h"
32
33 /* Private includes
       ----------------------------------------------------------*/
34 /* USER CODE BEGIN Includes */
35 #include "mouseDriver.h"
36 #include "mavlink.h"
37 /* USER CODE END Includes */
38
39 /* Exported types
       ------------------------------------------------------------
       */
40 /* USER CODE BEGIN ET */
41 /**
42  * A structure to represent one sensor
43  */
44 typedef struct SENSOR{
45   /*@{*/
46   GPIO_TypeDef * cs_port; /**< the chip select port for the sensor */
47   uint8_t cs_pin; /**< the chip select pin for the sensor */
48   GPIO_TypeDef * pw_port; /**< the power port for the sensor */
49   uint8_t pw_pin; /**< the power pin for the sensor */
50   uint8_t status; /**< the sensor status. This is the SROM_ID after the upload of the
51   firmware. This value should not be 0 otherwise the upload of the SROM is failed. */
52   /*@}*/
53 } sensor_t;
54 /* USER CODE END ET */
55
56 /* Exported constants
       --------------------------------------------------------*/
57 /* USER CODE BEGIN EC */
58
59 /* USER CODE END EC */
60
61 /* Exported macro
       ------------------------------------------------------------
```

```
    */
/* USER CODE BEGIN EM */

/* USER CODE END EM */

void HAL_TIM_MspPostInit(TIM_HandleTypeDef *htim);

/* Exported functions prototypes
    ---------------------------------------------------------*/
void Error_Handler(void);

/* USER CODE BEGIN EFP */
/*!
\fn main_transmit_buffer(uint8_t *outBuffer, uint16_t msg_size)
\param outBuffer buffer to be transmitted over UART
\param msg_size size of the buffer
\brief This function sends the buffer using UART.

\attention The transmission is done using a DMA. Before sending a message
it is important to check that the previous one has been sent. This can be done
using \ref main_get_huart_tx_state .
*/
void main_transmit_buffer(uint8_t *outBuffer, uint16_t msg_size);
/*!
\fn main_stop_motors()
\brief This function stops the motors

The PWM duty cycle is set to 0% for the two motors
\note The PWM duty cycle is represented by a uint type.
The min/max of that value are defined by how the timer is
setup in the microcontroller. The max value can be limited
by limitations in the motors or in the mechanical build of the
machine
*/
void main_stop_motors(void);
/*!
\fn main_set_motors_speed(mavlink_motor_setpoint_t motor )
\param motor PWM duty cycle for the two motors
\brief This sets the motor duty cycle to one specified in the
motor parameter

The PWM duty cycle is set to 0% for the two motors
\note The PWM duty cycle is represented by a uint type.
The min/max of that value are defined by how the timer is
setup in the microcontroller. The max value can be limited
by limitations in the motors or in the mechanical build of the
machine
*/
void main_set_motors_speed(mavlink_motor_setpoint_t motor );
/*!
\fn main_get_huart_tx_state()
\return the HAL_state of UART transmit
\brief Function used to verify if the channel for writing the buffer is available or busy.
*/
int main_get_huart_tx_state(void);
/*!
\fn main_write_sensor(sensor_t sensor, uint8_t adress, uint8_t data)
\param sensor sensor to which we want to write
```

```
118 \param adress adress of the register to be modified
119 \param data data to written in the given sensor and register
120 \brief This function writes a byte in a given register of a given sensor.
121
122 \note The writing is done by generating proper signals in the pins. For more details
123 on the sensor register and timing diagrams see resources/sensorDatasheet.pdf
124 */
125 void main_write_sensor (sensor_t sensor, uint8_t adress, uint8_t data);
126 /*!
127 \fn main_read_sensor(sensor_t sensor, uint8_t adress)
128 \param sensor sensor from which we want to read
129 \param adress adress of the register to be read
130 \return the value in the given register and sensor
131 \brief This function reads a byte in a given register of a given sensor.
132
133 \note The reading is done by generating proper signals in the pins. For more details
134 on the sensor register and timing diagrams see resources/sensorDatasheet.pdf
135 */
136 uint8_t main_read_sensor (sensor_t sensor, uint8_t adress );
137 /*!
138 \deprecated
139 \fn main_transmit_spi(uint8_t data)
140 \param data data to be transmitted on the spi2
141 \brief This function transmit one byte on the spi2
142 */
143 void main_transmit_spi(uint8_t data);
144 /*!
145 \fn main_wait_160us()
146 \brief function used to wait around 160 [us].
147 \note the wait is achieved by toggling the green LED.
148 */
149 void main_wait_160us(void);
150 /*!
151 \fn main_wait_20us()
152 \brief function used to wait around 20 [us].
153 \note the wait is achieved by toggling the green LED.
154 */
155 void main_wait_20us(void);
156 /*!
157 \fn main_write_sensor_burst(uint8_t data)
158 \param data by to be written during the burst
159 \brief function used during a write burst
160 \attention Use this function only during a burst write.
161 */
162 void main_write_sensor_burst(uint8_t data);
163 /*!
164 \fn main_read_sensor_motion_burst(uint8_t *data )
165 \param data pointer on a table of uint8_t used to store the
166 data read from a motion read burst
167 \brief function used to do a burst read for the motion read burst
168 as specified in resources/resources/sensorDatasheet.pdf
169
170 \attention Use this function only during a motion read burst.
171 \note The data received from the motion read burst are raw datas and have
172 to be treated to obtain meaningfull values and verify that the sensor is not
173 lifted and the surface quality is good enough to consider the measure as valid.
174 */
175 void main_read_sensor_motion_burst(uint8_t *data );
```

```
176 /*
177  * PW_0 is power pin for sensor X (PB_0)
178  * PW_1 is the power pin for sensor Y (PA_4)
179  * CS_0 is the chip select for sensor X (PC_0)
180  * CS_1 is the chip select for sensor Y (PC_1)
181  */
182
183 /* USER CODE END EFP */
184
185 /* Private defines
        -----------------------------------------------------------*/
186 #define DT_HEART 200
187 #define PRESCALER_HEART 1000
188 #define CLOCK_FREQ 80000000
189 #define COUNTER_PERIOD_HEART ((CLOCK_FREQ/(PRESCALER_HEART))*0.001*DT_HEART)
190 #define PRESCALER_PWM 9
191 #define COUNTER_PERIOD_PWM 255
192 #define PULSE_PWM 10
193 #define B1_Pin GPIO_PIN_13
194 #define B1_GPIO_Port GPIOC
195 #define CS_0_Pin GPIO_PIN_0
196 #define CS_0_GPIO_Port GPIOC
197 #define CS_1_Pin GPIO_PIN_1
198 #define CS_1_GPIO_Port GPIOC
199 #define USART_TX_Pin GPIO_PIN_2
200 #define USART_TX_GPIO_Port GPIOA
201 #define USART_RX_Pin GPIO_PIN_3
202 #define USART_RX_GPIO_Port GPIOA
203 #define PW_1_Pin GPIO_PIN_4
204 #define PW_1_GPIO_Port GPIOA
205 #define LD2_Pin GPIO_PIN_5
206 #define LD2_GPIO_Port GPIOA
207 #define PW_0_Pin GPIO_PIN_0
208 #define PW_0_GPIO_Port GPIOB
209 #define TMS_Pin GPIO_PIN_13
210 #define TMS_GPIO_Port GPIOA
211 #define TCK_Pin GPIO_PIN_14
212 #define TCK_GPIO_Port GPIOA
213 #define SWO_Pin GPIO_PIN_3
214 #define SWO_GPIO_Port GPIOB
215 /* USER CODE BEGIN Private defines */
216
217 /* USER CODE END Private defines */
218
219 #ifdef __cplusplus
220 }
221 #endif
222
223 #endif /* __MAIN_H */
224
225 /************************ (C) COPYRIGHT STMicroelectronics *****END OF FILE****/
```

```
1 /* USER CODE BEGIN Header */
2 /**
3  ******************************************************************************
4  * @file           : main.c
5  * @brief          : Main program body
```

```
6  ******************************************************************************
7  * @attention
8  *
9  * <h2><center>&copy; Copyright (c) 2019 STMicroelectronics.
10 * All rights reserved.</center></h2>
11 *
12 * This software component is licensed by ST under BSD 3-Clause license,
13 * the "License"; You may not use this file except in compliance with the
14 * License. You may obtain a copy of the License at:
15 *                        opensource.org/licenses/BSD-3-Clause
16 *
17 ******************************************************************************
18 */
19 /* USER CODE END Header */
20
21 /* Includes
       ------------------------------------------------------------------
       */
22 #include "main.h"
23
24 /* Private includes
       ----------------------------------------------------------*/
25 /* USER CODE BEGIN Includes */
26
27 /* USER CODE END Includes */
28
29 /* Private typedef
       -----------------------------------------------------------
       */
30 /* USER CODE BEGIN PTD */
31
32 /* USER CODE END PTD */
33
34 /* Private define
       ------------------------------------------------------------
       */
35 /* USER CODE BEGIN PD */
36 /*!
37 \def TIMEOUT
38 \brief Constant used as timeout in ms.
39 \deprecated Using DMA makes the transfer free from the processor, thus the
40 TIMEOUT never appens.
41 */
42 #define TIMEOUT 2
43 /* USER CODE END PD */
44
45 /* Private macro
       -------------------------------------------------------------
       */
46 /* USER CODE BEGIN PM */
47
48 /* USER CODE END PM */
49
50 /* Private variables
       ---------------------------------------------------------*/
51 SPI_HandleTypeDef hspi2;
52
53 TIM_HandleTypeDef htim1;
```

```
54 TIM_HandleTypeDef htim7;
55
56 UART_HandleTypeDef huart2;
57 DMA_HandleTypeDef hdma_usart2_tx;
58
59 /* USER CODE BEGIN PV */
60 /*!
61 \var inByte
62 \brief Buffer for one byte.
63
64 This is the buffer used to copy data form UART. When one byte is available it is stored in
65 inByte and then parsed using the mavlink_parse_char function. Everytime one
66 byte arrives the inByte variable is overwritten.
67 */
68 static uint8_t inByte = 0;
69 /* USER CODE END PV */
70
71 /* Private function prototypes
       -----------------------------------------------*/
72 void SystemClock_Config(void);
73 static void MX_GPIO_Init(void);
74 static void MX_USART2_UART_Init(void);
75 static void MX_TIM7_Init(void);
76 static void MX_TIM1_Init(void);
77 static void MX_DMA_Init(void);
78 static void MX_SPI2_Init(void);
79 /* USER CODE BEGIN PFP */
80 void main_wait_160us(void){
81   int i = 0;
82   i = 0;
83   while(i<900){
84     HAL_GPIO_TogglePin(GPIOA, GPIO_PIN_5);
85     i++;
86   }
87 }
88 void main_wait_20us(void){
89   int i = 0;
90   i = 0;
91   while(i<185){
92     HAL_GPIO_TogglePin(GPIOA, GPIO_PIN_5);
93     i++;
94   }
95 }
96 /*!
97 \fn main_wait_1us(void)
98 \brief Function for waiting approximately one microsecond
99 */
100 void main_wait_1us(void){
101   int i = 0;
102   i = 0;
103   while(i<25){
104     HAL_GPIO_TogglePin(GPIOA, GPIO_PIN_5);
105     i++;
106   }
107 }
108 int main_get_huart_tx_state(void){
109   return (HAL_DMA_GetState(&hdma_usart2_tx));
110 }
```

```
111 void main_transmit_buffer(uint8_t *outBuffer, uint16_t msg_size){
112   HAL_UART_Transmit_DMA(&huart2, outBuffer,msg_size);
113 }
114 void main_stop_motors(void)
115 {
116   HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_1);
117   HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_2);
118 }
119 void main_set_motors_speed(mavlink_motor_setpoint_t motor )
120 {
121
122   htim1.Instance->CCR1 = motor.motor_x;
123   htim1.Instance->CCR2 = motor.motor_y;
124
125   if (motor.motor_x == 0)
126     HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_1);
127   else
128     HAL_TIM_PWM_Start(&htim1, TIM_CHANNEL_1);
129
130   if (motor.motor_y == 0)
131     HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_2);
132   else
133     HAL_TIM_PWM_Start(&htim1, TIM_CHANNEL_2);
134
135 }
136 uint8_t main_read_sensor (const sensor_t sensor, uint8_t adress ){
137   uint8_t value = 0;
138   uint8_t adress_read = adress & 0x7F;
139
140   HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_RESET);
141   HAL_SPI_Transmit(&hspi2, &adress_read, 1, 100);
142   main_wait_160us();
143   HAL_SPI_Receive(&hspi2, &value, 1, 100);
144   main_wait_1us();
145   HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_SET);
146   main_wait_20us();
147   return (value);
148 }
149
150 void main_write_sensor (const sensor_t sensor, uint8_t adress, uint8_t data){
151   uint8_t value = data;
152   uint8_t adress_write = adress | 0x80;
153   uint8_t pack[2];
154   pack[0] = adress_write;
155   pack[1] = value;
156
157   HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_RESET);
158   HAL_SPI_Transmit(&hspi2, pack, 2, 10);
159   main_wait_20us();
160   HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_SET);
161   main_wait_160us();
162   main_wait_20us();
163 }
164 void main_write_sensor_burst(uint8_t data){
165   HAL_SPI_Transmit(&hspi2, &data, 1, 10);
166   main_wait_20us();
167 }
168 void main_read_sensor_motion_burst(uint8_t *data ){
```

```
169   HAL_SPI_Receive(&hspi2,data,12,100);
170   main_wait_1us();
171 }
172 void main_transmit_spi(uint8_t data){
173   uint8_t data_out = data;
174   HAL_SPI_Transmit(&hspi2, &data_out, 1, 10);
175 }
176 /* USER CODE END PFP */
177
178 /* Private user code
        ---------------------------------------------------------*/
179 /* USER CODE BEGIN 0 */
180 /*!
181 \fn TM7_IRQHandler(void)
182 \brief Handle for IRQ of Timer 7
183
184 Timer 7 is used to generate a periodic interrupt to send status messages.
185 Those messages give information about the status of the system and are sent periodically.
186 The messages giving more important information such as the speed of the ball are sent
187 as fast as possible, which means faster than the status messages.
188 */
189 void TM7_IRQHandler(void){
190   HAL_TIM_IRQHandler(&htim7);
191 }
192
193 /*!
194 \fn HAL_UART_RxCpltCallback(UART_HandleTypeDef *huart)
195 \param huart pointer on huart structure (as defined in the HAL library)
196 \brief Function called everytime a new byte is available from UART communication
197
198 This function is used to receive data from UART communication. Everytime one byte is
199 received by the STM32 it is copied in the \ref inByte and then passed to the mavlink_parse_char
200 function. Once enough byte are taken and one message is received the function
201 \ref mouseDriver_readMsg is called and a subsiquent action is taken.
202 */
203 void HAL_UART_RxCpltCallback(UART_HandleTypeDef *huart){
204   HAL_NVIC_DisableIRQ(USART2_IRQn);
205   mavlink_message_t inmsg;
206   mavlink_status_t msgStatus;
207   if (huart->Instance == USART2){
208     /* Receive one byte in interrupt mode */
209     HAL_UART_Receive_IT(&huart2, &inByte, 1);
210     if(mavlink_parse_char(0, inByte, &inmsg, &msgStatus)){
211
212       mouseDriver_readMsg(inmsg);
213     }
214   }
215   HAL_NVIC_EnableIRQ(USART2_IRQn);
216 }
217
218 /*!
219 \fn HAL_TIM_PeriodElapsedCallback(TIM_HandleTypeDef *htim)
220 \param htim pointer on timer structure (as defined in the HAL library)
221 \brief Function called everytime a certain time is enlapsed
222
223 This function is used to send periodically some status information to the PC.
224 */
225 void HAL_TIM_PeriodElapsedCallback(TIM_HandleTypeDef *htim){
```

```
226     if (htim->Instance==TIM7){
227       mouseDriver_send_status_msg();
228     }
229 }
230 /* USER CODE END 0 */
231
232 /**
233   * @brief  The application entry point.
234   * @retval int
235   */
236 int main(void)
237 {
238   /* USER CODE BEGIN 1 */
239
240   /* USER CODE END 1 */
241
242
243   /* MCU Configuration
        --------------------------------------------------------*/
244
245   /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
246   HAL_Init();
247
248   /* USER CODE BEGIN Init */
249
250   /* USER CODE END Init */
251
252   /* Configure the system clock */
253   SystemClock_Config();
254
255   /* USER CODE BEGIN SysInit */
256
257   /* USER CODE END SysInit */
258
259   /* Initialize all configured peripherals */
260   MX_GPIO_Init();
261   MX_USART2_UART_Init();
262   MX_TIM7_Init();
263   MX_TIM1_Init();
264   MX_DMA_Init();
265   MX_SPI2_Init();
266   /* USER CODE BEGIN 2 */
267   HAL_InitTick(0);
268   HAL_NVIC_SetPriority(USART2_IRQn,1,0);
269   HAL_NVIC_EnableIRQ(USART2_IRQn);
270   HAL_NVIC_SetPriority(TIM7_IRQn,2,0);
271   HAL_NVIC_EnableIRQ(TIM7_IRQn);
272   HAL_GPIO_WritePin(GPIOC, CS_0_Pin|CS_1_Pin, GPIO_PIN_SET);
273
274   HAL_UART_Receive_IT(&huart2, &inByte, 1);
275   HAL_TIM_Base_Start_IT(&htim7);
276   HAL_GPIO_WritePin(GPIOC, GPIO_PIN_0, GPIO_PIN_SET);
277
278   mouseDriver_init();
279
280   /* USER CODE END 2 */
281
282   /* Infinite loop */
```

```
283   /* USER CODE BEGIN WHILE */
284
285   while (1)
286   {
287    mouseDriver_idle();
288     /* USER CODE END WHILE */
289
290   /* USER CODE BEGIN 3 */
291   }
292   /* USER CODE END 3 */
293 }
294
295 /**
296   * @brief System Clock Configuration
297   * @retval None
298   */
299 void SystemClock_Config(void)
300 {
301   RCC_OscInitTypeDef RCC_OscInitStruct = {0};
302   RCC_ClkInitTypeDef RCC_ClkInitStruct = {0};
303   RCC_PeriphCLKInitTypeDef PeriphClkInit = {0};
304
305   /** Initializes the CPU, AHB and APB busses clocks
306   */
307   RCC_OscInitStruct.OscillatorType = RCC_OSCILLATORTYPE_HSI;
308   RCC_OscInitStruct.HSIState = RCC_HSI_ON;
309   RCC_OscInitStruct.HSICalibrationValue = RCC_HSICALIBRATION_DEFAULT;
310   RCC_OscInitStruct.PLL.PLLState = RCC_PLL_ON;
311   RCC_OscInitStruct.PLL.PLLSource = RCC_PLLSOURCE_HSI;
312   RCC_OscInitStruct.PLL.PLLM = 1;
313   RCC_OscInitStruct.PLL.PLLN = 10;
314   RCC_OscInitStruct.PLL.PLLP = RCC_PLLP_DIV7;
315   RCC_OscInitStruct.PLL.PLLQ = RCC_PLLQ_DIV2;
316   RCC_OscInitStruct.PLL.PLLR = RCC_PLLR_DIV2;
317   if (HAL_RCC_OscConfig(&RCC_OscInitStruct) != HAL_OK)
318   {
319     Error_Handler();
320   }
321   /** Initializes the CPU, AHB and APB busses clocks
322   */
323   RCC_ClkInitStruct.ClockType = RCC_CLOCKTYPE_HCLK|RCC_CLOCKTYPE_SYSCLK
324                                 |RCC_CLOCKTYPE_PCLK1|RCC_CLOCKTYPE_PCLK2;
325   RCC_ClkInitStruct.SYSCLKSource = RCC_SYSCLKSOURCE_PLLCLK;
326   RCC_ClkInitStruct.AHBCLKDivider = RCC_SYSCLK_DIV1;
327   RCC_ClkInitStruct.APB1CLKDivider = RCC_HCLK_DIV1;
328   RCC_ClkInitStruct.APB2CLKDivider = RCC_HCLK_DIV1;
329
330   if (HAL_RCC_ClockConfig(&RCC_ClkInitStruct, FLASH_LATENCY_4) != HAL_OK)
331   {
332     Error_Handler();
333   }
334   PeriphClkInit.PeriphClockSelection = RCC_PERIPHCLK_USART2;
335   PeriphClkInit.Usart2ClockSelection = RCC_USART2CLKSOURCE_PCLK1;
336   if (HAL_RCCEx_PeriphCLKConfig(&PeriphClkInit) != HAL_OK)
337   {
338     Error_Handler();
339   }
340   /** Configure the main internal regulator output voltage
```

```
341   */
342   if (HAL_PWREx_ControlVoltageScaling(PWR_REGULATOR_VOLTAGE_SCALE1) != HAL_OK)
343   {
344     Error_Handler();
345   }
346 }
347
348 /**
349   * @brief SPI2 Initialization Function
350   * @param None
351   * @retval None
352   */
353 static void MX_SPI2_Init(void)
354 {
355
356   /* USER CODE BEGIN SPI2_Init 0 */
357   HAL_GPIO_DeInit(GPIOC, GPIO_PIN_3);
358
359   /*GPIO_InitTypeDef pin;
360   pin.Pin = GPIO_PIN_3;
361   pin.Mode = GPIO_MODE_OUTPUT_PP;
362   pin.Pull = GPIO_PULLDOWN;
363   pin.Speed = GPIO_SPEED_MEDIUM;
364   HAL_GPIO_Init(GPIOC, &pin);
365   HAL_GPIO_WritePin(GPIOC,GPIO_PIN_3, GPIO_PIN_RESET);*/
366
367   __HAL_RCC_SPI2_CLK_ENABLE();
368   __SPI2_CLK_ENABLE();
369   /* USER CODE END SPI2_Init 0 */
370
371   /* USER CODE BEGIN SPI2_Init 1 */
372
373   /* USER CODE END SPI2_Init 1 */
374   /* SPI2 parameter configuration*/
375   hspi2.Instance = SPI2;
376   hspi2.Init.Mode = SPI_MODE_MASTER;
377   hspi2.Init.Direction = SPI_DIRECTION_2LINES;
378   hspi2.Init.DataSize = SPI_DATASIZE_8BIT;
379   hspi2.Init.CLKPolarity = SPI_POLARITY_HIGH;
380   hspi2.Init.CLKPhase = SPI_PHASE_2EDGE;
381   hspi2.Init.NSS = SPI_NSS_SOFT;
382   hspi2.Init.BaudRatePrescaler = SPI_BAUDRATEPRESCALER_256;
383   hspi2.Init.FirstBit = SPI_FIRSTBIT_MSB;
384   hspi2.Init.TIMode = SPI_TIMODE_DISABLE;
385   hspi2.Init.CRCCalculation = SPI_CRCCALCULATION_DISABLE;
386   hspi2.Init.CRCPolynomial = 7;
387   hspi2.Init.CRCLength = SPI_CRC_LENGTH_DATASIZE;
388   hspi2.Init.NSSPMode = SPI_NSS_PULSE_DISABLE;
389   if (HAL_SPI_Init(&hspi2) != HAL_OK)
390   {
391     Error_Handler();
392   }
393   /* USER CODE BEGIN SPI2_Init 2 */
394
395
396   /* USER CODE END SPI2_Init 2 */
397
398 }
```

```
399
400 /**
401   * @brief TIM1 Initialization Function
402   * @param None
403   * @retval None
404   */
405 static void MX_TIM1_Init(void)
406 {
407
408   /* USER CODE BEGIN TIM1_Init 0 */
409
410   /* USER CODE END TIM1_Init 0 */
411
412   TIM_ClockConfigTypeDef sClockSourceConfig = {0};
413   TIM_MasterConfigTypeDef sMasterConfig = {0};
414   TIM_OC_InitTypeDef sConfigOC = {0};
415   TIM_BreakDeadTimeConfigTypeDef sBreakDeadTimeConfig = {0};
416
417   /* USER CODE BEGIN TIM1_Init 1 */
418
419   /* USER CODE END TIM1_Init 1 */
420   htim1.Instance = TIM1;
421   htim1.Init.Prescaler = PRESCALER_PWM;
422   htim1.Init.CounterMode = TIM_COUNTERMODE_UP;
423   htim1.Init.Period = COUNTER_PERIOD_PWM;
424   htim1.Init.ClockDivision = TIM_CLOCKDIVISION_DIV1;
425   htim1.Init.RepetitionCounter = 0;
426   htim1.Init.AutoReloadPreload = TIM_AUTORELOAD_PRELOAD_DISABLE;
427   if (HAL_TIM_Base_Init(&htim1) != HAL_OK)
428   {
429     Error_Handler();
430   }
431   sClockSourceConfig.ClockSource = TIM_CLOCKSOURCE_INTERNAL;
432   if (HAL_TIM_ConfigClockSource(&htim1, &sClockSourceConfig) != HAL_OK)
433   {
434     Error_Handler();
435   }
436   if (HAL_TIM_PWM_Init(&htim1) != HAL_OK)
437   {
438     Error_Handler();
439   }
440   sMasterConfig.MasterOutputTrigger = TIM_TRGO_RESET;
441   sMasterConfig.MasterOutputTrigger2 = TIM_TRGO2_RESET;
442   sMasterConfig.MasterSlaveMode = TIM_MASTERSLAVEMODE_DISABLE;
443   if (HAL_TIMEx_MasterConfigSynchronization(&htim1, &sMasterConfig) != HAL_OK)
444   {
445     Error_Handler();
446   }
447   sConfigOC.OCMode = TIM_OCMODE_PWM1;
448   sConfigOC.Pulse = PULSE_PWM;
449   sConfigOC.OCPolarity = TIM_OCPOLARITY_HIGH;
450   sConfigOC.OCNPolarity = TIM_OCNPOLARITY_HIGH;
451   sConfigOC.OCFastMode = TIM_OCFAST_DISABLE;
452   sConfigOC.OCIdleState = TIM_OCIDLESTATE_RESET;
453   sConfigOC.OCNIdleState = TIM_OCNIDLESTATE_RESET;
454   if (HAL_TIM_PWM_ConfigChannel(&htim1, &sConfigOC, TIM_CHANNEL_1) != HAL_OK)
455   {
456     Error_Handler();
```

```
457   }
458   if (HAL_TIM_PWM_ConfigChannel(&htim1, &sConfigOC, TIM_CHANNEL_2) != HAL_OK)
459   {
460     Error_Handler();
461   }
462   sBreakDeadTimeConfig.OffStateRunMode = TIM_OSSR_DISABLE;
463   sBreakDeadTimeConfig.OffStateIDLEMode = TIM_OSSI_DISABLE;
464   sBreakDeadTimeConfig.LockLevel = TIM_LOCKLEVEL_OFF;
465   sBreakDeadTimeConfig.DeadTime = 0;
466   sBreakDeadTimeConfig.BreakState = TIM_BREAK_DISABLE;
467   sBreakDeadTimeConfig.BreakPolarity = TIM_BREAKPOLARITY_HIGH;
468   sBreakDeadTimeConfig.BreakFilter = 0;
469   sBreakDeadTimeConfig.Break2State = TIM_BREAK2_DISABLE;
470   sBreakDeadTimeConfig.Break2Polarity = TIM_BREAK2POLARITY_HIGH;
471   sBreakDeadTimeConfig.Break2Filter = 0;
472   sBreakDeadTimeConfig.AutomaticOutput = TIM_AUTOMATICOUTPUT_DISABLE;
473   if (HAL_TIMEx_ConfigBreakDeadTime(&htim1, &sBreakDeadTimeConfig) != HAL_OK)
474   {
475     Error_Handler();
476   }
477   /* USER CODE BEGIN TIM1_Init 2 */
478
479   /* USER CODE END TIM1_Init 2 */
480   HAL_TIM_MspPostInit(&htim1);
481
482 }
483
484 /**
485   * @brief TIM7 Initialization Function
486   * @param None
487   * @retval None
488   */
489 static void MX_TIM7_Init(void)
490 {
491
492   /* USER CODE BEGIN TIM7_Init 0 */
493
494   /* USER CODE END TIM7_Init 0 */
495
496   TIM_MasterConfigTypeDef sMasterConfig = {0};
497
498   /* USER CODE BEGIN TIM7_Init 1 */
499
500   /* USER CODE END TIM7_Init 1 */
501   htim7.Instance = TIM7;
502   htim7.Init.Prescaler = PRESCALER_HEART;
503   htim7.Init.CounterMode = TIM_COUNTERMODE_UP;
504   htim7.Init.Period = COUNTER_PERIOD_HEART;
505   htim7.Init.AutoReloadPreload = TIM_AUTORELOAD_PRELOAD_DISABLE;
506   if (HAL_TIM_Base_Init(&htim7) != HAL_OK)
507   {
508     Error_Handler();
509   }
510   sMasterConfig.MasterOutputTrigger = TIM_TRGO_RESET;
511   sMasterConfig.MasterSlaveMode = TIM_MASTERSLAVEMODE_DISABLE;
512   if (HAL_TIMEx_MasterConfigSynchronization(&htim7, &sMasterConfig) != HAL_OK)
513   {
514     Error_Handler();
```

```
515   }
516   /* USER CODE BEGIN TIM7_Init 2 */
517
518   /* USER CODE END TIM7_Init 2 */
519
520 }
521
522 /**
523   * @brief USART2 Initialization Function
524   * @param None
525   * @retval None
526   */
527 static void MX_USART2_UART_Init(void)
528 {
529
530   /* USER CODE BEGIN USART2_Init 0 */
531   /* DMA controller clock enable */
532   __DMA1_CLK_ENABLE();
533
534   /* Peripheral DMA init*/
535   hdma_usart2_tx.Init.Direction = DMA_MEMORY_TO_PERIPH;
536   hdma_usart2_tx.Init.PeriphInc = DMA_PINC_DISABLE;
537   hdma_usart2_tx.Init.MemInc = DMA_MINC_ENABLE;
538   hdma_usart2_tx.Init.PeriphDataAlignment = DMA_MDATAALIGN_BYTE;
539   hdma_usart2_tx.Init.MemDataAlignment = DMA_MDATAALIGN_BYTE;
540   hdma_usart2_tx.Init.Mode = DMA_NORMAL;
541   hdma_usart2_tx.Init.Priority = DMA_PRIORITY_LOW;
542   HAL_DMA_Init(&hdma_usart2_tx);
543
544   __HAL_LINKDMA(&huart2,hdmatx,hdma_usart2_tx);
545   /* USER CODE END USART2_Init 0 */
546
547   /* USER CODE BEGIN USART2_Init 1 */
548
549   /* USER CODE END USART2_Init 1 */
550   huart2.Instance = USART2;
551   huart2.Init.BaudRate = 230400;
552   huart2.Init.WordLength = UART_WORDLENGTH_8B;
553   huart2.Init.StopBits = UART_STOPBITS_1;
554   huart2.Init.Parity = UART_PARITY_NONE;
555   huart2.Init.Mode = UART_MODE_TX_RX;
556   huart2.Init.HwFlowCtl = UART_HWCONTROL_NONE;
557   huart2.Init.OverSampling = UART_OVERSAMPLING_16;
558   huart2.Init.OneBitSampling = UART_ONE_BIT_SAMPLE_DISABLE;
559   huart2.AdvancedInit.AdvFeatureInit = UART_ADVFEATURE_NO_INIT;
560   if (HAL_UART_Init(&huart2) != HAL_OK)
561   {
562     Error_Handler();
563   }
564   /* USER CODE BEGIN USART2_Init 2 */
565
566   /* USER CODE END USART2_Init 2 */
567
568 }
569
570 /**
571   * Enable DMA controller clock
572   */
```

```
573 static void MX_DMA_Init(void)
574 {
575
576   /* DMA controller clock enable */
577   __HAL_RCC_DMA1_CLK_ENABLE();
578
579   /* DMA interrupt init */
580   /* DMA1_Channel7_IRQn interrupt configuration */
581   HAL_NVIC_SetPriority(DMA1_Channel7_IRQn, 0, 0);
582   HAL_NVIC_EnableIRQ(DMA1_Channel7_IRQn);
583
584 }
585
586 /**
587   * @brief GPIO Initialization Function
588   * @param None
589   * @retval None
590   */
591 static void MX_GPIO_Init(void)
592 {
593   GPIO_InitTypeDef GPIO_InitStruct = {0};
594
595   /* GPIO Ports Clock Enable */
596   __HAL_RCC_GPIOC_CLK_ENABLE();
597   __HAL_RCC_GPIOH_CLK_ENABLE();
598   __HAL_RCC_GPIOA_CLK_ENABLE();
599   __HAL_RCC_GPIOB_CLK_ENABLE();
600
601   /*Configure GPIO pin Output Level */
602   HAL_GPIO_WritePin(GPIOC, CS_0_Pin|CS_1_Pin, GPIO_PIN_RESET);
603
604   /*Configure GPIO pin Output Level */
605   HAL_GPIO_WritePin(GPIOA, PW_1_Pin|LD2_Pin, GPIO_PIN_RESET);
606
607   /*Configure GPIO pin Output Level */
608   HAL_GPIO_WritePin(PW_0_GPIO_Port, PW_0_Pin, GPIO_PIN_RESET);
609
610   /*Configure GPIO pin : B1_Pin */
611   GPIO_InitStruct.Pin = B1_Pin;
612   GPIO_InitStruct.Mode = GPIO_MODE_IT_FALLING;
613   GPIO_InitStruct.Pull = GPIO_NOPULL;
614   HAL_GPIO_Init(B1_GPIO_Port, &GPIO_InitStruct);
615
616   /*Configure GPIO pins : CS_0_Pin CS_1_Pin */
617   GPIO_InitStruct.Pin = CS_0_Pin|CS_1_Pin;
618   GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;
619   GPIO_InitStruct.Pull = GPIO_NOPULL;
620   GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_LOW;
621   HAL_GPIO_Init(GPIOC, &GPIO_InitStruct);
622
623   /*Configure GPIO pins : PW_1_Pin LD2_Pin */
624   GPIO_InitStruct.Pin = PW_1_Pin|LD2_Pin;
625   GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;
626   GPIO_InitStruct.Pull = GPIO_NOPULL;
627   GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_LOW;
628   HAL_GPIO_Init(GPIOA, &GPIO_InitStruct);
629
630   /*Configure GPIO pin : PW_0_Pin */
```

```
631   GPIO_InitStruct.Pin = PW_0_Pin;
632   GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;
633   GPIO_InitStruct.Pull = GPIO_NOPULL;
634   GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_LOW;
635   HAL_GPIO_Init(PW_0_GPIO_Port, &GPIO_InitStruct);
636
637 }
638
639 /* USER CODE BEGIN 4 */
640
641 /* USER CODE END 4 */
642
643 /**
644   * @brief  This function is executed in case of error occurrence.
645   * @retval None
646   */
647 void Error_Handler(void)
648 {
649   /* USER CODE BEGIN Error_Handler_Debug */
650   /* User can add his own implementation to report the HAL error return state */
651
652   /* USER CODE END Error_Handler_Debug */
653 }
654
655 #ifdef  USE_FULL_ASSERT
656 /**
657   * @brief  Reports the name of the source file and the source line number
658   *         where the assert_param error has occurred.
659   * @param  file: pointer to the source file name
660   * @param  line: assert_param error line source number
661   * @retval None
662   */
663 void assert_failed(char *file, uint32_t line)
664 {
665   /* USER CODE BEGIN 6 */
666   /* User can add his own implementation to report the file name and line number,
667     tex: printf("Wrong parameters value: file %s on line %d\r\n", file, line) */
668   /* USER CODE END 6 */
669 }
670 #endif /* USE_FULL_ASSERT */
671
672 /************************ (C) COPYRIGHT STMicroelectronics *****END OF FILE****/
```

B.2 Treadmill driver

```
1  /*! \file mouseDriver.c
2  \brief Implementation of the driver for the mouse treadmil project.
3
4  \author Didier Negretto
5  */
6  #ifndef MOUSEDRIVER_C_
7  #define MOUSEDRIVER_C_
8
9  #ifndef TEST
10 #include "mouseDriver.h"
11 #else
12 #include "../test/test_mouseDriver.h"
13 #endif
```

```
14 /*!
15 \def K
16 \brief Proportional coefficient for motor control.
17 */
18 #define K 10
19 /*!
20 \def K
21 \brief Proportional coefficient for motor control.
22 */
23 #define I 10
24 /*!
25 \def I
26 \brief Integral coefficient for motor control.
27 */
28 #define MAX_MOTOR_SIGNAL 100
29 /*!
30 \def MAX_MOTOR_SIGNAL
31 \brief Max value for the motor signal
32 \attention This value is used to limit the motor speed. If this is changed the motors might break !!
33
34 This value limits the motor speed and thus is used to vaoid spinning the motor too fast and break it.
35 If this value is changed the motor might spin too fast and destroy itself or the gear box. Extreme caution
36 needs to be taken if this value is modified.
37 */
38 #define MIN_MOTOR_SIGNAL 10
39 /*!
40 \def MIN_MOTOR_SIGNAL
41 \brief Min value for the motor signal. Any value lower than that will cause the motor to stop
42 */
43 #define MAX_MISSING_MEASURES 15
44 /*!
45 \def MAX_MISSING_MEASURES
46 \brief After MAX_MISSING_MEASURES non valid measures from sensors the motors are stopped and
       mode goes
47 to stop.
48 */
49 #ifndef TEST
50 /*!
51 \var actual_mode
52 \brief Global variable defining the mode of the machine
53
54 This value is updated based on the received messages. When a routine is running it is
55 only possible to stop the machine.
56 */
57 static uint8_t actual_mode = MOUSE_MODE_STOP;
58 /*!
59 \var actual_speed_measure
60 \brief Global variable for the measured speed
61
62 This value is updated based on sensor.
63 */
64 static mavlink_speed_info_t actual_speed_measure;
65 /*!
66 \var actual_speed_setpoint
67 \brief Global variable for the speed setpoint
68
69 This value is updated based on messages when the mode is set to SPEED.
70 */
```

```
71 static mavlink_speed_setpoint_t actual_speed_setpoint;
72 /*!
73 \var actual_motor_signal
74 \brief Global variable for the speed motor signal
75
76 This value is updated based on closed-loop control and the value provided in
77 \ref actual_speed_setpoint and \ref actual_speed_measure.
78 It is also possible to overwrite it by sending a mavlink_motor_setpoint_t message if the
79 mode is set to SPEED.
80 */
81 static mavlink_motor_setpoint_t actual_motor_signal;
82 /*!
83 \var points
84 \brief Global variable for storing the points to be followed in AUTO mode
85
86 The maximum amout of points is defined by \ref MAX_POINTS. This array is emptied after
87 every reset of the system. If not all the points are defined the routine is interrupted as
88 soon as a point with duration == 0 is detected.
89 */
90 static mavlink_point_t points[255];
91 /*!
92 \var actual_point
93 \brief Global variable for keeping track of the index in the \ref points array.
94 */
95 static uint8_t actual_point = 0;
96 /*!
97 \var actual_point_start_time
98 \brief Global variable for keeping track of the time when the last point in \ref points array started.
99 */
100 static uint32_t actual_point_start_time = 0;
101 /*!
102 \var actual_error
103 \brief Global variable to store and send the last error occured
104 */
105 static mavlink_error_t actual_error;
106 /*!
107 \var actual_raw_sensor
108 \brief Global variable to store and send the row sensor values from X and Y sensors
109 */
110 static mavlink_raw_sensor_t actual_raw_sensor[2];
111 /*!
112 \var send_msg
113 \brief Flag for sending status messages. Those messages are sent with lower freqency.
114 */
115 static int send_msg = 1;
116 /*!
117 \fn mouseDriver_initSetpoint
118 \brief Function that initializes the setpoint to 0
119
120 This function modifies \ref actual_speed_setpoint by setting it to 0.
121 */
122 #endif
123 /*!
124 \fn mouseDriver_sendMsg(uint32_t msgid)
125 \param msgid is the ID of the message to be sent.
126 \brief Function that sends a message given its ID.
127 \attention This function can be called in interrupts whith a priority lower than 0 (1,2,3,...),
128 otherwise the HAL_Delay() function stall and the STM32 crashes.
```

```
129
130 This function access global variables to send information to the computer.
131 Given one message ID the functions reads the information from a global variable and
132 sends it using the DMA as soon as the previous messages are sent.
133 */
134 void mouseDriver_sendMsg(uint32_t msgid);
135 /*!
136 \fn mouseDriver_initSetpoint
137 \brief Function that initializes the motor setpoint to 0.
138
139 This function initializes \ref actual_speed_setpoint.
140 */
141 void mouseDriver_initSetpoint(void);
142 /*!
143 \fn mouseDriver_initMode
144 \brief Function that initializes the mode to MOUSE_MODE_STOP
145
146 This function modifies \ref actual_mode by setting it to MOUSE_MODE_STOP.
147 */
148 void mouseDriver_initMode(void);
149 /*!
150 \fn mouseDriver_initPoints
151 \brief Function that initializes the routine points for AUTO mode to 0.
152
153 This function modifies \ref points by setting all their fields to 0.
154 */
155 void mouseDriver_initPoints(void);/*!
156 \fn mouseDriver_setMode(uint8_t mode)
157 \param mode is the mode in which the driver should be set.
158 \brief Function that sets the mode of the machine.
159
160 This functions modifies the mode of the machine. Not all transitions are possible,
161 this functions verifies that the transitions are lawful.
162 */
163 void mouseDriver_setMode(uint8_t mode);
164
165 /*!
166 \fn mouseDriver_initMotorSignal
167 \brief Function that initializes the motor signals to 0.
168
169 This function modifies \ref actual_motor_signal by setting all their fields to 0.
170 */
171 void mouseDriver_initMotorSignal(void);
172
173 void mouseDriver_initSetpoint(void){
174   actual_speed_setpoint.setpoint_x = 0;
175   actual_speed_setpoint.setpoint_y = 0;
176 }
177 void mouseDriver_initMode(void){
178   actual_mode = MOUSE_MODE_STOP;
179 }
180 void mouseDriver_initPoints(void){
181   for(int i=0; i<MAX_POINTS; i++){
182     points[i].duration = 0;
183     points[i].setpoint_x = 0;
184     points[i].setpoint_y = 0;
185     points[i].point_id = 0;
186   }
```

```
187   actual_point = 0;
188   actual_point_start_time = 0;
189 }
190 void mouseDriver_initMotorSignal(void){
191     actual_motor_signal.motor_x = 0;
192     actual_motor_signal.motor_y = 0;
193 }
194 void mouseDriver_init(void){
195   mouseDriver_initMode();
196   mouseDriver_initSetpoint();
197   mouseDriver_initPoints();
198   mouseDriver_initMotorSignal();
199
200   /* Init sensor as well */
201   sensorDriver_init();
202   main_stop_motors();
203 }
204 uint32_t mouseDriver_getTime (void){
205   return (HAL_GetTick());
206 }
207 void mouseDriver_send_status_msg(void){
208   send_msg = 1;
209 }
210 void mouseDriver_control_idle(void){
211   static int count = 0;
212     static float integral_x = 0;
213     static float integral_y = 0;
214     float error_x = 0;
215     float error_y = 0;
216   if (actual_speed_measure.valid == 0){
217     count ++;
218     if(count >= MAX_MISSING_MEASURES){
219       main_stop_motors();
220       mouseDriver_setMode(MOUSE_MODE_STOP);
221           integral_x = 0;
222           integral_y = 0;
223     }
224     return;
225   }
226   if (actual_mode == MOUSE_MODE_SPEED || actual_mode == MOUSE_MODE_AUTO_RUN){
227     actual_motor_signal.time = mouseDriver_getTime();
228         error_x = actual_speed_setpoint.setpoint_x-actual_speed_measure.speed_x;
229         error_y = actual_speed_setpoint.setpoint_y-actual_speed_measure.speed_y;
230     actual_motor_signal.motor_x = (float)K*(error_x)+(float)I*integral_x;
231     actual_motor_signal.motor_y = (float)K*(error_y)+(float)I*integral_y;
232
233     if (actual_motor_signal.motor_x > MAX_MOTOR_SIGNAL){
234         actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL;
235     }
236     if(actual_motor_signal.motor_y  > MAX_MOTOR_SIGNAL){
237           actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL;
238         }
239
240     main_set_motors_speed(actual_motor_signal);
241         integral_x += (actual_motor_signal.motor_x < MAX_MOTOR_SIGNAL)? error_x : 0;
242         integral_y += (actual_motor_signal.motor_y < MAX_MOTOR_SIGNAL)? error_y : 0;
243     count = 0;
244   }
```

```
245  else{
246    actual_motor_signal.motor_x = 0;
247    actual_motor_signal.motor_y = 0;
248    main_stop_motors();
249        integral_x = 0;
250        integral_y = 0;
251  }
252 }
253
254 void mouseDriver_setMode(uint8_t mode){
255    if (mode == MOUSE_MODE_STOP){
256        main_stop_motors();
257        actual_point = 0;
258        actual_mode = MOUSE_MODE_STOP;
259        mouseDriver_initMotorSignal();
260    }
261    if (mode == MOUSE_MODE_AUTO_LOAD){
262        actual_mode = mode;
263        mouseDriver_sendMsg(MAVLINK_MSG_ID_HEARTBEAT);
264    }
265    if (actual_mode == MOUSE_MODE_AUTO_LOAD && mode == MOUSE_MODE_AUTO_RUN ){
266        actual_point = 0;
267        actual_point_start_time = mouseDriver_getTime();
268        actual_speed_setpoint.setpoint_x = points[0].setpoint_x;
269        actual_speed_setpoint.setpoint_y = points[0].setpoint_y;
270        actual_mode = mode;
271    }
272
273    if (actual_mode != MOUSE_MODE_AUTO_RUN)
274        actual_mode = mode;
275 }
276 void mouseDriver_sendMsg(uint32_t msgid){
277    mavlink_message_t msg;
278    static uint8_t outBuffer[MAX_BYTE_BUFFER_SIZE];
279    static uint16_t msg_size = 0;
280
281    while (main_get_huart_tx_state() == HAL_BUSY){
282        /*Wait for other messages to be sent*/
283        HAL_Delay(1);
284    }
285
286    switch(msgid){
287        case MAVLINK_MSG_ID_HEARTBEAT:
288            mavlink_msg_heartbeat_pack(SYS_ID,COMP_ID, &msg, actual_mode, mouseDriver_getTime())
      ;
289            msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
290            main_transmit_buffer(outBuffer, msg_size);
291            break;
292        case MAVLINK_MSG_ID_SPEED_SETPOINT:
293            mavlink_msg_speed_setpoint_encode(SYS_ID,COMP_ID, &msg, &actual_speed_setpoint);
294            msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
295            main_transmit_buffer(outBuffer, msg_size);
296            break;
297        case MAVLINK_MSG_ID_MOTOR_SETPOINT:
298            mavlink_msg_motor_setpoint_encode(SYS_ID,COMP_ID, &msg, &actual_motor_signal);
299            msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
300            main_transmit_buffer(outBuffer, msg_size);
301            break;
```

```
302         case MAVLINK_MSG_ID_SPEED_INFO:
303             /* DEMO CODE INIT*/
304                 actual_speed_measure.time_x = mouseDriver_getTime();
305             /* DEMO CODE END*/
306             mavlink_msg_speed_info_encode(SYS_ID,COMP_ID, &msg, &actual_speed_measure);
307             msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
308             main_transmit_buffer(outBuffer, msg_size);
309             break;
310         case MAVLINK_MSG_ID_ERROR:
311             mavlink_msg_error_encode(SYS_ID,COMP_ID,&msg,&actual_error);
312             msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
313             main_transmit_buffer(outBuffer, msg_size);
314             break;
315         case MAVLINK_MSG_ID_POINT_LOADED:
316             mavlink_msg_point_loaded_pack(SYS_ID,COMP_ID,&msg,actual_point);
317             msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
318             main_transmit_buffer(outBuffer, msg_size);
319             break;
320         case MAVLINK_MSG_ID_POINT:
321             mavlink_msg_point_encode(SYS_ID,COMP_ID,&msg,&points[actual_point]);
322             msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
323             main_transmit_buffer(outBuffer, msg_size);
324             break;
325         case MAVLINK_MSG_ID_RAW_SENSOR:
326             mavlink_msg_raw_sensor_encode(SYS_ID,COMP_ID,&msg,&actual_raw_sensor[0]);
327             msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
328             main_transmit_buffer(outBuffer, msg_size);
329             while (main_get_huart_tx_state() == HAL_BUSY){
330                 /*Wait for other messages to be sent*/
331                 HAL_Delay(1);
332             }
333             mavlink_msg_raw_sensor_encode(SYS_ID,COMP_ID,&msg,&actual_raw_sensor[1]);
334             msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
335             main_transmit_buffer(outBuffer, msg_size);
336             break;
337         default:
338             break;
339     }
340 }
341 void mouseDriver_idle (void){
342     uint64_t difference = 0;
343     sensorDriver_motion_read_speed(actual_raw_sensor, &actual_speed_measure);
344     switch(actual_mode){
345     case MOUSE_MODE_STOP:
346         mouseDriver_initSetpoint();
347         mouseDriver_initMotorSignal();
348         actual_motor_signal.time = mouseDriver_getTime();
349         main_stop_motors();
350         mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_INFO);
351 
352         break;
353     case MOUSE_MODE_SPEED:
354         mouseDriver_control_idle();
355         mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_INFO);
356         mouseDriver_sendMsg(MAVLINK_MSG_ID_MOTOR_SETPOINT);
357 
358         break;
359     case MOUSE_MODE_AUTO_LOAD:
```

```
360         if (actual_point == 255){
361             actual_error.error = MOUSE_ROUTINE_TOO_LONG;
362             actual_error.time = mouseDriver_getTime();
363             mouseDriver_sendMsg(MAVLINK_MSG_ID_ERROR);
364         }
365         break;
366     case MOUSE_MODE_AUTO_RUN:
367         difference = mouseDriver_getTime()-actual_point_start_time;
368         if (difference >= points[actual_point].duration){
369             if (actual_point < MAX_POINTS-1){
370                 actual_point++;
371 
372                 if(points[actual_point].duration == 0){
373                     actual_point = 0;
374                 }
375                 actual_speed_setpoint.setpoint_x = points[actual_point].setpoint_x;
376                 actual_speed_setpoint.setpoint_y = points[actual_point].setpoint_y;
377                 actual_point_start_time = mouseDriver_getTime();
378             }
379         }
380         if (actual_point == MAX_POINTS){
381             mouseDriver_setMode(MOUSE_MODE_AUTO_LOAD);
382         }
383         mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_INFO);
384         mouseDriver_sendMsg(MAVLINK_MSG_ID_MOTOR_SETPOINT);
385         mouseDriver_control_idle();
386         break;
387     default:
388         break;
389     }
390     if (send_msg == 1){
391         send_msg = 0;
392         mouseDriver_sendMsg(MAVLINK_MSG_ID_HEARTBEAT);
393         if(actual_mode != MOUSE_MODE_AUTO_LOAD){
394             mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_SETPOINT);
395             mouseDriver_sendMsg(MAVLINK_MSG_ID_RAW_SENSOR);
396             mouseDriver_sendMsg(MAVLINK_MSG_ID_MOTOR_SETPOINT);
397         }
398     }
399 
400 }
401 void mouseDriver_readMsg(const mavlink_message_t msg){
402 
403     switch(msg.msgid){
404 
405     case MAVLINK_MSG_ID_MODE_SELECTION:
406         mouseDriver_setMode( mavlink_msg_mode_selection_get_mode(&msg));
407         break;
408 
409     case MAVLINK_MSG_ID_SPEED_SETPOINT:
410         if (actual_mode == MOUSE_MODE_SPEED)
411             mavlink_msg_speed_setpoint_decode(&msg, &actual_speed_setpoint);
412         break;
413 
414     case MAVLINK_MSG_ID_MOTOR_SETPOINT:
415         if (actual_mode == MOUSE_MODE_SPEED)
416             mavlink_msg_speed_setpoint_decode(&msg, &actual_speed_setpoint);
417         break;
```

```
418     case MAVLINK_MSG_ID_POINT:
419         if(actual_mode == MOUSE_MODE_AUTO_LOAD){
420             mavlink_msg_point_decode(&msg, &points[actual_point]);
421             if (actual_point == 255){
422                 actual_error.error = MOUSE_ROUTINE_TOO_LONG;
423                 actual_error.time = mouseDriver_getTime();
424                 mouseDriver_sendMsg(MAVLINK_MSG_ID_ERROR);
425             }
426             mouseDriver_sendMsg(MAVLINK_MSG_ID_POINT_LOADED);
427             actual_point ++;
428 
429         }
430         break;
431     default:
432         break;
433     };
434 }
435 #endif
```

```
1  /*! \file mouseDriver.h
2  \brief Header of the driver for the mouse treadmil project.
3  
4  \author Didier Negretto
5  */
6  
7  /*
8   * Code used for driving the 3D mouse treadmill
9   * Author: Didier Negretto
10  *
11  */
12 
13 #pragma once
14 #ifndef MOUSEDRIVER_N_H
15 /*!
16 \def MOUSEDRIVER_N_H
17 \brief To avoid double includes
18 */
19 #define MOUSEDRIVER_N_H
20 
21 #ifndef TEST
22 #include "mavlink.h"
23 #include "utils.h"
24 #include "sensorDriver.h"
25 #endif
26 
27 #include <math.h>
28 /* Constants for MALINK functions*/
29 
30 /*!
31 \def SYS_ID
32 \brief System ID for MAVLink
33 */
34 #define SYS_ID 0
35 
36 /*!
37 \def COMP_ID
38 \brief Component ID for MAVLink
39 */
```

```
40 #define COMP_ID 0
41
42 /* maximum size of the trasmit buffer */
43 /*!
44 \def MAX_BYTE_BUFFER_SIZE
45 \brief MAX size of transmit buffer in bytes
46 */
47 #define MAX_BYTE_BUFFER_SIZE 500
48
49 /*!
50 \def MAX_POINTS
51 \brief MAX amount of points that can be defined in AUTO mode
52 */
53 #define MAX_POINTS 255
54
55 /*!
56 \fn mouseDriver_init
57 \brief Function that initializes the driver of the mouse treadmill.
58
59 This functions initialites the mouse treadmill driver. It initializes the sensors as well.
60 */
61 void mouseDriver_init(void);
62
63 /*!
64 \fn mouseDriver_control_idle
65 \brief Function doing the control on the motors.
66 \attention This function is in charge of generating the control signals for the
67 motors. If it is modified, make sure to respect the specifications of the motor
68 to avoid damaging or destroing them !!
69
70 This function is called periodially to update the control signal for the motors.
71 */
72 void mouseDriver_control_idle(void);
73
74 /*!
75 \fn mouseDriver_send_status_msg
76 \brief Function generating the signal for sending messages.
77
78 This function is called periodially to set the flag for sending status messages.
79 */
80 void mouseDriver_send_status_msg(void);
81
82 /*!
83 \fn mouseDriver_readMsg(const mavlink_message_t msg)
84 \param msg MAVLink message to be decoded
85 \brief Function that reads one message.
86
87 This function is called in main.c. Depending on the received message different actions are taken.
88 */
89 void mouseDriver_readMsg(const mavlink_message_t msg);
90
91 /*!
92 \fn mouseDriver_getTime
93 \return The actual time in ms from boot of the system.
94 \brief Function that gets the time of the system from boot.
95 */
96 uint32_t mouseDriver_getTime (void);
97
```

```
98 /*!
99 \fn mouseDriver_idle
100 \brief Idle function for the mouse treadmill driver.
101 \note This function needs to be called periodically to ensure a correct behaviour.
102
103 This is the idle function of the mouse treadmill. It reads values from the sensors,
104 calls \ref mouseDriver_control_idle, and sends high frequency messages (not the status ones).
105 */
106 void mouseDriver_idle (void);
107
108
109 #endif
```

B.3 Sensor driver

```
1 /*! \file sensorDriver.c
2 \brief Implementation of the sensor driver for the mouse treadmill project.
3
4 \author Didier Negretto
5 */
6 # include "sensorDriver.h"
7
8 /*!
9  \var sensor_x
10  \brief variable for storing data for the x sensor.
11  */
12 static sensor_t sensor_x = {CS_0_GPIO_Port,CS_0_Pin,PW_0_GPIO_Port,PW_0_Pin,0};
13
14 /*!
15  \var sensor_y
16  \brief variable for storing data for the y sensor.
17  */
18 static sensor_t sensor_y = {CS_1_GPIO_Port,CS_1_Pin,PW_1_GPIO_Port,PW_1_Pin,0};
19
20 /*!
21  \fn sensorDriver_powerup(sensor_t *sensor)
22  \param sensor sensor structure of the sensor to be powered up
23  \brief This function turns off and the on the sensor. It then performs the power up routine
24  \note This routine is time consuming and done only at start up.
25
26  After Flashing the SROM the SROM_ID register is read to confirm that the
27  SROM have been flashed correctly.
28 */
29 void sensorDriver_powerup(sensor_t * sensor);
30
31 /*!
32  \fn sensorDriver_motion_read_raw(uint8_t sensor_id, mavlink_raw_sensor_t * sensor_data)
33  \param sensor_id 0 for sensor x, 1 for sensor y
34  \param sensor_data pointer to a structure for storing the raw sensor value
35  \brief This function reads raw data from the sensor given its ID and puts the result in the pointer.
36  */
37 void sensorDriver_motion_read_raw(uint8_t sensor_id, mavlink_raw_sensor_t * sensor_data);
38
39 void sensorDriver_powerup(sensor_t * sensor){
40   /* Disable the sensor */
41   HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_SET);
42
43   /* Make sure all sensor is switched off */
```

```
44  HAL_GPIO_WritePin(sensor->pw_port, sensor->pw_pin, GPIO_PIN_RESET);
45  main_write_sensor(*sensor, 0x00, 0x00);
46  HAL_Delay(100);
47
48  /* Gives voltage to sensors */
49  HAL_GPIO_WritePin(sensor->pw_port, sensor->pw_pin , GPIO_PIN_SET);
50  HAL_Delay(300);
51
52  /* Reset SPI port */
53  HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin,  GPIO_PIN_SET);
54  HAL_Delay(5);
55  HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin,  GPIO_PIN_RESET);
56  HAL_Delay(5);
57  HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin,  GPIO_PIN_SET);
58  HAL_Delay(5);
59
60  /* Write to Power_up_Reset register */
61  main_write_sensor(*sensor, Power_Up_Reset, 0x5A);
62
63  /* Wait at least 50 ms */
64  HAL_Delay(50);
65
66  /* Read from data registers */
67  main_read_sensor(*sensor, 0x02);
68  main_read_sensor(*sensor, 0x03);
69  main_read_sensor(*sensor, 0x04);
70  main_read_sensor(*sensor, 0x05);
71  main_read_sensor(*sensor, 0x06);
72
73  /* Start ROM Download */
74  main_write_sensor(*sensor, Config2, 0x20);
75  main_write_sensor(*sensor, SROM_Enable, 0x1d);
76  HAL_Delay(10);
77  main_write_sensor(*sensor,SROM_Enable, 0x18);
78  main_wait_160us();
79  main_wait_20us();
80
81  /* Burst start with adress */
82  HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_RESET);
83  main_write_sensor_burst(SROM_Load_Burst|0x80);
84  for (int i = 0; i < firmware_length; i++ ){
85    main_write_sensor_burst(firmware_data[i]);
86  }
87  HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_SET);
88  main_wait_160us();
89  main_wait_20us();
90  main_wait_20us();
91
92  /* Read SROM_ID for verification */
93  sensor->status = main_read_sensor(*sensor, SROM_ID);
94
95  /* Write to Config2 for wired mouse */
96  main_write_sensor(*sensor, Config2, 0x00);
97 }
98 void sensorDriver_init(void){
99  sensorDriver_powerup(&sensor_x);
100 sensorDriver_powerup(&sensor_y);
101 }
```

```
102 void sensorDriver_motion_read_raw(uint8_t sensor_id, mavlink_raw_sensor_t * sensor_data){
103   uint8_t data[12];
104   int16_t temp = 0;
105   sensor_t sensor;
106 
107   if (sensor_id == SENSOR_X) sensor = sensor_x;
108   else if (sensor_id == SENSOR_Y) sensor = sensor_y;
109   else return;
110   sensor_data->sensor_id = sensor_id;
111 
112   /* write to motion burst adress */
113   main_write_sensor(sensor, Motion_Burst, 0xbb);
114 
115   /* Prepare for burst */
116   HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_RESET);
117   sensor_data->time = mouseDriver_getTime();
118   main_write_sensor_burst(Motion_Burst);
119   /* Start burst */
120   main_read_sensor_motion_burst(data);
121   HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_SET);
122   /* END of burst */
123   main_wait_20us();
124 
125   /* Read other register for stopping burst mode */
126   sensor_data->product_id = main_read_sensor(sensor,  Product_ID);
127 
128   /* TWO's Complement */
129   temp = (data[DELTA_X_H]<<8) | (data[DELTA_X_L]);
130   temp = ~temp + 1;
131   sensor_data->delta_x = temp;
132   temp = (data[DELTA_Y_H]<<8) | (data[DELTA_Y_L]);
133   temp = ~temp +1;
134   sensor_data->delta_y = temp;
135 
136   sensor_data->squal = data[SQUAL_READ];
137   sensor_data->lift = (data[MOTION] & 0x08) >> 3;
138   sensor_data->srom_id = sensor.status;
139 }
140 void sensorDriver_motion_read_speed(mavlink_raw_sensor_t sensor_data[2], mavlink_speed_info_t *
        speed_info){
141   mavlink_raw_sensor_t raw_values[2];
142     uint32_t old_time[2];
143 
144     speed_info->valid = 0;
145     old_time[0] = speed_info->time_x;
146     old_time[1] = speed_info->time_y;
147 
148   sensorDriver_motion_read_raw(SENSOR_X, &raw_values[0]);
149   sensorDriver_motion_read_raw(SENSOR_Y, &raw_values[1]);
150 
151   speed_info->speed_x =  (float)raw_values[0].delta_x*(float)INCH2METER/(float)RESOLUTION;
152   speed_info->speed_x /= (float)(raw_values[0].time-old_time[0])/(float)1000;
153   speed_info->time_x = raw_values[0].time;
154   speed_info->speed_y =  (float)raw_values[1].delta_x*(float)INCH2METER/(float)RESOLUTION;
155   speed_info->speed_y /= (float)(raw_values[1].time-old_time[1])/(float)1000;
156   speed_info->time_y = raw_values[1].time;
157   sensor_data[0] = raw_values[0];
158   sensor_data[1] = raw_values[1];
```

```

  if((raw_values[0].lift == 0) && (raw_values[1].lift == 0) &&
    (raw_values[0].squal >= SQUAL_THRESH) && (raw_values[0].squal >= SQUAL_THRESH) &&
    (raw_values[0].product_id == 66) && (raw_values[1].product_id == 66)){
    speed_info->valid = 1;
  }
  else{
    speed_info->valid = 0;
  }
}
```

```
/*! \file sensorDriver.h
\brief Header of the sensor driver for the mouse treadmil project.

\author Didier Negretto
*/
#pragma once

#ifndef SENSORDRIVER_H_
#define SENSORDRIVER_H_

#ifndef TEST
#include "main.h"
#include "mavlink.h"
#include "sensorSROM.h"
#endif

/* BEGIN DEFINES FOR SENSOR INTERNAL REGISTERS */
#define Product_ID  0x00
#define Revision_ID 0x01
#define Motion  0x02
#define Delta_X_L 0x03
#define Delta_X_H 0x04
#define Delta_Y_L 0x05
#define Delta_Y_H 0x06
#define SQUAL 0x07
#define Raw_Data_Sum  0x08
#define Maximum_Raw_data  0x09
#define Minimum_Raw_data  0x0A
#define Shutter_Lower 0x0B
#define Shutter_Upper 0x0C
#define Control 0x0D
#define Config1 0x0F
#define Config2 0x10
#define Angle_Tune  0x11
#define Frame_Capture 0x12
#define SROM_Enable 0x13
#define Run_Downshift 0x14
#define Rest1_Rate_Lower  0x15
#define Rest1_Rate_Upper  0x16
#define Rest1_Downshift 0x17
#define Rest2_Rate_Lower  0x18
#define Rest2_Rate_Upper  0x19
#define Rest2_Downshift 0x1A
#define Rest3_Rate_Lower  0x1B
#define Rest3_Rate_Upper  0x1C
#define Observation 0x24
#define Data_Out_Lower  0x25
```

```
48 #define Data_Out_Upper  0x26
49 #define Raw_Data_Dump 0x29
50 #define SROM_ID 0x2A
51 #define Min_SQ_Run  0x2B
52 #define Raw_Data_Threshold  0x2C
53 #define Config5 0x2F
54 #define Power_Up_Reset  0x3A
55 #define Shutdown  0x3B
56 #define Inverse_Product_ID  0x3F
57 #define LiftCutoff_Tune3  0x41
58 #define Angle_Snap  0x42
59 #define LiftCutoff_Tune1  0x4A
60 #define Motion_Burst  0x50
61 #define LiftCutoff_Tune_Timeout 0x58
62 #define LiftCutoff_Tune_Min_Length  0x5A
63 #define SROM_Load_Burst 0x62
64 #define Lift_Config 0x63
65 #define Raw_Data_Burst  0x64
66 #define LiftCutoff_Tune2  0x65
67 /* END DEFINES FOR SENSOR INTERNAL REGISTERS */
68
69 #include <mavlink_msg_raw_sensor.h>
70 #include <stdint.h>
71
72 /* DEFINES FOR BURST READ (only usefull data) */
73 #define MOTION 0
74 #define OBSERVATION 1
75 #define DELTA_X_L 2
76 #define DELTA_X_H 3
77 #define DELTA_Y_L 4
78 #define DELTA_Y_H 5
79 #define SQUAL_READ 6
80
81 /*!
82 \def SQUAL_THRESH
83 \brief Threshold value on SQUAL to consider the measure valid.
84 */
85 #define SQUAL_THRESH 16
86
87 /*!
88 \def RESOLUTION
89 \brief Resolution of the sensor in Count per Inch (CPI)
90 \note This value needs to be updated if the resolution of the sensors is changed,
91
92 This value is used to convert the raw sensor value in counts to meter per second.
93 */
94 #define RESOLUTION 5000
95
96 /*!
97 \def INCH2METER
98 \brief Conversion factor to convert inches in meters.
99 */
100 #define INCH2METER 0.0254
101
102 /*!
103 \fn sensorDriver_init
104 \brief Initializes all sensors.
105
```

```
106 This functions powers down the sensor and does the powering up routine.
107 \note This routine takes a long time, so it is done only at start up.
108 */
109 void sensorDriver_init(void);
110
111 /*!
112 \fn sensorDriver_motion_read_speed(mavlink_raw_sensor_t sensor_data[2], mavlink_speed_info_t *
        speed_info)
113 \param sensor_data[2] array for the raw values of the 2 sensors
114 \param speed_info pointer to a mavlink_speed_info_t
115 \brief Function for reading the raw data and speed measures from the sensors.
116 \attention The speed_info.time_x/y is used to compute speed. This value should NOT BE MODIFIED by
117 the caller function
118
119 This function reads values from the sensors and puts them in the given pointers.
120 It also flags invalid readings, so that \ref mouseDriver_control_idle do not use them.
121 */
122 void sensorDriver_motion_read_speed(mavlink_raw_sensor_t sensor_data[2], mavlink_speed_info_t *
        speed_info);
123
124 #endif
```

B.4 Code for unit tests

```
1  /*! \file display.h
2  \brief Header and implementation of display function for unit tests
3
4  \author Didier Negretto
5  */
6
7  #ifndef DISPLAY_H_
8  #define DISPLAY_H_
9
10 /* DEFINES COLORS FOR DISPLAY IN TERMINAL */
11 /*!
12 \def RED
13 \brief Prints text between RED and \ref END in red color
14 */
15 #define RED     "\x1b[31m"
16 /*!
17 \def GREEN
18 \brief Prints text between GREEN and \ref END in green color
19 */
20 #define GREEN   "\x1b[32m"
21 /*!
22 \def END
23 \brief stops printin using color.
24 */
25 #define END   "\x1b[0m"
26
27 #include <stdio.h>
28 #include <stdbool.h>
29 #include <stdlib.h>
30
31 #ifdef COLOR
32 static inline bool display (bool correct, const char *name){
33     if(correct == 1){
34         printf("    ["GREEN "OK" END"] ");
```

```
        printf(name);
        printf(GREEN " DONE SUCCESSFULY\n" END);
        return 1;
    }
    else{
       printf("["RED "NO" END"]     ");
       printf(name);
       printf(RED " PERFORMED INCORRECTLY OR NOT AT ALL\n" END);
       return 0;
    }
    return 0;
}
#else
/*!
 \fn static inline bool display (bool correct, const char *name)
 \param correct 1 if the test is successfull 0 if it is not
 \param name pointer to string with the name of the test that is run
 \return The result of the test (1 if correct == 1, 0 if correct == 0).
 \brief This function prints on the terminal is the test is passed successfully
 or not
 */
static inline bool display (bool correct, const char *name){
    if(correct == 1){
        printf("    [OK] ");
        printf("%s", name);
        printf(" DONE SUCCESSFULY\n");
        return 1;
    }
    else{
       printf("[NO]     ");
       printf("%s", name);
       printf(" PERFORMED INCORRECTLY OR NOT AT ALL\n");
       return 0;
    }
    return 0;
}
#endif
#endif /* DISPLAY_H_ */
```

```
/*! \file main.c
\brief Main for unit testss
\author Didier Negretto

This main is compiled and run after the compilation of the stm32 project
This main runs the unit tests and prints which tests are passed and which are not
\attention  The bash script for the automatic unit testing after compilation
was written for MAC and may not work on LINUX or Windows. To solve this issue
modify CodeSTM32/src/build.sh
*/

#include "test_mouseDriver.h"
#include "test_sensorDriver.h"

int main(void){

    bool test = 1;

    printf("=====================================================\n");
```

```
    printf("**********TESTING CODE FOR MOUSE TREADMILL *********\n");
    printf("============================================================\n\n
      ");
    printf("------------------------------------------------------------\n");
    printf("TESTING mouseDriver.c\n");
    printf("TESTING mouseDriver_init()\n");
    test &= test_mouseDriver_init();
    printf("TESTING mouseDriver_idle()\n");
    test &= test_mouseDriver_idle();
    printf("TESTING mouseDriver_getTime()\n");
    test &= test_mouseDriver_getTime();
    printf("TESTING mouseDriver_send_status_msg()\n");
    test &= test_mouseDriver_send_status_msg();
    printf("TESTING mouseDriver_control_idle()\n");
    test &= test_mouseDriver_control_idle();
    /*printf("------------------------------------------------------------\n
      ");
    printf("TESTING mouseDriver.c\n");
    if (! test_mouseDriver_init()) printf(RED"ERRORS IN mouseDriver_init\n"END);*/


    if (test == 1){
        printf("ALL TEST PASSED SUCCESSUFULLY\n");
    }
    else{
        printf("============================================================\n
      ");
        printf("!!!!!!!!!!!! SOME TESTS NOT PASSED !!!!!!!!!!!!!!!!!!\n");
        printf("============================================================\n
      \n");

    }
    return test;
}
```

```
/*
 * mock_mouseDriver.h
 *
 *  Created on: Nov 24, 2019
 *      Author: Didier
 */

#ifndef MOCK_MOUSEDRIVER_H_
#define MOCK_MOUSEDRIVER_H_

#define HAL_BUSY  0
#define SYS_ID 0
#define COMP_ID 0
#define MAX_BYTE_BUFFER_SIZE 500
#define MAX_POINTS 255


static int stop_motor = 0;
static int sensor_init = 0;
static int sensor_read_x = 0;
static int sensor_read_y = 0;

/* Define mock variables for testing */
```

```
24 static int send_msg = 1;
25 static uint8_t actual_mode = MOUSE_MODE_STOP;
26 static mavlink_speed_setpoint_t actual_speed_setpoint;
27 static mavlink_speed_info_t actual_speed_measure;
28 static mavlink_motor_setpoint_t actual_motor_signal;
29 static mavlink_point_t points[255];
30 static uint8_t actual_point = 0;
31 static uint32_t actual_point_start_time = 0;
32 static mavlink_error_t actual_error;
33 static mavlink_raw_sensor_t actual_raw_sensor[2];
34
35 /* Define mock functions */
36 static inline void sensorDriver_init(void){sensor_init = 1; };
37 static inline uint32_t HAL_GetTick(void){
38     static uint32_t i = 0;
39     i++;
40     return i;
41 };
42 static inline void main_set_motors_speed(mavlink_motor_setpoint_t actual_motor_signal){stop_motor
       = 0;};
43 static inline void main_stop_motors(void){stop_motor = 1;};
44 static inline int main_get_huart_tx_state(void){return 1;};
45 static inline void HAL_Delay(int delay){};
46 static inline void main_transmit_buffer(uint8_t * outbuffer, int msg_size){};
47
48 static inline void sensorDriver_motion_read_speed(mavlink_raw_sensor_t actual_raw_sensor[2],
       mavlink_speed_info_t * actual_speed_measure){
49     sensor_read_x = 1;
50     sensor_read_y = 1;
51     actual_raw_sensor[0].delta_x = 0;
52     actual_raw_sensor[1].delta_y = 0;
53     actual_speed_measure->speed_x = 0;
54     actual_speed_measure->speed_y = 0;
55 };
56
57 #endif /* MOCK_MOUSEDRIVER_H_ */
```

```
1  /*! \file mock_sensorDriver.h
2  \brief In this file mock functions are defined for the sensor driver unit tests
3
4  \author Didier Negretto
5  */
6
7
8  #ifndef MOCK_SENSORDRIVER_H_
9  #define MOCK_SENSORDRIVER_H_
10
11 /**
12  * A mock structure to represent one sensor
13  */
14 typedef struct SENSOR{
15     /*@{*/
16     int cs_port; /**< the chip select port for the sensor */
17     uint8_t cs_pin;/**< the chip select pin for the sensor */
18     int pw_port; /**< the power port for the sensor */
19     uint8_t pw_pin;/**< the power pin for the sensor */
20     uint8_t status;/**< the sensor status. This is the SROM_ID after the upload of the
21   firmware. This value should not be 0 otherwise the upload of the SROM is failed. */
```

```
22    /*@}*/
23 } sensor_t;
24
25 #define CS_0_GPIO_Port 0
26 #define CS_0_Pin 0
27 #define PW_0_GPIO_Port 0
28 #define PW_0_Pin 0
29
30 #define CS_1_GPIO_Port 1
31 #define CS_1_Pin 1
32 #define PW_1_GPIO_Port 1
33 #define PW_1_Pin 1
34
35 #define GPIO_PIN_SET 1
36 #define GPIO_PIN_RESET 0
37
38 static int firmware_length = 3;
39 static int firmware_data[3] = {1,2,3};
40
41 static inline void main_wait_160us(void){};
42 static inline void main_wait_20us(void){};
43 static inline uint8_t main_read_sensor(sensor_t sensor, uint8_t adress ){return adress;};
44 static inline void main_write_sensor(sensor_t sensor, uint8_t adress, uint8_t value){};
45 static inline void main_read_sensor_motion_burst(uint8_t* buffer){};
46 static inline void main_write_sensor_burst(uint8_t adress){};
47 static inline void HAL_Delay(int delay){};
48 static inline void HAL_GPIO_WritePin(int port, int pin, int state){};
49 static inline uint32_t mouseDriver_getTime(void){
50   static uint32_t i = 0;
51   i++;
52   return i;
53 }
54
55 #endif /* MOCK_SENSORDRIVER_H_ */
```

```
1 /*
2  * test.h
3  *
4  *  Created on: Nov 24, 2019
5  *      Author: Didier
6  */
7
8 #ifndef TEST_MOUSEDRIVER_H_
9 #define TEST_MOUSEDRIVER_H_
10
11 #include <stdio.h>
12 #include <stdlib.h>
13 #include <stdbool.h>
14 #include <math.h>
15 #include "mavlink.h"
16
17 /* Define testing functions*/
18 bool test_mouseDriver_init(void);
19 bool test_mouseDriver_idle(void);
20 bool test_mouseDriver_getTime(void);
21 bool test_mouseDriver_send_status_msg(void);
22 bool test_mouseDriver_control_idle(void);
23
```

```
#endif /* TEST_MOUSEDRIVER_H_ */
```

```
/*
 * test_sensorDriver.h
 *
 *  Created on: Nov 25, 2019
 *      Author: Didier
 */

#ifndef TEST_SENSORDRIVER_H_
#define TEST_SENSORDRIVER_H_

#include <stdio.h>
#include <stdlib.h>
#include <stdbool.h>
#include <math.h>
#include "mavlink.h"

/* Define test functions */
bool test_sensorDriver_init(void);

#endif /* TEST_SENSORDRIVER_H_ */
```

```
/*
 * test_mouseDriver.c
 *
 *  Created on: Nov 24, 2019
 *      Author: Didier
 */
#include "test_mouseDriver.h"
#include "mock_mouseDriver.h"
#include "display.h"
#include "mouseDriver.c"


bool test_mouseDriver_init(void){

    bool test = 1;

    actual_mode = 5;
    for(int i = 0; i < MAX_POINTS; i++){
        points[i].duration = i;
        points[i].setpoint_x = i;
        points[i].setpoint_y = i;
        points[i].point_id = i;
    }
    actual_point = 10;
    actual_point_start_time = 10;
    actual_speed_setpoint.setpoint_x = 10;
    actual_speed_setpoint.setpoint_y = 10;
    actual_motor_signal.motor_x = 10;
    actual_motor_signal.motor_y = 10;

    sensor_init = 0;
    stop_motor = 0;

    mouseDriver_init();

    test &= display(actual_mode == 0, "actual_mode initialization");
```

```
37    test &= display(actual_point == 0, "actual_point initialization");
38    test &= display(actual_point_start_time == 0, "actual_point_start_time initialization");
39    test &= display((actual_speed_setpoint.setpoint_y  == 0)&& (actual_speed_setpoint.setpoint_x  ==
        0), "actual_speed_setpoint initialization");
40    bool test_sub = 1;
41    for(int i = 0; i < MAX_POINTS; i++){
42        test_sub &= ((points[i].duration == 0) && (points[i].setpoint_x == 0) &&
43                (points[i].setpoint_y == 0) && (points[i].point_id == 0));
44    }
45    test &= display(test_sub, "points initialized correctly");
46    test &= display(sensor_init == 1, "sensor_init initialization");
47    test &= display(stop_motor == 1, "stop_motor initialization");
48    test &= display((actual_motor_signal.motor_x  == 0)&& (actual_motor_signal.motor_y  == 0), "
        actual_motor_signal initialization");
49
50    return test;
51 }
52
53 bool test_mouseDriver_idle(void){
54    bool test = false;
55    actual_speed_measure.speed_x = -10;
56    actual_speed_measure.speed_y = -10;
57    actual_speed_measure.valid = 1;
58    actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
59    actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
60    actual_point_start_time = 0;
61    actual_point = 0;
62    points[0].duration = 100;
63    points[0].setpoint_x = 10;
64    points[0].setpoint_y = 10;
65    points[0].point_id = 0;
66
67    /* Test reading of sensors in SPEED mode */
68    actual_mode = MOUSE_MODE_SPEED;
69    sensor_read_x = 0;
70    sensor_read_y = 0;
71    stop_motor = 1;
72    mouseDriver_idle();
73    test = display(sensor_read_x == 1, "read sensor x in MOUSE_MODE_SPEED");
74    test &= display(sensor_read_y == 1, "read sensor y in MOUSE_MODE_SPEED");
75    test &= display(stop_motor == 0, "motor started in MOUSE_MODE_SPEED");
76
77    /* Test reading of sensors in MOUSE_MODE_AUTO_RUN mode */
78    actual_mode = MOUSE_MODE_AUTO_RUN;
79    sensor_read_x = 0;
80    sensor_read_y = 0;
81    stop_motor = 1;
82    mouseDriver_idle();
83    test &= display(sensor_read_x == 1, "read sensor x in MOUSE_MODE_AUTO_RUN");
84    test &= display(sensor_read_y == 1, "read sensor y in MOUSE_MODE_AUTO_RUN");
85    test &= display(stop_motor == 0, "motor started in MOUSE_MODE_AUTO_RUN");
86    return test;
87 }
88 bool test_mouseDriver_getTime(void){
89    bool test = 1;
90    uint32_t start = HAL_GetTick();
91    test &= mouseDriver_getTime() == start+1;
92    test &= mouseDriver_getTime() == start+2;
```

```
93      test &= mouseDriver_getTime() == start+3;
94      test &= mouseDriver_getTime() == start+4;
95      test &= mouseDriver_getTime() == start+5;
96      display(test, "time update");
97
98      return test;
99  }
100 bool test_mouseDriver_send_status_msg(void){
101     bool test = false;
102     send_msg = 0;
103
104     mouseDriver_send_status_msg();
105
106     test = send_msg;
107     display(test, "status message send request");
108     return test;
109 }
110 bool test_mouseDriver_control_idle(void){
111     bool test = 1;
112     stop_motor = 0;
113     actual_speed_measure.speed_x = -10;
114     actual_speed_measure.speed_y = -10;
115     actual_motor_signal.motor_x = 10;
116     actual_motor_signal.motor_y = 10;
117     actual_mode = MOUSE_MODE_STOP;
118
119     /* Case actual mode == STOP */
120     printf("if (actual_mode ==  MOUSE_MODE_STOP)\n");
121     mouseDriver_control_idle();
122     test &= display((actual_motor_signal.motor_x  == 0)&& (actual_motor_signal.motor_y  == 0), "
          actual_motor_signal reset");
123     test &= display(stop_motor == 1, "motor stop");
124
125     /* Case actual mode == SPEED */
126     actual_mode = MOUSE_MODE_SPEED;
127     stop_motor = 1;
128     actual_speed_setpoint.setpoint_y = 0;
129     actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
130     actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
131     actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
132     printf("if (actual_mode ==  MOUSE_MODE_SPEED)\n");
133     mouseDriver_control_idle();
134     test &= display(stop_motor == 0, "motor_x speed changed");
135     for(int i = 0; i < 100; i++)
136         mouseDriver_control_idle();
137     test &= display(actual_motor_signal.motor_x <= MAX_MOTOR_SIGNAL, "motor_x with
          MAX_MOTOR_SIGNAL limit");
138
139     stop_motor = 1;
140     actual_speed_setpoint.setpoint_x = 0;
141     actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
142     actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
143     actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
144     mouseDriver_control_idle();
145     test &= display(stop_motor == 0, "motor_y speed changed");
146     for(int i = 0; i < 100; i++)
147         mouseDriver_control_idle();
148     test &= display(actual_motor_signal.motor_y <= MAX_MOTOR_SIGNAL, "motor_y with
```

```
    MAX_MOTOR_SIGNAL limit");
149
150 actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
151 actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
152 actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
153 actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
154 mouseDriver_control_idle();
155 test &= display(stop_motor == 0, "motor_y and motor_x speed changed");
156 for(int i = 0; i < 100; i++)
157     mouseDriver_control_idle();
158 test &= display((actual_motor_signal.motor_y <= MAX_MOTOR_SIGNAL) && (
    actual_motor_signal.motor_x <= MAX_MOTOR_SIGNAL), "motor_y and motor_x with
    MAX_MOTOR_SIGNAL limit");
159
160 /* Reaction to invalid measures */
161 actual_speed_setpoint.setpoint_x = 0;
162 actual_speed_setpoint.setpoint_y = 0;
163 actual_speed_measure.speed_x = 1000;
164 actual_speed_measure.speed_y = 1000;
165 actual_motor_signal.motor_x = 10;
166 actual_motor_signal.motor_y = 10;
167 bool test_stop = true;
168 actual_speed_measure.valid = 0;
169 for(int i = 0;i < MAX_MISSING_MEASURES-1; i++ ){
170     test_stop &= (actual_motor_signal.motor_x == 10);
171     test_stop &= (actual_motor_signal.motor_y == 10);
172     mouseDriver_control_idle();
173 }
174 mouseDriver_control_idle();
175 test &= display(test_stop, "constant motor signal if invalid measure");
176 test &= display(actual_mode == MOUSE_MODE_STOP, "stop motor after too many invalid measures
    ");
177
178
179
180 /* Case actual mode == SPEED */
181 actual_mode = MOUSE_MODE_AUTO_RUN;
182 stop_motor = 1;
183 actual_speed_setpoint.setpoint_y = 0;
184 actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
185 actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
186 actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
187 actual_speed_measure.valid = 1;
188 printf("if (actual_mode ==  MOUSE_MODE_AUTO_RUN)\n");
189 mouseDriver_control_idle();
190 test &= display(stop_motor == 0, "motor_x speed changed");
191 for(int i = 0; i < 100; i++)
192     mouseDriver_control_idle();
193 test &= display(actual_motor_signal.motor_x <= MAX_MOTOR_SIGNAL, "motor_x with
    MAX_MOTOR_SIGNAL limit");
194
195 stop_motor = 1;
196 actual_speed_setpoint.setpoint_x = 0;
197 actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
198 actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
199 actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
200 mouseDriver_control_idle();
201 test &= display(stop_motor == 0, "motor_y speed changed");
```

```
202     for(int i = 0; i < 100; i++)
203         mouseDriver_control_idle();
204     test &= display(actual_motor_signal.motor_y <= MAX_MOTOR_SIGNAL, "motor_y with
          MAX_MOTOR_SIGNAL limit");
205
206     actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
207     actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
208     actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
209     actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
210     mouseDriver_control_idle();
211     test &= display(stop_motor == 0, "motor_y and motor_x speed changed");
212     for(int i = 0; i < 100; i++)
213         mouseDriver_control_idle();
214     test &= display((actual_motor_signal.motor_y <= MAX_MOTOR_SIGNAL) && (
          actual_motor_signal.motor_x <= MAX_MOTOR_SIGNAL), "motor_y and motor_x with
          MAX_MOTOR_SIGNAL limit");
215
216     test_stop = true;
217     actual_speed_measure.valid = 0;
218     actual_motor_signal.motor_x = 10;
219     actual_motor_signal.motor_y = 10;
220     for(int i = 0;i < MAX_MISSING_MEASURES-1; i++ ){
221         test_stop &= (actual_motor_signal.motor_x == 10);
222         test_stop &= (actual_motor_signal.motor_y == 10);
223         mouseDriver_control_idle();
224     }
225     mouseDriver_control_idle();
226     test &= display(test_stop, "constant motor signal if invalid measure");
227     test &= display(actual_mode == MOUSE_MODE_STOP, "stop motor after too many invalid measures
          ");
228
229     return test;
230 }
```

```
1  /*
2   * test_sensorDriver.c
3   *
4   *  Created on: Nov 25, 2019
5   *      Author: Didier
6   */
7
8  #include "test_sensorDriver.h"
9  #include "mock_sensorDriver.h"
10 #include "display.h"
11 #include "sensorDriver.c"
12
13 bool test_sensorDriver_init(void){
14     return display(0,"TEST SENSOR DRIVER");
15 }
```

B.5 Build script

```
1 #!/bin/bash
2 # Script for compiling and running test before compilation
3 # of the STM32 code and upload.
4 echo PRE-BUILD STEPS
5 echo CLEANING TESTS
6 make clean -C ../../CodeSTM32/test/Debug/
```

```
echo COMPILING TESTS
make all -C ../../CodeSTM32/test/Debug/
echo RUNNING TESTS
./../../CodeSTM32/test/Debug/test
```

C Code for PC

C.1 GUI

```
import serial
import os
import sys
import numpy as np
#import matplotlib as plt
from appJar import gui
import time
import json
from tqdm import tqdm
import routine as mouseRoutine
from pymavlink.dialects.v20 import mouse as mouseController

"""
PATH

/Users/Didier/Desktop/EPFL/Secondo_master/SemesterProject2019/GITRepository/3DMouseTreadmill/
    MouseTreadmillPC/python
"""
SENSOR_STATUS_MSG = ["SENSOR STATUS", "ID 66 = ", "LIFT 0 = ", "SQUAL > 20 = ", "ROM 4
    = "]
MODES = ["STOP", "SPEED","AUTO","RUNNING"]
MODES_NUM = {"STOP": int(0),"SPEED": int(1),"AUTO": int(2),"RUNNING": int(3) }
DATA = { "HEARTBEAT": {"time": [], "mode": []},
        "SPEED_SETPOINT": {"time": [], "setpoint_x": [], "setpoint_y": [], "start": 0},
        "SPEED_INFO":  {"time": [], "speed_x": [], "speed_y": [], "start": 0},
        "MOTOR_SETPOINT": {"time": [], "motor_x": [], "motor_y": [], "start": 0}
        }
LOG = []
MAX_SAMPLES_ON_SCREEN = 200
print(mouseController.MAVLink_speed_info_message.fieldnames)
port = "/dev/cu.usbmodem14102"

class MyApplication():
    actualMode = 0
    actualTime = 0
    actualSpeedSetpoint = [None, None]
    actualMotorSetpoint = [None, None]
    actualSpeedInfo = [None, None]
    connection = serial.Serial(port, baudrate = 230400, timeout = 50)
    mavlink = mouseController.MAVLink(file = connection )
    setpointX = 0.0
    setpointY = 0.0

    def commSTM32 (self):
        # Init variables
        m = None
        while(self.connection.in_waiting>0):
            # Recive messages
```

```
47          try:
48              m = self.mavlink.parse_char(self.connection.read())
49          except:
50              pass
51          if m:
52              LOG.append(m)
53              if m.name == "HEARTBEAT":
54                  self.actualTime = m.time
55                  self.actualMode = m.mode
56                  DATA["HEARTBEAT"]["time"].append(self.actualTime)
57                  DATA["HEARTBEAT"]["mode"].append(self.actualMode)
58              elif m.name == "SPEED_SETPOINT":
59                  self.actualSpeedSetpoint[0] = m.setpoint_x
60                  self.actualSpeedSetpoint[1] = m.setpoint_y
61                  DATA["SPEED_SETPOINT"]["time"].append(self.actualTime)
62                  DATA["SPEED_SETPOINT"]["setpoint_x"].append(self.actualSpeedSetpoint[0])
63                  DATA["SPEED_SETPOINT"]["setpoint_y"].append(self.actualSpeedSetpoint[1])
64                  #DATA["SPEED_SETPOINT"]["setpoint_z"].append(self.actualSpeedSetpoint[2])
65              elif m.name == "MOTOR_SETPOINT":
66                  self.actualMotorSetpoint[0] = m.motor_x
67                  self.actualMotorSetpoint[1] = m.motor_y
68                  DATA["MOTOR_SETPOINT"]["time"].append(m.time)
69                  DATA["MOTOR_SETPOINT"]["motor_x"].append(self.actualMotorSetpoint[0])
70                  DATA["MOTOR_SETPOINT"]["motor_y"].append(self.actualMotorSetpoint[1])
71                  #DATA["SPEED_SETPOINT"]["motor_z"].append(self.actualMotorSetpoint[2])
72              elif m.name == "SPEED_INFO":
73                  #print(m)
74                  DATA["SPEED_INFO"]["time"].append(m.time_x)
75                  DATA["SPEED_INFO"]["speed_x"].append(m.speed_x)
76                  #DATA["SPEED_INFO"]["speed_y"].append(m.speed_y)
77                  DATA["SPEED_INFO"]["speed_y"].append(0)
78              elif m.name == "RAW_SENSOR":
79                  if m.sensor_id == 0:
80                      status_x = []
81                      status_x.append(m.product_id)
82                      status_x.append(m.lift)
83                      status_x.append(m.squal)
84                      status_x.append(m.srom_id)
85                  elif m.sensor_id == 1:
86                      status_y = []
87                      status_y.append(m.product_id)
88                      status_y.append(m.lift)
89                      status_y.append(m.squal)
90                      status_y.append(m.srom_id)
91                  try:
92                      if (len(status_x) == 4) and (len(status_y) == 4):
93                          self.app.setLabel("sensorStatus1",SENSOR_STATUS_MSG[1]+str(status_x[0])+"|"+
    str(status_y[0]))
94                          self.app.setLabel("sensorStatus2",SENSOR_STATUS_MSG[2]+str(status_x[1])+"|"+
    str(status_y[1]))
95                          self.app.setLabel("sensorStatus3",SENSOR_STATUS_MSG[3]+str(status_x[2])+"|"+
    str(status_y[2]))
96                          self.app.setLabel("sensorStatus4",SENSOR_STATUS_MSG[4]+str(status_x[3])+"|"+
    str(status_y[3]))
97                  except:
98                      pass
99
100
```

```
101             elif m.name == "POINT":
102                 print(m)
103             else:
104                 pass
105         m = None
106     def refreshPlot(self):
107 
108         # Clear plot
109         for i in range(3):
110             self.ax[i].clear()
111 
112         # Define labels
113         """
114         self.ax[2].set_xlabel("Time")
115         self.ax[2].set_ylabel("Measured speed [m/s]")
116         self.ax[1].set_ylabel("Speed setpoint [m/s]")
117         self.ax[0].set_ylabel("Motor signal [ ]")
118         """
119 
120         # Limit max amout of points on one graph
121         if len(DATA["SPEED_INFO"]["time"][DATA["SPEED_INFO"]["start"]:])-1>
    MAX_SAMPLES_ON_SCREEN:
122             DATA["SPEED_INFO"]["start"] = -MAX_SAMPLES_ON_SCREEN
123             DATA["SPEED_SETPOINT"]["start"] = -MAX_SAMPLES_ON_SCREEN
124             DATA["MOTOR_SETPOINT"]["start"] = -MAX_SAMPLES_ON_SCREEN
125 
126         # Re-plot all graphs
127         self.ax[2].plot(DATA["SPEED_INFO"]["time"][DATA["SPEED_INFO"]["start"]:], DATA["
    SPEED_INFO"]["speed_x"][DATA["SPEED_INFO"]["start"]:], 'b.')
128         self.ax[2].plot(DATA["SPEED_INFO"]["time"][DATA["SPEED_INFO"]["start"]:], DATA["
    SPEED_INFO"]["speed_y"][DATA["SPEED_INFO"]["start"]:], 'r.')
129         self.ax[1].plot(DATA["SPEED_SETPOINT"]["time"][DATA["SPEED_SETPOINT"]["start"]:], DATA[
    "SPEED_SETPOINT"]["setpoint_x"][DATA["SPEED_SETPOINT"]["start"]:],'b.')
130         self.ax[1].plot(DATA["SPEED_SETPOINT"]["time"][DATA["SPEED_SETPOINT"]["start"]:], DATA[
    "SPEED_SETPOINT"]["setpoint_y"][DATA["SPEED_SETPOINT"]["start"]:],'r.')
131         self.ax[0].plot(DATA["MOTOR_SETPOINT"]["time"][DATA["MOTOR_SETPOINT"]["start"]:],
    DATA["MOTOR_SETPOINT"]["motor_x"][DATA["MOTOR_SETPOINT"]["start"]:],'b.')
132         self.ax[0].plot(DATA["MOTOR_SETPOINT"]["time"][DATA["MOTOR_SETPOINT"]["start"]:],
    DATA["MOTOR_SETPOINT"]["motor_y"][DATA["MOTOR_SETPOINT"]["start"]:],'r.')
133         self.ax[0].set_adjustable('box',True)
134         self.app.refreshPlot("plot")
135 
136     def resetPlot(self):
137         DATA["SPEED_INFO"]["start"] = len(DATA["SPEED_INFO"]["time"])-3
138         DATA["SPEED_SETPOINT"]["start"] = len(DATA["SPEED_SETPOINT"]["time"])-3
139         DATA["MOTOR_SETPOINT"]["start"] = len(DATA["MOTOR_SETPOINT"]["time"])-3
140 
141     def refreshGUI(self):
142         self.commSTM32()
143 
144         # Refresh status bar
145         self.app.setStatusbar("Time: "+str(self.actualTime)+" [ms]", 0)
146         self.app.setStatusbar("Modes: "+str(MODES[self.actualMode]), 1)
147         self.refreshPlot()
148         """
149         self.app.setLabel("speedSetpointX", str(self.actualSpeedSetpoint[0]))
150         self.app.setLabel("speedSetpointY", str(self.actualSpeedSetpoint[1]))
151         self.app.setLabel("motorSetpointX", str(self.actualMotorSetpoint[0]))
```

```
152         self.app.setLabel("motorSetpointY", str(self.actualMotorSetpoint[1]))
153         """
154 
155     def setMode(self):
156         self.mavlink.mode_selection_send(MODES_NUM[self.app.getRadioButton("optionMode")])
157         while(self.connection.out_waiting > 0):
158             time.sleep(0.001)
159         time.sleep(0.001)
160         if self.actualMode == mouseController.MOUSE_MODE_STOP:
161             self.setpointX = 0
162             self.setpointY = 0
163 
164 
165     def setSpeedX(self):
166         if self.actualMode == mouseController.MOUSE_MODE_SPEED:
167             self.setpointX = self.app.getEntry("speedX")
168             if self.setpointX is None or  self.setpointY is None :
169                 pass
170             else:
171                 self.mavlink.speed_setpoint_send(float(self.setpointX), float(self.setpointY))
172                 while(self.connection.out_waiting > 0):
173                     time.sleep(0.001)
174                 time.sleep(0.001)
175 
176     def setSpeedY(self):
177         if self.actualMode == mouseController.MOUSE_MODE_SPEED:
178             self.setpointY = self.app.getEntry("speedY")
179             if self.setpointX is None or  self.setpointY is None :
180                 pass
181             else:
182                 self.mavlink.speed_setpoint_send(float(self.setpointX), float(self.setpointY))
183             while(self.connection.out_waiting > 0):
184                 time.sleep(0.001)
185             time.sleep(0.001)
186 
187     def loadRoutine(self):
188         if self.actualMode == mouseController.MOUSE_MODE_AUTO_LOAD:
189             if (len(mouseRoutine.ROUTINE["duration"])>254 or len(mouseRoutine.ROUTINE["setpoint_x"])
    >254 or len(mouseRoutine.ROUTINE["setpoint_y"])>254):
190                 raise ValueError("mouseRoutine too long")
191             if not (len(mouseRoutine.ROUTINE["duration"]) == len(mouseRoutine.ROUTINE["setpoint_x"])
    == len(mouseRoutine.ROUTINE["setpoint_y"])):
192                 raise ValueError("not all components of mouseRoutine have the same lenght")
193 
194 
195             # TODO add verification on max speed and min speed
196 
197 
198             for i in tqdm(range(len(mouseRoutine.ROUTINE["duration"]))):
199                 self.mavlink.point_send(mouseRoutine.ROUTINE["duration"][i],i,mouseRoutine.ROUTINE["
    setpoint_x"][i], mouseRoutine.ROUTINE["setpoint_y"][i])
200                 stop = True
201                 while(self.connection.in_waiting>0 or stop):
202                     # Recive messages
203                     try:
204                         m = self.mavlink.parse_char(self.connection.read())
205                     except:
206                         pass
```

```
207                 if m:
208                     #print(m)
209                     if m.name == "POINT_LOADED":
210                         if m.point_id == i:
211                             stop = False
212                         else:
213                             raise Exception("ERROR LOADING DATA, wrong msg_id received")
214     def saveLog(self):
215         with open('log/log.txt', 'w+') as f:
216             for item in LOG:
217                 f.write("%s\n" % item)
218 
219     def runRoutine(self):
220         if self.actualMode == mouseController.MOUSE_MODE_AUTO_LOAD:
221             self.mavlink.mode_selection_send(mouseController.MOUSE_MODE_AUTO_RUN)
222             while(self.connection.out_waiting > 0):
223                 time.sleep(0.001)
224             time.sleep(0.001)
225 
226     def Prepare(self, app):
227         self.ax = []
228 
229         app.setTitle("Mouse treadmill GUI")
230         app.setFont(12)
231         row = 0
232         column = 0
233 
234         # Mode Selection
235         app.startFrame("modeSelection",row = row, column = column, colspan=4, rowspan = 1)
236         app.addLabel("optionModeLabel","Mode",0,0,1,1)
237         app.addRadioButton("optionMode",MODES[0],0,1,1,1)
238         app.addRadioButton("optionMode",MODES[1],0,2,1,1)
239         app.addRadioButton("optionMode",MODES[2],0,3,1,1)
240         app.setRadioButtonChangeFunction("optionMode",self.setMode)
241         app.stopFrame()
242         row = row+1
243 
244         # Speed entry
245         app.startFrame("speedEntry",row = row, column = column, colspan=4, rowspan=2)
246         app.addLabel("speedXLabel", "Speed X", 0,0,2,1)
247         app.addNumericEntry("speedX",1,0,2,2)
248         app.setEntry("speedX", 0.0)
249         app.setEntryChangeFunction("speedX", self.setSpeedX)
250         app.addLabel("speedYLabel", "Speed Y",0,2,2,1)
251         app.addNumericEntry("speedY",1,2,2,2)
252         app.setEntry("speedY", 0.0)
253         app.setEntryChangeFunction("speedY", self.setSpeedY)
254         app.stopFrame()
255         row = row+2
256 
257         # Reset plot button
258         app.startFrame("GUIButtons", row = row, column = column, colspan=2, rowspan=2)
259         self.app.addButton("RESET PLOTS", self.resetPlot, 0,0,1,1)
260         self.app.addButton("LOAD POINTS", self.loadRoutine, 1,0,1,1)
261         self.app.addButton("RUN ROUTINE", self.runRoutine,1,1,1,1 )
262         self.app.addButton("SAVE LOG",self.saveLog,0,1,1,1)
263         row = row+1
264 
```

```
265         # Sensor Status
266         app.startFrame("sensorStatus", row = row, column = 0)
267         self.app.addLabel("sensorStatus0",SENSOR_STATUS_MSG[0], 0,0,1,1)
268         self.app.addLabel("sensorStatus1",SENSOR_STATUS_MSG[1], 1,0,3,1)
269         self.app.addLabel("sensorStatus2",SENSOR_STATUS_MSG[2], 2,0,3,1)
270         self.app.addLabel("sensorStatus3",SENSOR_STATUS_MSG[3], 3,0,3,1)
271         self.app.addLabel("sensorStatus4",SENSOR_STATUS_MSG[4], 4,0,3,1)
272         row = row+4
273 
274         # Real-time data plotting
275         app.startFrame("realTimePlot", row = row, column = column, colspan = 4, rowspan = 4)
276         self.fig = app.addPlotFig("plot",0,0,4,4, showNav = True )
277         self.ax.append(self.fig.add_subplot(311))
278         self.ax.append(self.fig.add_subplot(312))
279         self.ax.append(self.fig.add_subplot(313))
280         app.stopFrame()
281         row = row+4
282 
283 
284         # Add status bar
285         app.addStatusbar(fields = 2, side=None)
286         app.setStatusbar("Time: 0", 0)
287         app.setStatusbar("Mode: "+MODES[0], 1)
288 
289         # refresh funciton
290         app.setPollTime(100)
291         app.registerEvent(self.refreshGUI)
292 
293         # Window for sensor status
294         app.startSubWindow("sensorStatus")
295         app.addLabel("status", "SENSOR_X")
296         app.stopSubWindow()
297         app.openSubWindow("sensorStatus")
298 
299         return app
300     # Build and Start your application
301     def Start(self):
302         app = gui()
303 
304         self.app = app
305 
306         # Run the prebuild method that adds items to the UI
307         self.app = self.Prepare(self.app)
308         self.app.showAllSubWindow()
309         # Start appJar
310         self.app.go()
311 
312 if __name__ == '__main__':
313     print("
        ==========================================================================
        ")
314     print("Running GUI for mouse treadmill")
315     print("
        ==========================================================================
        ")
316 
317     # Create an instance of your application
318     App = MyApplication()
```

```
319
320     # Start your app !
321     App.Start()
```

C.2 Routine example

```
1 ROUTINE = {
2     "duration":[500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
        100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500,
         500, 100,500, 500, 500, 100, 500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
        100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500,
         500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
        100,500, 500, 500, 100, 500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100],
3     "setpoint_x": [500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
        100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500,
         500, 100,500, 500, 500, 100, 500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
        100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500,
         500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
        100,500, 500, 500, 100, 500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100],
4     "setpoint_y": [500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
        100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500,
         500, 100,500, 500, 500, 100, 500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
        100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500,
         500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
        100,500, 500, 500, 100, 500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100],
5 }
```

D Data-sheets

D.1 Sensor Data-sheet

PMW3360DM-T2QU: Optical Gaming Navigation Chip

General Description:

PMW3360DM-T2QU is PixArt Imaging's high end gaming integrated chip which comprises of navigation chip and IR LED integrated in a 16pin molded lead-frame DIP package. It provides best in class gaming experience with the enhanced features of high speed, high resolution, high accuracy and selectable lift detection height to fulfill professional gamers' need. The chip comes with self-adjusting variable frame rate algorithm to enable wireless gaming application. It is designed to be used with LM19-LSI lens to achieve optimum performance.

Key Features:

- Integrated 16 pin molded lead-frame DIP package with IR LED
- Operating Voltage: 1.8V - 2.1V
- Lift detection options
  - Manual lift cut off calibration
  - 2mm
  - 3mm
- High speed motion detection 250ips (typical) and acceleration 50g (max).
- Selectable resolutions up to 12000cpi with 100cpi step size
- Resolution error of 1% (typical)
- Four wire serial port interface (SPI)
- External interrupt output for motion detection
- Internal oscillator — no clock input needed
- Self-adjusting variable frame rate for optimum power performance in wireless application
- Customizable response time and downshift time for rest modes
- Enhanced programmability
  - Angle snapping
  - Angle tunability

Applications:

- Wired and Wireless Optical gaming mice
- Integrated input devices
- Battery-powered input devices

Key Chip Parameters:

Parameter	Value
Power supply Range	1.8V - 2.1V
Optical Lens	1:1
Interface	4 wire Serial Port Interface (SPI)
System Clock	70MHz
Frame Rate	Up to 12000 fps
Speed	250ips (typical)
Resolution	12000 cpi
Package Type	16 pin molded lead-frame DIP package with integrated IR LED

Ordering Information:

Part Number	Package Type
PMW3360DM-T2QU	16pin-DIP
LM19-LSI	Lens

RoHS compliant

Contents

1.0 System Level Description

This section covers PMW3360's guidelines and recommendations in term of chip, lens & PCB assemblies.

1.1 Pin Configuration

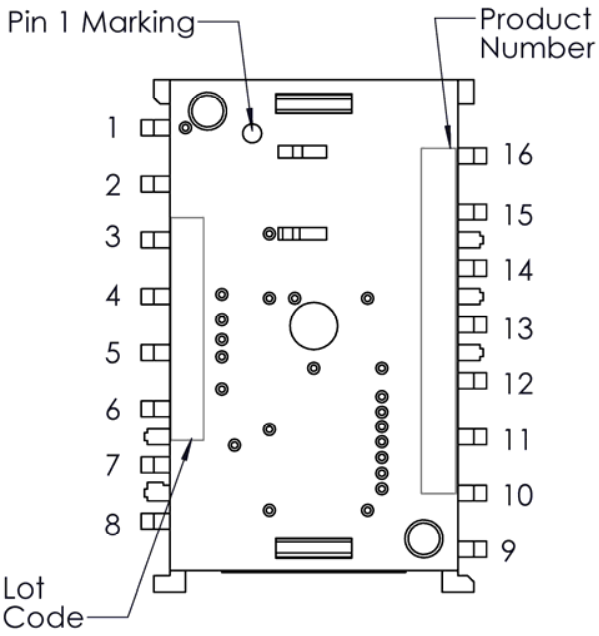


Figure 1. Device output pins

Pin No.	Function	Symbol	Type	Description
1	NA	NC	NC	(Float)
2	NA	NC	NC	(Float)
3	Supply Voltage and I/O Voltage	VDDPIX	Power	LDO output for selective analog circuit
4		VDD	Power	Input power supply
5		VDDIO	Power	I/O reference voltage
6	NA	NC	NC	(Float)
7	Reset control	NRESET	Input	Chip reset(active low)
8	Ground	GND	GND	Ground
9	Motion Output	MOTION	Output	Motion detect
10	4-wire spi communication	SCLK	Input	Serial data clock
11		MOSI	Input	Serial data input
12		MISO	Output	Serial data output
13		NCS	Input	Chip select(active low)
14	NA	NC	NC	(Float)
15	LED	LED_P	Input	LED Anode
16	NA	NC	NC	(Float)

Table 1. PMW3360DM-T2QU Pin Description

Items	Marking	Remark
Product Number	PMW3360DM-T2QU	
Lot Code	AYWWXXXXX	**A** : Assembly house **Y**: Year **WW**: Week **XXXXX**: PixArt reference

1.2 Package Outline Drawing

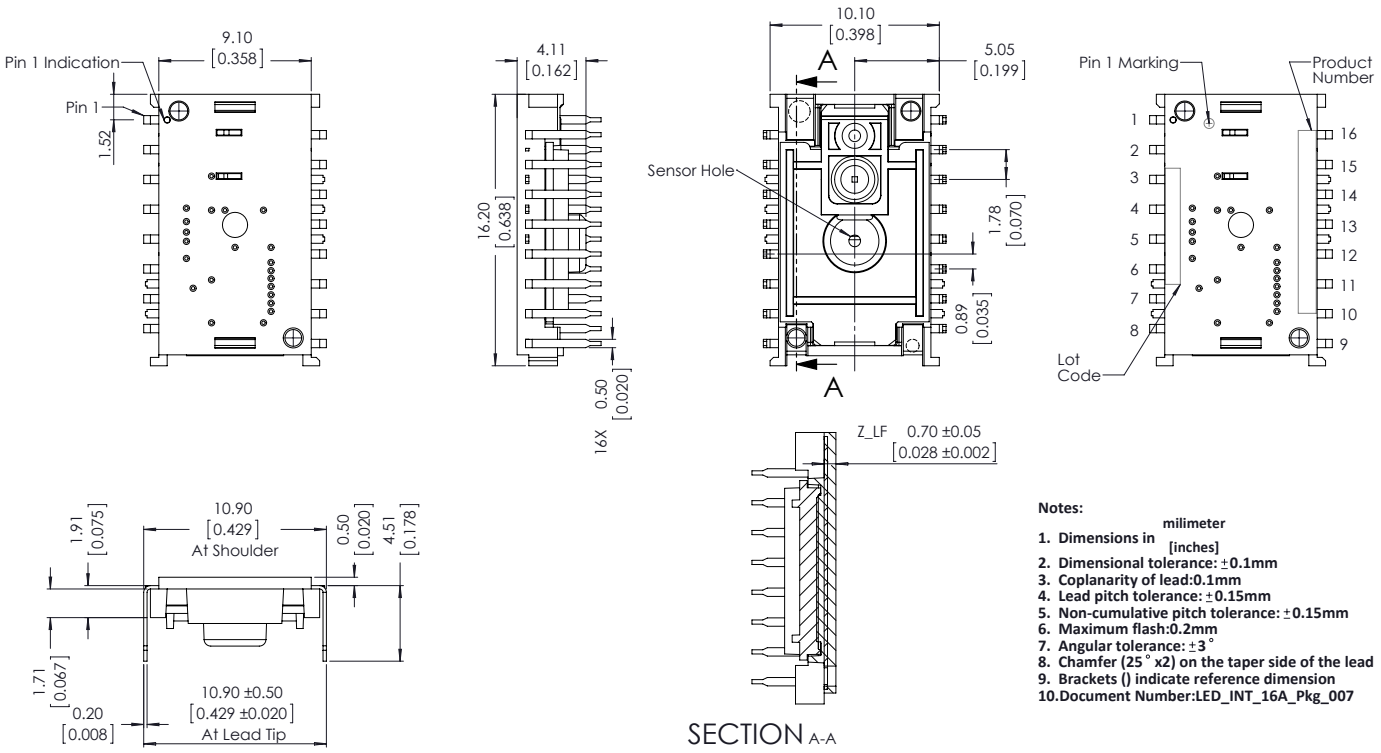


Figure 2. Package Outline Drawing

CAUTION: It is advised that normal static discharge precautions be taken in handling and assembling of this component to prevent damage and/or degradation which may be induced by ESD.

1.3 Assembly Drawings

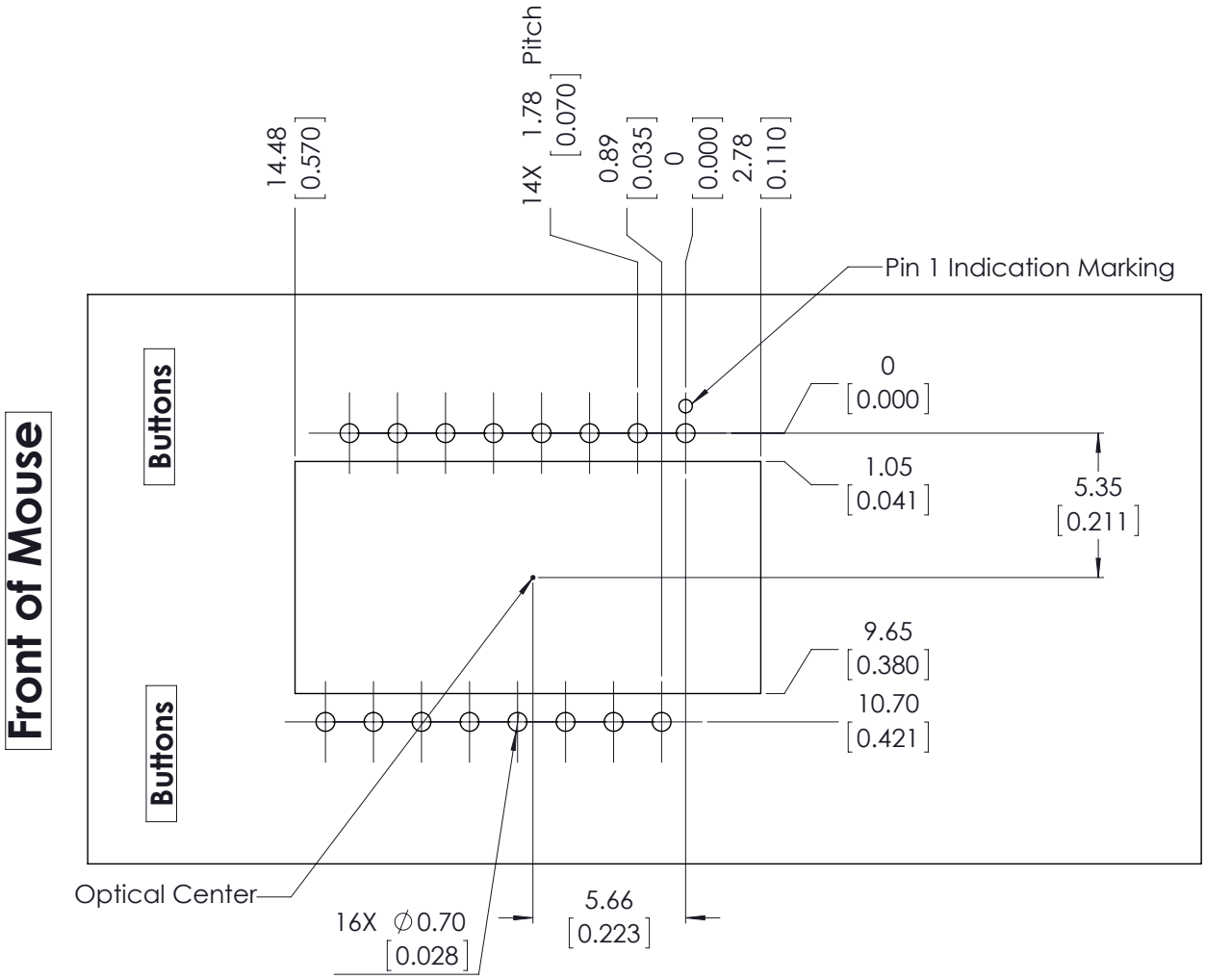


Figure 3. Recommended chip orientation, mechanical cutouts and spacing (Top View)

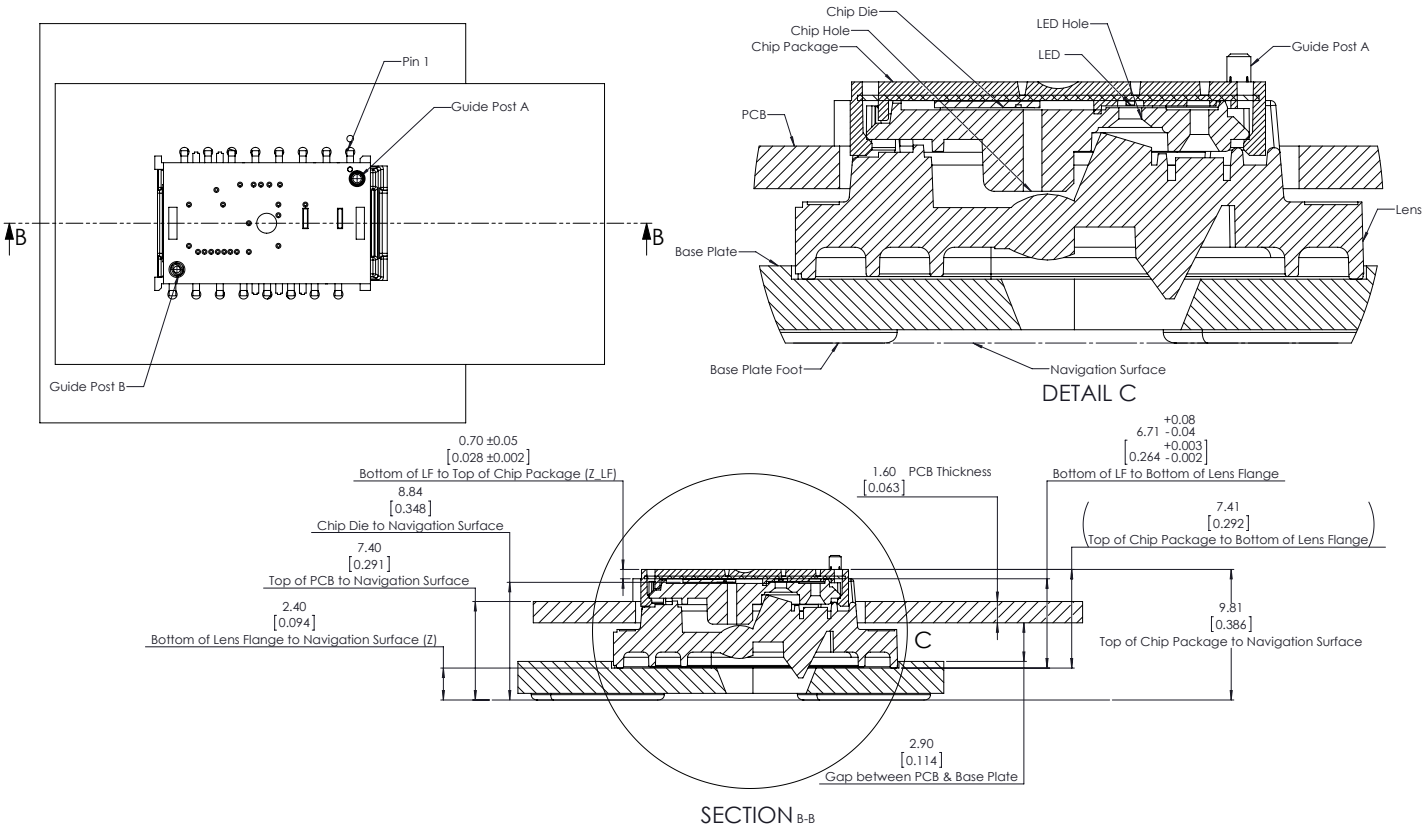


Figure 4. Assembly drawing of PMW3360DM-T2QU and distance from lens reference plane to tracking surface (Z)

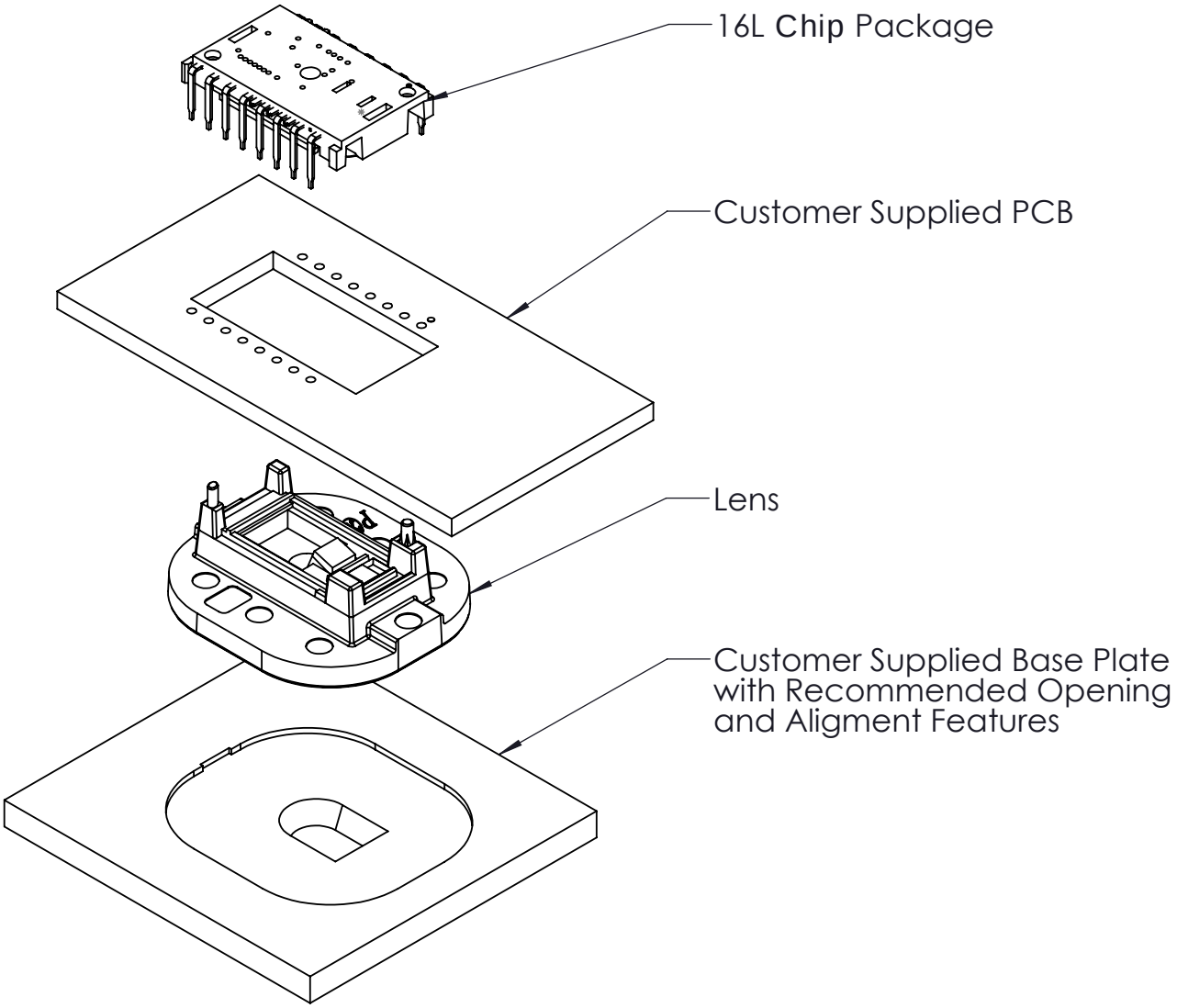


Figure 5. Exploded Assembly View

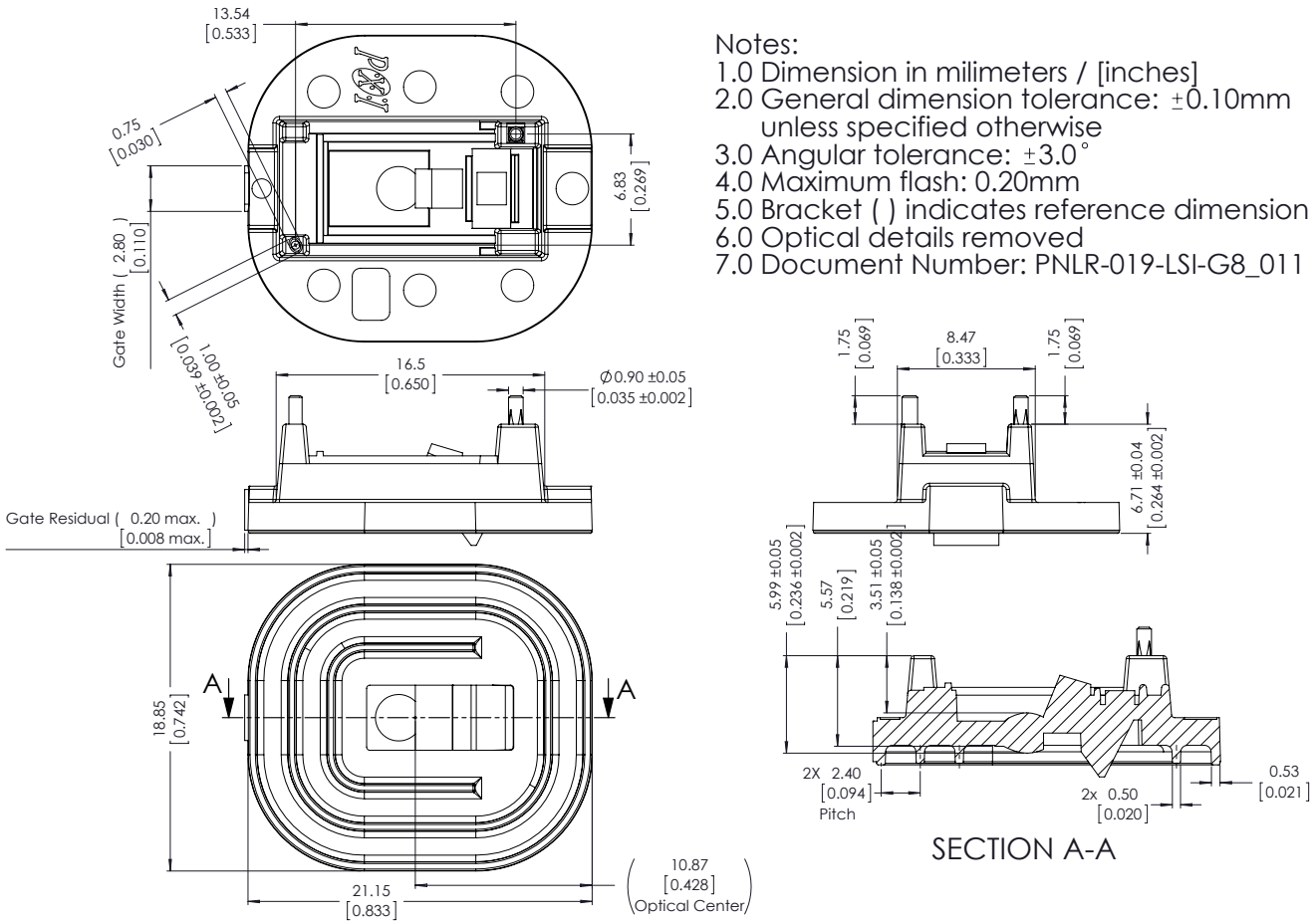


Figure 6. Lens Outline Drawing

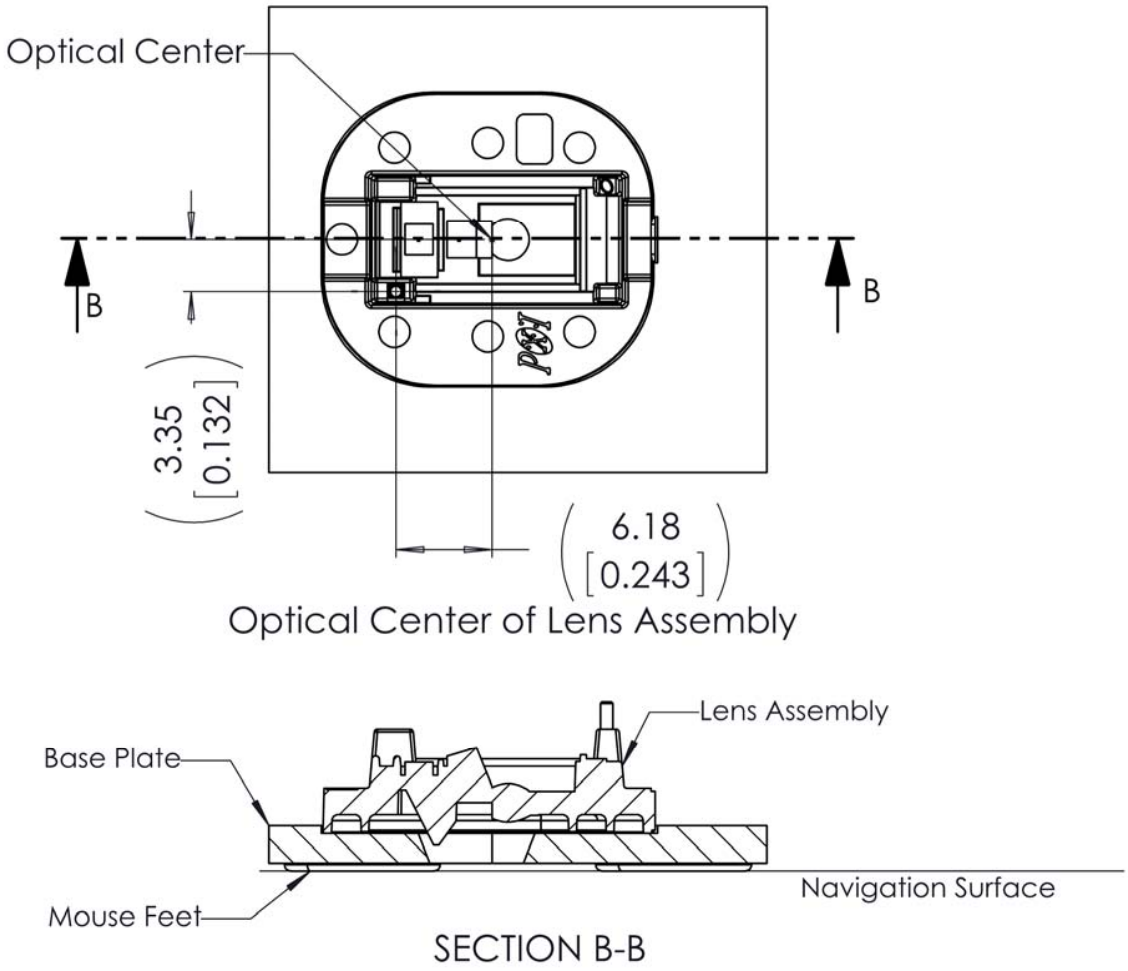


Figure 7. Cross section view of lens assembly

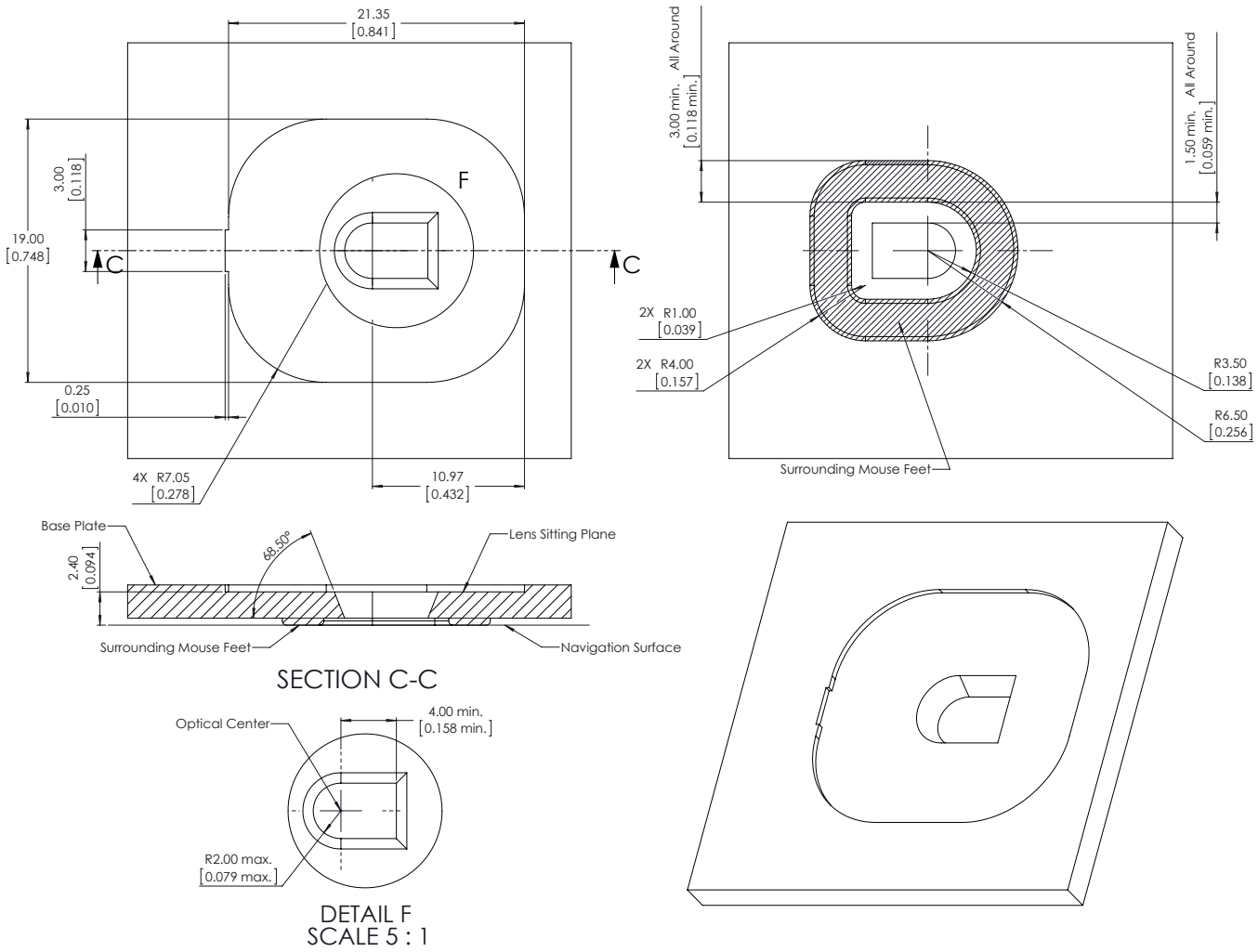


Figure 8. Recommended Base Plate Opening

Note: *Mouse feet should be placed close to the opening to stabilize the surface within the FOV of the chip.*

1.4 PCB Assembly Recommendation

1) Insert the integrated chip and all other electrical components into PCB.
2) Wave-solder the entire assembly in a no-wash solder process utilizing solder-fixture. A solder-fixture is required to protect the chip from flux spray and wave solder.
3) Avoid getting any solder flux onto the chip body as there is potential for flux to seep into the chip package, the solder fixture should be designed to expose only the chip leads to flux spray & molten solder while shielding the chip body and optical apertures. The fixture should also set the chip at the correct position and height on the PCB.
4) Place the lens onto the base plate. Care must be taken to avoid contamination on the optical surfaces.
5) Remove the protective kapton tapes from optical apertures of the chip. Care must be taken to prevent Contaminants from entering the apertures. Do not place the PCB with the chip facing up during the entire mouse assembly process. Hold the PCB vertically when removing kapton tape.
6) Insert PCB assembly over the lens onto the base plate aligning post to retain PCB assembly. The chip package will self-align to the lens via the guide posts. The optical position reference for the PCB is set by the base plate and lens. Note that the PCB motion due to button presses must be minimized to maintain optical alignment.
7) Recommendation: The lens can be permanently secured to the chip package by melting the lens' guide posts over the chip with heat staking process. Please refer to the application note PMS0122-LM19-LSI-AN for more details.
8) Install mouse top case. There must be a feature in the top case to press down onto the PCB assembly to ensure all components are stacked or interlocked to the correct vertical height.

Chip Block Diagram

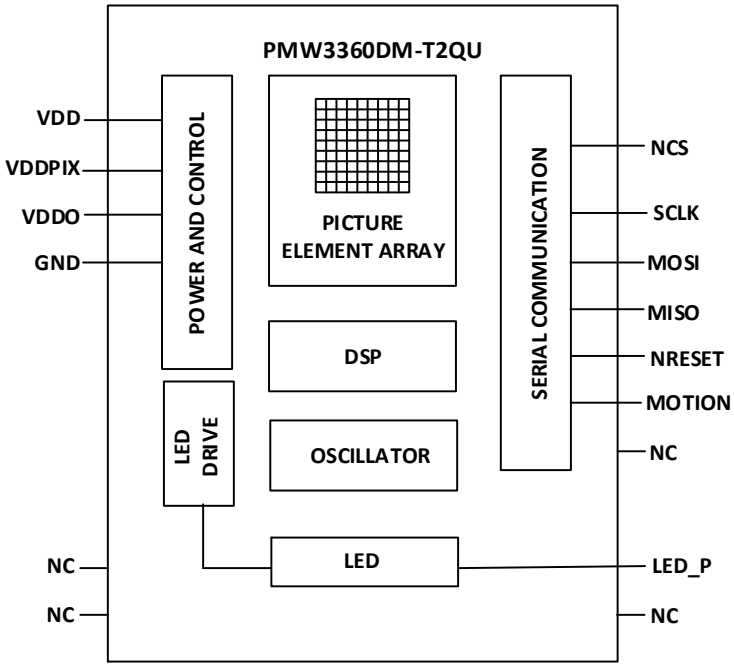


Figure 9. Block diagram of PMW3360DM-T2QU

1.5 Reference Schematics

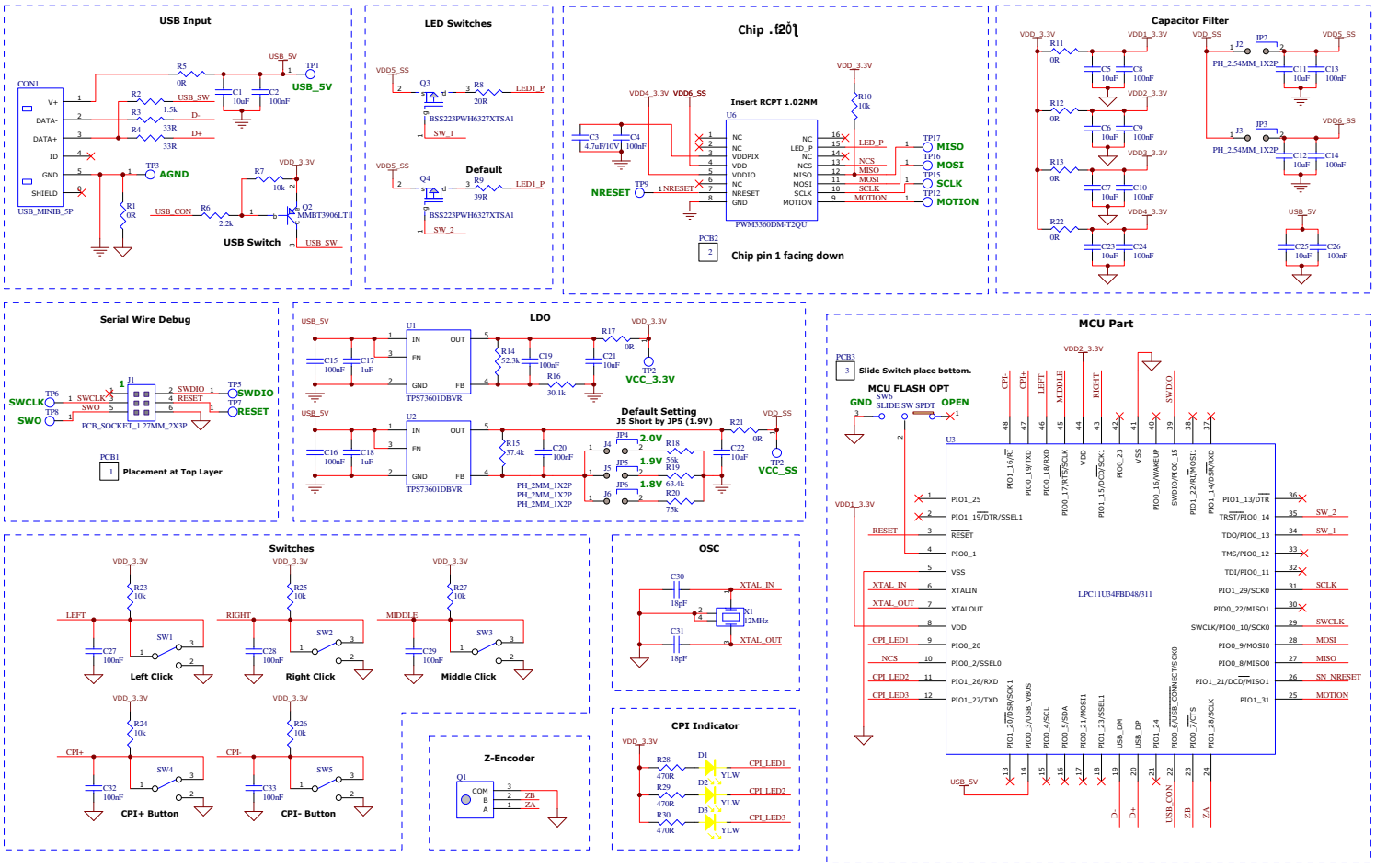


Figure 10. Schematic diagram for interface between PMW3360DM-T2QU and microcontroller on a wired solution

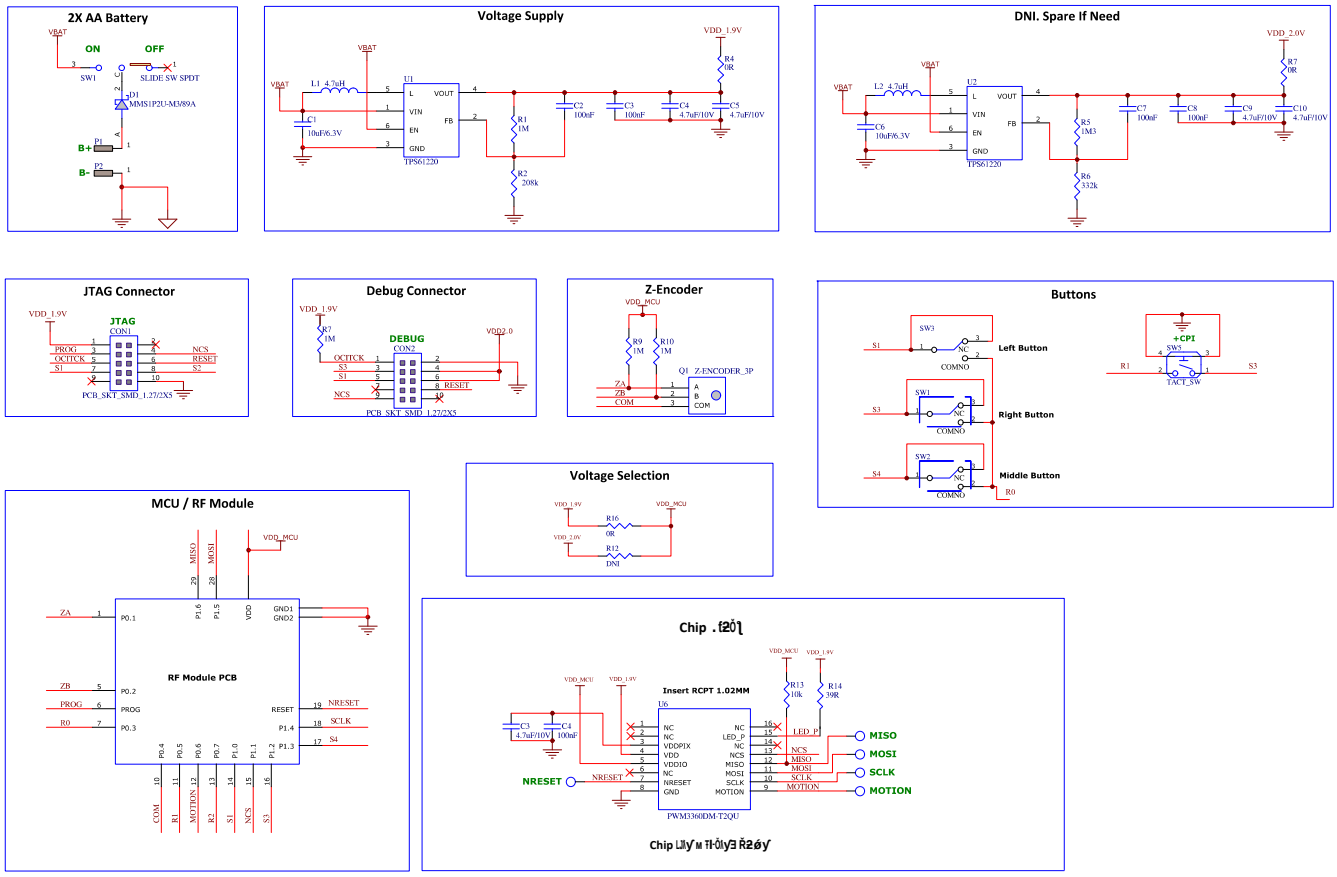


Figure 11. Schematic diagram for interface between PMW3360DM-T2QU and microcontroller on a wireless solution

2.0 Electrical Specifications

Regulatory Requirements

- Passes FCC "Part15, Subpart B, Class B", "CISPR 22 1997 Class B" and worldwide analogous emission limits when assembled into a mouse with shielded cable and following PixArt Imaging's recommendations.
- Passes IEC 62471: 2006 Photo biological safety of lamps and lamp systems

2.1 Absolute Maximum Ratings

Table 2: Absolute Maximum Ratings

Parameter	Symbol	Minimum	Maximum	Units	Notes
Storage Temperature	T_S	-40	85	°C	
Lead Solder Temperature	T_{SOLDER}		260	°C	For 7 seconds, 1.6mm below seating plane.
Supply Voltage	V_{DD}	-0.5	2.10	V	
	V_{DDIO}	-0.5	3.60	V	
ESD (Human Body Model)			2	kV	All pins
Input Voltage	V_{IN}	-0.5	3.6	V	All I/O pins.

2.2 Recommended Operating Conditions

Table 3: Recommended Operating Condition

Parameter	Symbol	Min	Typ.	Max	Units	Notes
Operating Temperature	T_A	0		40	°C	
Power Supply Voltage	V_{DD}	1.80	1.90	2.10	V	excluding supply noise
	V_{DDIO}	1.80	1.90	3.60	V	excluding supply noise. (VDDIO must be same or greater than VDD)
Power Supply Rise Time	t_{RT}	0.15		20	ms	0 to VDD min
Supply Noise (Sinusoidal)	V_{NA}			100	mVp-p	10 kHz —75 MHz
Serial Port Clock Frequency	f_{SCLK}			2.0	MHz	50% duty cycle
Distance from Lens Reference Plane to Tracking Surface	Z	2.2	2.4	2.6	mm	
Speed	S		250		ips	300ips on QCK, Vespula Speed, Vespula Control and FUNC 1030 surfaces
Resolution error	R_{esErr}		1		%	Up to 200ips on QCK with 5000 cpi
Acceleration	A			50	g	In run mode

2.3 AC Electrical Specifications

Table 4. AC Electrical Specifications

Electrical characteristics over recommended operating conditions. Typical values at 25 °C, V_{DD} = 1.9 V, V_{DDIO} = 1.9V.

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Motion Delay After Reset	$t_{MOT-RST}$	50			ms	From reset to valid motion, assuming motion is present
Shutdown	t_{STDWN}			500	µs	From Shutdown mode active to low current
Wake From Shutdown	t_{WAKEUP}	50			ms	From Shutdown mode inactive to valid motion. Notes: A RESET must be asserted after a shutdown. Refer to section "Notes on Shutdown", also note $t_{MOT-RST}$
MISO Rise Time	t_{r-MISO}		50		ns	C_L = 100pF
MISO Fall Time	t_{f-MISO}		50		ns	C_L = 100pF
MISO Delay After SCLK	$t_{DLY-MISO}$			90	ns	From SCLK falling edge to MISO data valid, no load conditions
MISO Hold Time	$t_{hold-MISO}$	200			ns	Data held until next falling SCLK edge
MOSI Hold Time	$t_{hold-MOSI}$	200			ns	Amount of time data is valid after SCLK rising edge
MOSI Setup Time	$t_{setup-MOSI}$	120			ns	From data valid to SCLK rising edge
SPI Time Between Write Commands	t_{SWW}	180			µs	From rising SCLK for last bit of the first data byte, to rising SCLK for last bit of the second data byte.
SPI Time Between Write And Read Commands	t_{SWR}	180			µs	From rising SCLK for last bit of the first data byte, to rising SCLK for last bit of the second address byte.
SPI Time Between Read And Subsequent Commands	t_{SRW} t_{SRR}	20			µs	From rising SCLK for last bit of the first data byte, to falling SCLK for the first bit of the address byte of the next command.
SPI Read Address-Data Delay	t_{SRAD}	160			µs	From rising SCLK for last bit of the address byte, to falling SCLK for first bit of data being read.
SPI Read Address-Data Delay for Burst Mode Motion Read	t_{SRAD_MOTBR}	35			µs	From rising SCLK for last bit of the address byte, to falling SCLK for first bit of data being read. Applicable for Burst Mode Motion Read only.
NCS Inactive After Motion Burst	t_{BEXIT}	500			ns	Minimum NCS inactive time after motion burst before next SPI usage
NCS To SCLK Active	$t_{NCS-SCLK}$	120			ns	From last NCS falling edge to first SCLK rising edge

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
SCLK To NCS Inactive (For Read Operation)	$t_{SCLK-NCS}$	120			ns	From last SCLK rising edge to NCS rising edge, for valid MISO data transfer
SCLK To NCS Inactive (For Write Operation)	$t_{SCLK-NCS}$	35			µs	From last SCLK rising edge to NCS rising edge, for valid MOSI data transfer
NCS To MISO High-Z	$t_{NCS-MISO}$			500	ns	From NCS rising edge to MISO high-Z state
MOTION Rise Time	$t_{r-MOTION}$		50		ns	C_L = 100pF
MOTION Fall Time	$t_{f-MOTION}$		50		ns	C_L = 100pF
Input Capacitance	C_{in}		50		pF	SCLK, MOSI, NCS
Load Capacitance	C_L			100	pF	MISO, MOTION
Transient Supply Current	I_{DDT}			70	mA	Max supply current during the supply ramp from 0V to V_{DD} with min 150 us and max 20ms rise time. (Does not include charging currents for bypass capacitors)
	I_{DDTIO}			60	mA	Max supply current during the supply ramp from 0V to V_{DDIO} with min 150 us and max 20ms rise time. (Does not include charging currents for bypass capacitors)

2.4 DC Electrical Specifications

Table 5. DC Electrical Specifications

Electrical characteristics, over recommended operating conditions. Typical values at 25 °C, V_{DD} = 1.9 V, V_{DDIO} = 1.9V, LED current at 12mA, 70MHz (internal), and 1.1kHz (slow clock).

Parameter	Symbol	Min	Typ.	Max	Units	Notes
DC Supply Current	I_{DD_RUN1} I_{DD_RUN2} I_{DD_RUN3} I_{DD_RUN4} I_{DD_REST1} I_{DD_REST2} I_{DD_REST3}		16.3 18.6 21.6 37.0 2.8 61.0 32.0		mA mA mA mA mA uA uA	Average current consumption, including LED current with 1ms polling.
Power Down Current	I_{PD}		10		µA	
Input Low Voltage	V_{IL}			0.3 x V_{DDIO}	V	SCLK, MOSI, NCS
Input High Voltage	V_{IH}	0.7 x V_{DDIO}			V	SCLK, MOSI, NCS
Input Hysteresis	V_{I_HYS}		100		mV	SCLK, MOSI, NCS
Input Leakage Current	I_{leak}		±1	±10	µA	Vin=V_{DDIO} or 0V, SCLK, MOSI, NCS
Output Low Voltage	V_{OL}			0.45	V	Iout=1mA, MISO, MOTION
Output High Voltage	V_{OH}	V_{DDIO} - 0.45			V	Iout=-1mA, MISO, MOTION

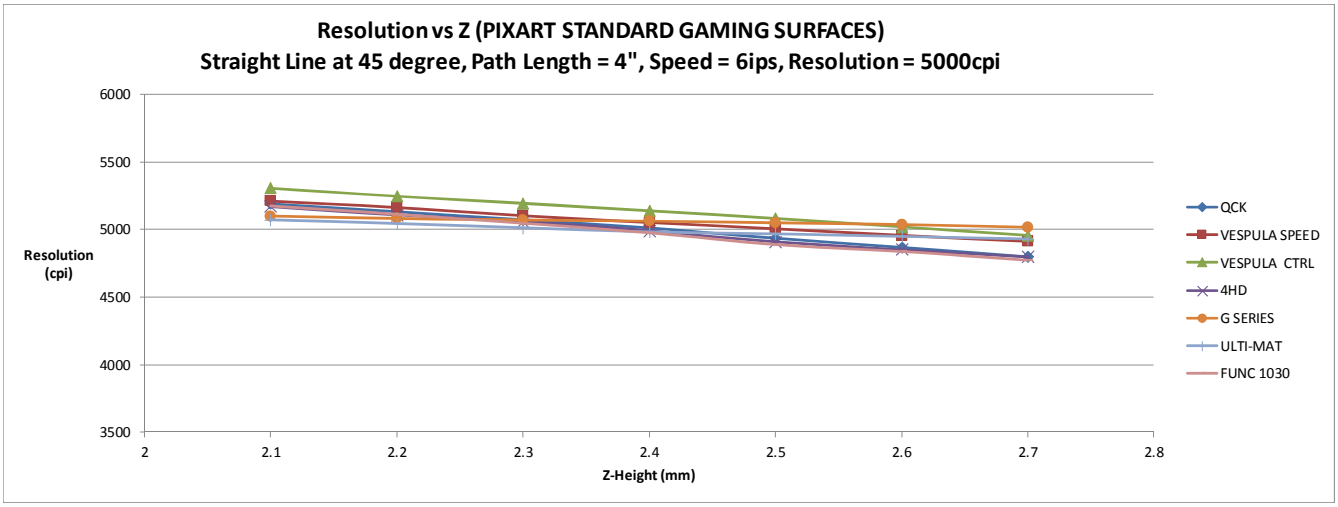


Figure 12 Mean Resolution vs. Z at default resolution at 5000cpi

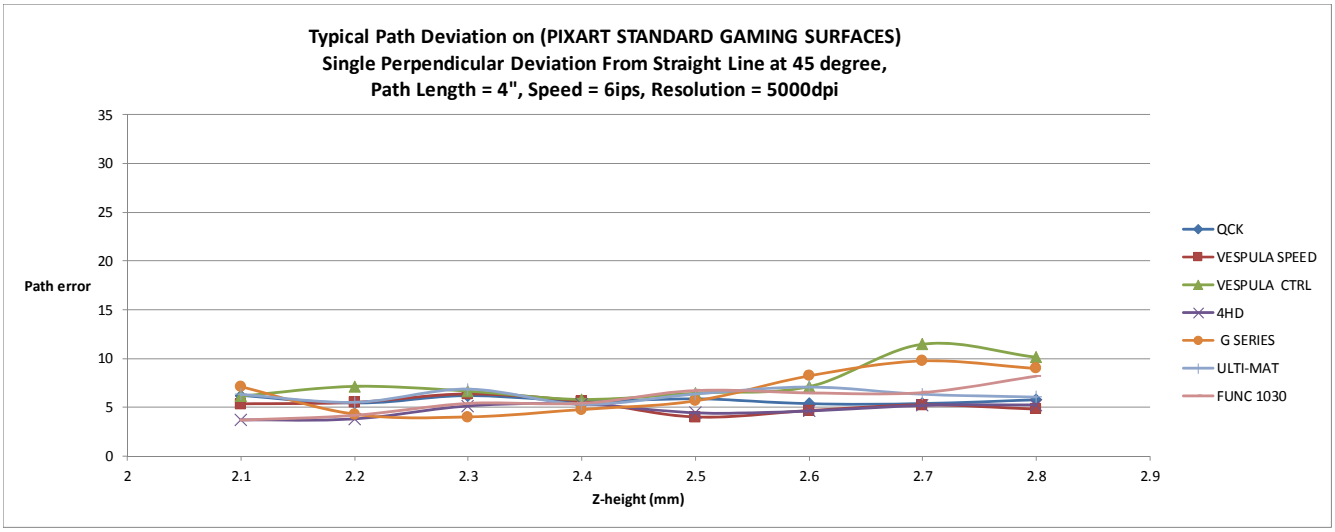


Figure 13 Path error vs. Z-height at default resolution at 5000cpi (mm)

3.0 Serial Peripheral Interface (SPI)

The synchronous serial port is used to set and read parameters in PMW3360DM-T2QU chip, and to read out the motion information. The serial port is also used to load SROM data into PMW3360DM-T2QU chip.

The port is a four wire port. The host microcontroller always initiates communication; PMW3360DM-T2QU chip never initiates data transfers. SCLK, MOSI, and NCS may be driven directly by a microcontroller. The port pins may be shared with other SPI slave devices. When the NCS pin is high, the inputs are ignored and the output is tri-stated.

The lines that comprise the SPI port are:

SCLK	Clock input, generated by the master (microcontroller).
MOSI	Input data. (Master Out/Slave In)
MISO	Output data. (Master In/Slave Out)
NCS	Chip select input (active low). NCS needs to be low to activate the serial port; otherwise, MISO will be high Z, and MOSI & SCLK will be ignored. NCS can also be used to reset the serial port in case of an error.

Motion Pin Timing

The motion pin is an active low output that signals the micro-controller when motion has occurred. The motion pin is lowered whenever the motion bit is set; in other words, whenever there is non-zero data in the Delta_X_L, Delta_X_H, Delta_Y_L or Delta_Y_H registers. Clearing the motion bit (by reading Delta_X_L, Delta_X_H, Delta_Y_L or Delta_Y_H registers) will put the motion pin high.

Chip Select Operation

The serial port is activated after NCS goes low. If NCS is raised during a transaction, the entire transaction is aborted and the serial port will be reset. This is true for all transactions including SROM download. After a transaction is aborted, the normal address-to-data or transaction-to-transaction delay is still required before beginning the next transaction. To improve communication reliability, all serial transactions should be framed by NCS. In other words, the port should not remain enabled during periods of non-use because ESD and EFT/B events could be interpreted as serial communication and put the chip into an unknown state. In addition, NCS must be raised after each burst-mode transaction is complete to terminate burst-mode. The port is not available for further use until burst-mode is terminated.

Write Operation

Write operation, defined as data going from the micro-controller to PMW3360DM-T2QU chip, is always initiated by the micro-controller and consists of two bytes. The first byte contains the address (seven bits) and has a "1" as its MSB to indicate data direction. The second byte contains the data. PMW3360DM-T2QU chip reads MOSI on rising edges of SCLK.

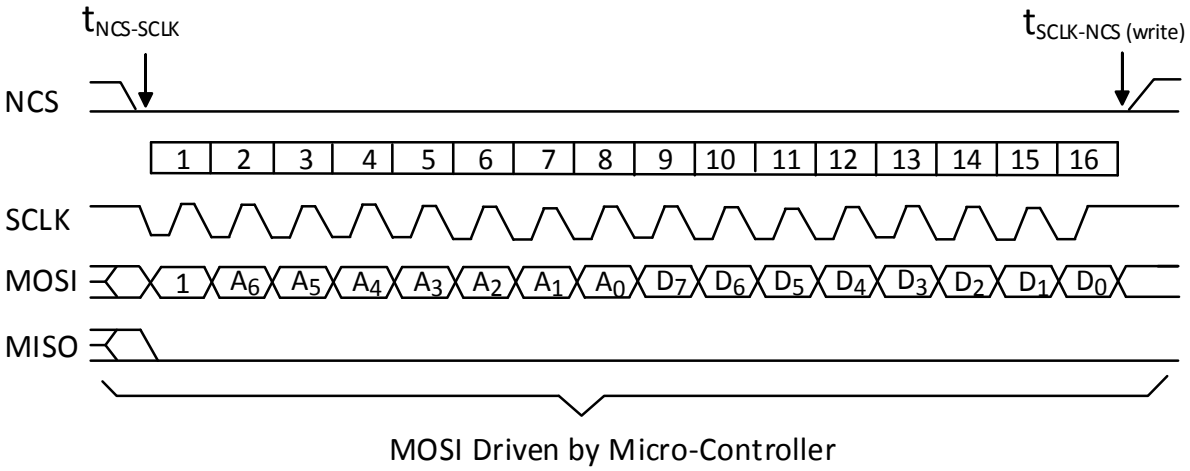


Figure 14. Write operation

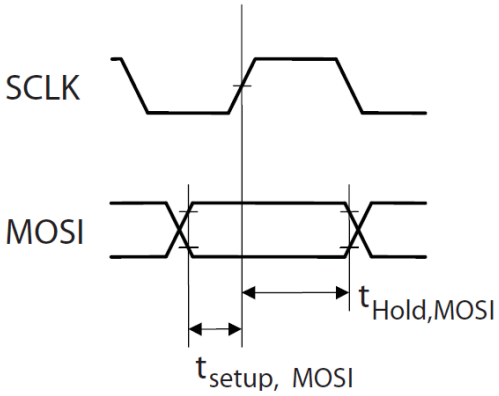


Figure 15. MOSI setup and hold time

Read Operation

A read operation, defined as data going from PMW3360DM-T2QU chip to the micro-controller, is always initiated by the micro-controller and consists of two bytes. The first byte contains the address, is sent by the micro-controller over MOSI, and has a "0" as its MSB to indicate data direction. The second byte contains the data and is driven by PMW3360DM-T2QU chip over MISO. The chip outputs MISO bits on falling edges of SCLK and samples MOSI bits on every rising edge of SCLK.

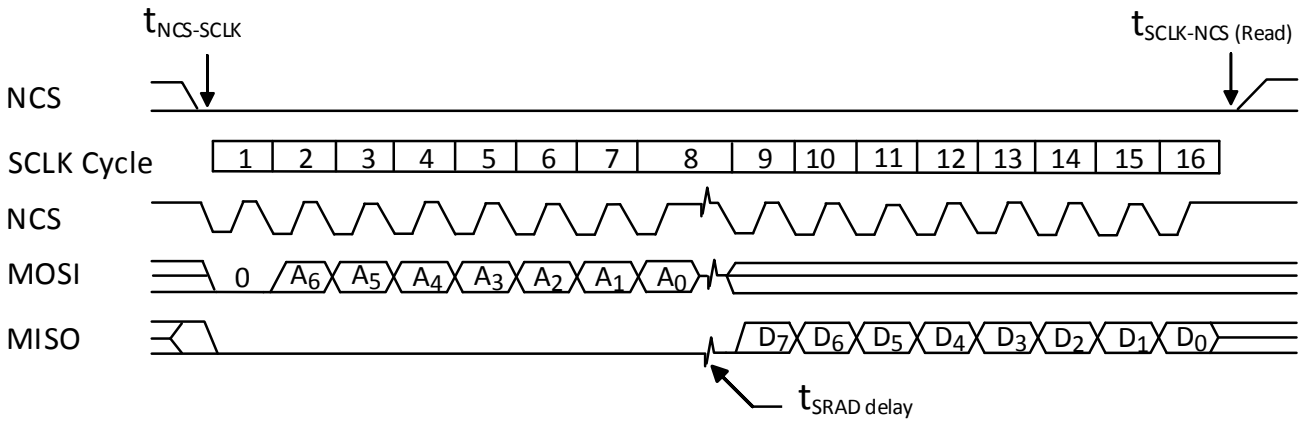


Figure 16. Read operation

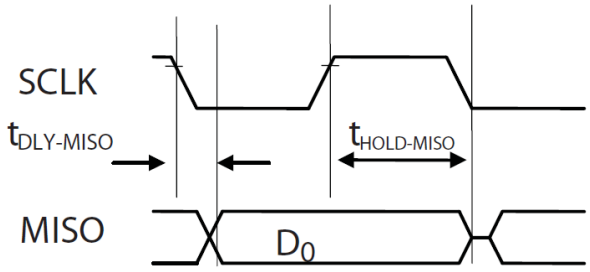


Figure 17. MISO Delay and hold time

Note: The minimum high state of SCLK is also the minimum MISO data hold time of PMW3360DM-T2QU chip. Since the falling edge of SCLK is actually the start of the next read or write command, PMW3360DM-T2QU chip will hold the state of data on MISO until the falling edge of SCLK.

Required timing between Read and Write Commands (tsxx)

There are minimum timing requirements between read and write commands on the serial port.

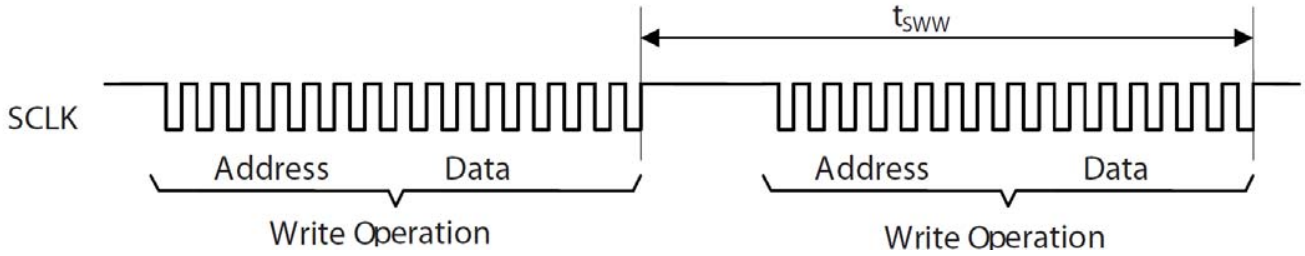


Figure 18. Timing between two write commands

If the rising edge of the SCLK for the last data bit of the second write command occurs before the t_{SWW} delay, then the first write command may not complete correctly.

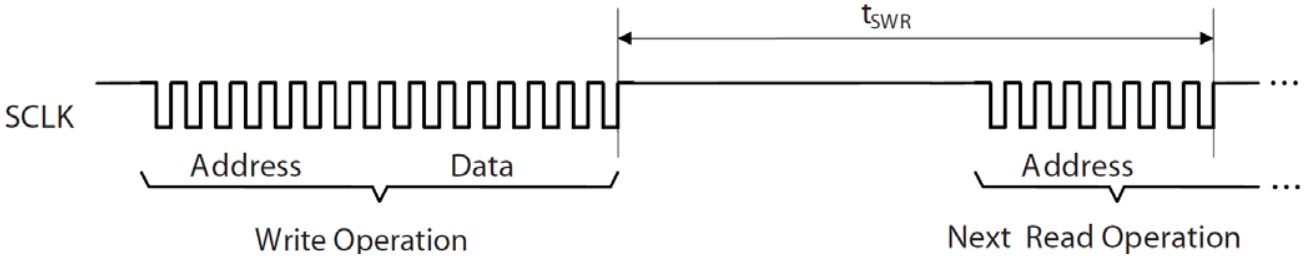


Figure 19. Timing between write and either write or subsequent read commands

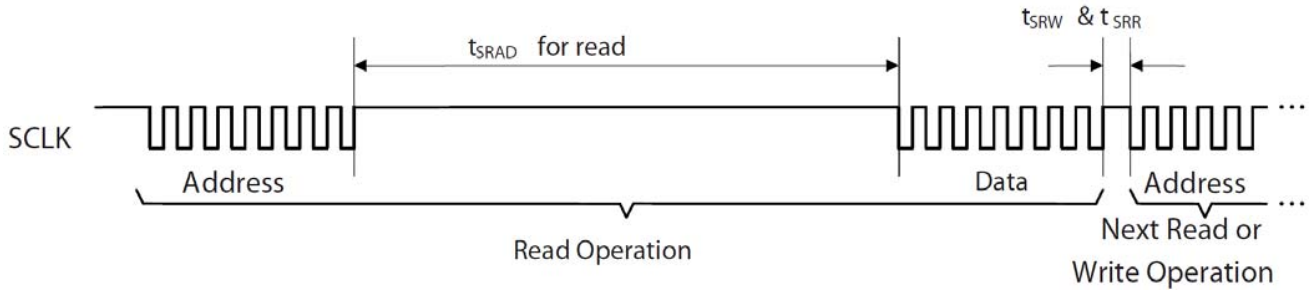


Figure 20. Timing between read and either write or subsequent read commands

If the rising edge of SCLK for the last address bit of the read command occurs before the t_{SWR} required delay, the write command may not complete correctly. During a read operation SCLK should be delayed at least t_{SRAD} after the last address data bit to ensure that the Chip has time to prepare the requested data.

The falling edge of SCLK for the first address bit of either the read or write command must be at least t_{SRR} or t_{SRW} after the last SCLK rising edge of the last data bit of the previous read operation. In addition, during a read operation SCLK should be delayed after the last address data bit to ensure that PMW3360DM-T2QU chip has time to prepare the requested data.

4.0 Burst mode operation

Burst Mode Operation

Burst mode is a special serial port operation mode which may be used to reduce the serial transaction time for three predefined operations: motion read and SROM download and frame capture. The speed improvement is achieved by continuous data clocking to or from multiple registers without the need to specify the register address, and by not requiring the normal delay period between data bytes.

Motion Read

Reading the Motion_Burst register activates this mode. PMW3360DM-T2QU chip will respond with the following motion burst report in order. Motion burst report:

BYTE[00] = Motion
BYTE[01] = Observation
BYTE[02] = Delta_X_L
BYTE[03] = Delta_X_H
BYTE[04] = Delta_Y_L
BYTE[05] = Delta_Y_H
BYTE[06] = SQUAL
BYTE[07] = Raw_Data_Sum
BYTE[08] = Maximum_Raw_Data
BYTE[09] = Minimum_Raw_Data
BYTE[10] = Shutter_Upper
BYTE[11] = Shutter_Lower

After sending the register address, the microcontroller must wait for t_{SRAD_MOTBR}, and then begin reading data. All data bits can be read with no delay between bytes by driving SCLK at the normal rate. The data are latched into the output buffer after the last address bit is received. After the burst transmission is complete, the microcontroller must raise the NCS line for at least t_{BEXIT} to terminate burst mode. The serial port is not available for use until it is reset with NCS, even for a second burst transmission.

Procedure to start motion burst:

1. Write any value to Motion_Burst register.
2. Lower NCS
3. Send Motion_Burst address (0x50).
4. Wait for t_{SRAD_MOTBR}
5. Start reading SPI Data continuously up to 12 bytes. Motion burst may be terminated by pulling NCS high for at least t_{BEXIT}.
6. To read new motion burst data, repeat from step 2.
7. If a non-burst register read operation was executed; then, to read new burst data, start from step 1 instead.

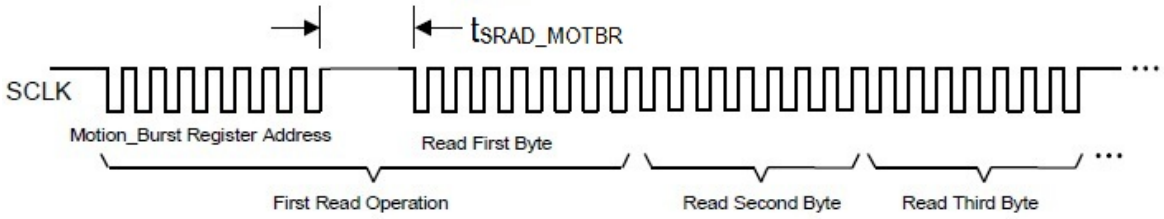


Figure 21. Motion Read sequence for step 3 to 5

Note: Motion burst data can be read from the Motion_Burst registers even in run or rest mode.

5.0 SROM Download

This function is used to load the supplied firmware file contents into PMW3360DM-T2QU after chip power up sequence. The firmware file is an ASCII text file.

SROM download procedure:

1. Perform the Power-Up sequence (steps 1 to 8)
2. Write 0 to Rest_En bit of Config2 register to disable Rest mode.
3. Write 0x1d to SROM_Enable register for initializing
4. Wait for 10 ms
5. Write 0x18 to SROM_Enable register again to start SROM Download
6. Write SROM file into SROM_Load_Burst register, 1st data must start with SROM_Load_Burst address. All the SROM data must be downloaded before SROM starts running.
7. Read the SROM_ID register to verify the ID before any other register reads or writes.
8. Write 0x00 to Config2 register for wired mouse **or** 0x20 for wireless mouse design.

The SROM download success may be verified in two ways. Once execution from SROM space begins, the SROM_ID register will report the firmware version. At any time, a self-test may be executed which performs a CRC on the SROM contents and reports the results in a register. Take note that the self-test does disrupt tracking performance and also reset registers to default value. The test is initiated by writing 0x15 to the SROM_Enable register and the result is placed in the Data_Out_Lower and Data_Out_Upper registers. See register description for more details.

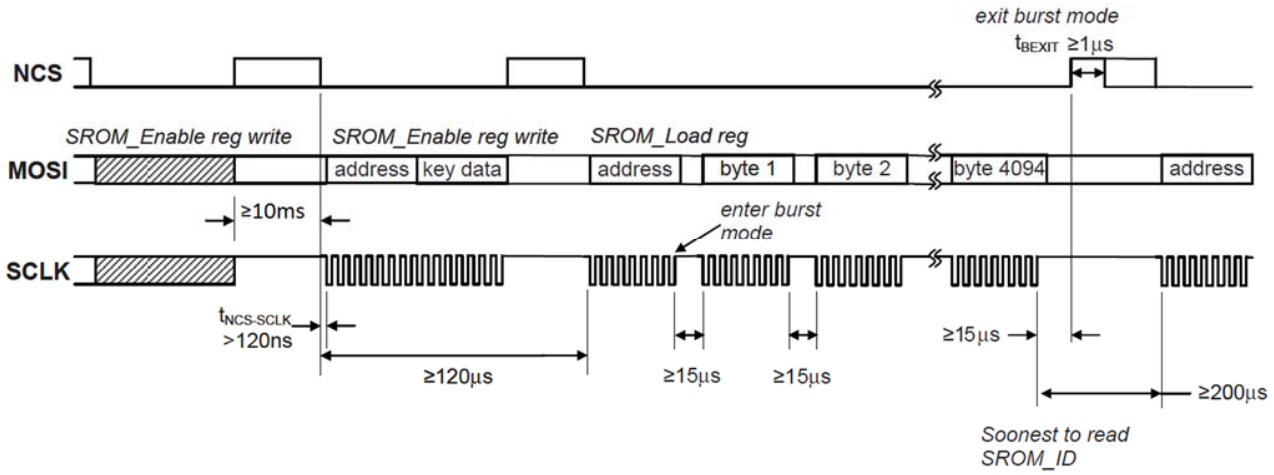


Figure 22. SROM Download Burst Mode

6.0 Frame Capture

This is a fast way to download a full array of raw data values from a single frame. This mode disables navigation and overwrites any downloaded firmware. A hardware reset is required to restore navigation, and the firmware must be reloaded.

To trigger the capture, write to the Frame_Capture register. The next available complete 1 frame image will be stored to memory. The data is retrieved by reading the Raw_Data_Burst register using burst read method per the waveform below. If the Raw_ Data_Burst register is read before the data is ready (step 6 below), it will return all zeros.

Frame Capture procedure:

1. The chip should be powered up and reset correctly (SROM download should be part of this powered up and reset sequence - refer to Power Up sequence in data sheet for more information).
2. Wait for 250ms.
3. Write 0 to Rest_En bit of Config2 register to disable Rest mode.
4. Write 0x83 to Frame_Capture register.
5. Write 0xC5 to Frame_Capture register.
6. Wait for 20ms.
7. Continue burst read from Raw_data_Burst register until all 1296 raw data are transferred.
8. Continue step 1-8 to capture another frame.

Note: Manual reset and SROM download are needed after frame capture to restore navigation.

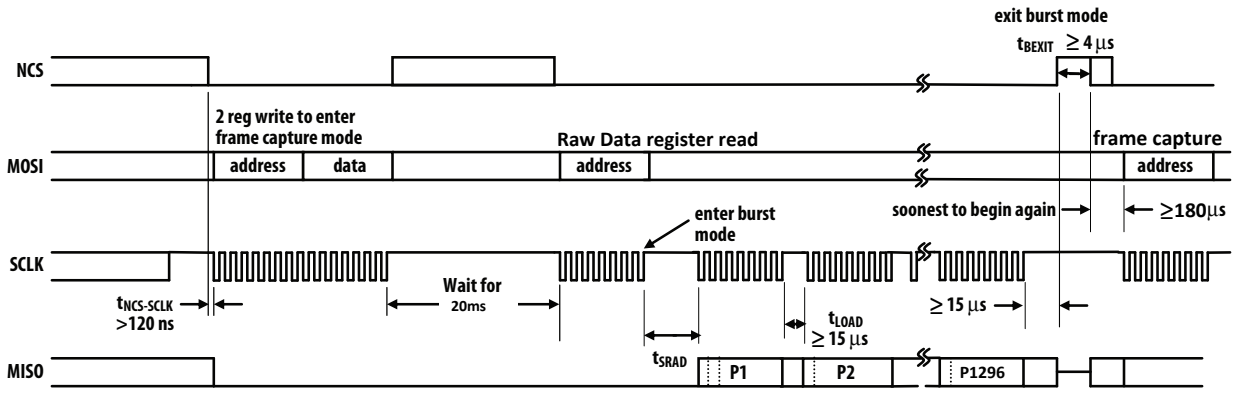
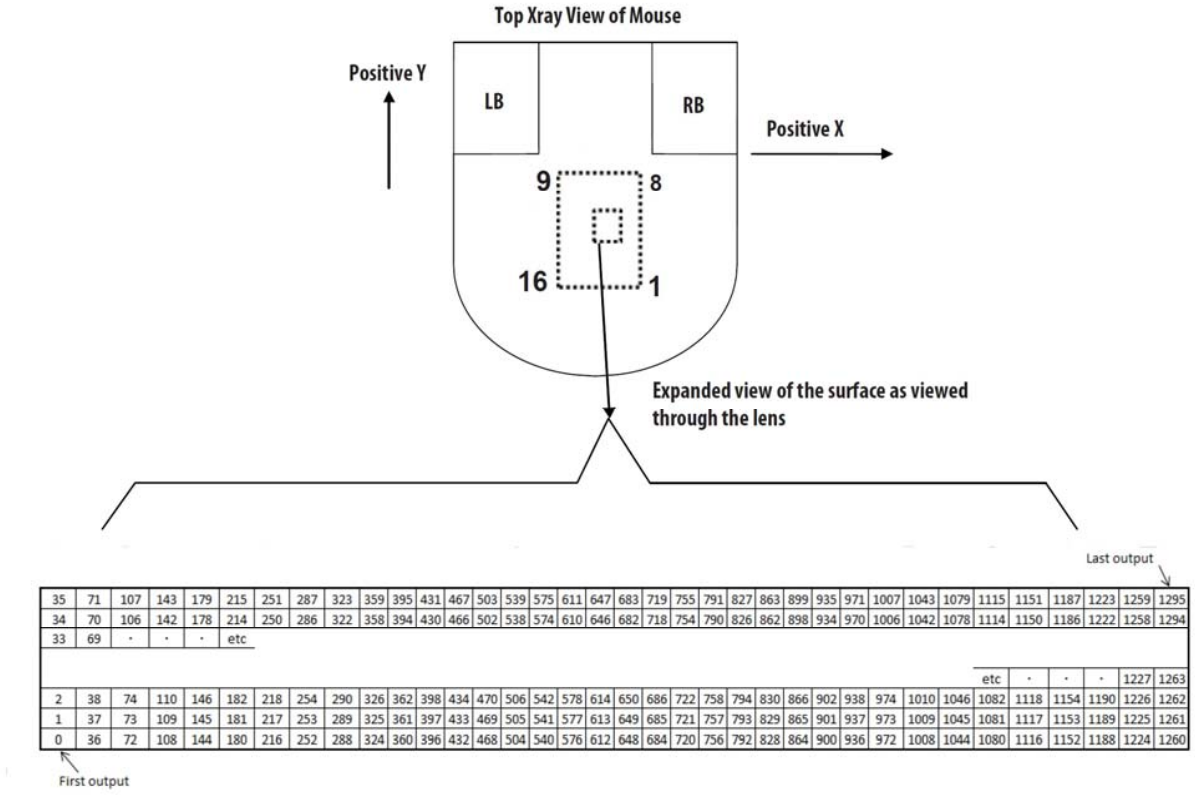


Figure 23. Frame Capture Burst Mode



35	71	107	143	179	215	251	287	323	359	395	431	467	503	539	575	611	647	683	719	755	791	827	863	899	935	971	1007	1043	1079	1115	1151	1187	1223	1259	1295
34	70	106	142	178	214	250	286	322	358	394	430	466	502	538	574	610	646	682	718	754	790	826	862	898	934	970	1006	1042	1078	1114	1150	1186	1222	1258	1294
33	69	·	·	·	etc																														
																													etc	·	·	·	1227	1263
2	38	74	110	146	182	218	254	290	326	362	398	434	470	506	542	578	614	650	686	722	758	794	830	866	902	938	974	1010	1046	1082	1118	1154	1190	1226	1262
1	37	73	109	145	181	217	253	289	325	361	397	433	469	505	541	577	613	649	685	721	757	793	829	865	901	937	973	1009	1045	1081	1117	1153	1189	1225	1261
0	36	72	108	144	180	216	252	288	324	360	396	432	468	504	540	576	612	648	684	720	756	792	828	864	900	936	972	1008	1044	1080	1116	1152	1188	1224	1260

Figure 24. Raw data Map (Surface referenced)

7.0 Power Up

Although the chip performs an internal power up self reset, it is still recommend that the Power_Up_Reset register is written every time power is applied. The appropriate sequence is as follows:

1. Apply power to VDD and VDDIO in any order, with a delay of no more than 100ms in between each supply. Ensure all supplies are stable.
2. Drive NCS high, and then low to reset the SPI port.
3. Write 0x5A to Power_Up_Reset register (or, alternatively toggle the NRESET pin).
4. Wait for at least 50ms.
5. Read from registers 0x02, 0x03, 0x04, 0x05 and 0x06 one time regardless of the motion pin state.
6. Perform SROM download.
7. Load configuration for other registers.

During power-up there will be a period of time after the power supply is high but before normal operation. The table below shows the state of the various pins during power-up and reset.

State of Signal Pins After VDD is Valid		
Pin	During Reset	After Reset
NRESET	Functional	Functional
NCS	Ignored	Functional
MISO	Undefined	Depends on NCS
SCLK	Ignored	Depends on NCS
MOSI	Ignored	Depends on NCS
MOTION	Undefined	Functional

NRESET

The NRESET pin can be used to perform a full chip reset. When asserted, it performs the same reset function as the Power_Up_Reset_Register. The NRESET pin needs to be asserted (held to logic 0) for at least 100 ns.

Note:- NRESET pin has a built in weak pull up circuit. During active low reset phase, it can draw a static current of up to 600uA.

8.0 Shutdown

PMW3360DM-T2QU can be set in Shutdown mode by writing to Shutdown register. The SPI port should not be accessed when Shutdown mode is asserted, except the power-up command (writing 0x5a to register 0x3a). Other ICs on the same SPI bus can be accessed, as long as the chip's NCS pin is not asserted. The SROM download is required when wake up from Shutdown mode.

To de-assert Shutdown mode:

1. Drive NCS high, and then low to reset the SPI port.
2. Write 0x5A to Power_Up_Reset register (or, alternatively toggle the NRESET pin).
3. Wait for at least 50ms.
4. Read from registers 0x02, 0x03, 0x04, 0x05 and 0x06 one time regardless of the motion pin state.
5. Perform SROM download.
6. Load configuration for other registers.

Pin	Status when Shutdown Mode
NRESET	High
NCS	High*1
MISO	Hi-Z*2
SCLK	Ignore if NCS = 1*3
MOSI	Ignore if NCS = 1*4
MOTION	Output High

*1. NCS pin must be held to 1 (high) if SPI bus is shared with other devices. It is recommended to hold to 1 (high) during Shutdown unless powering up the chip. It must be held to 0 (low) if the chip is to be re-powered up from shutdown (writing 0x5a to register 0x3a).
*2. MISO should be either pull up or down during shutdown in order to meet the low power consumption specification in the datasheet.
*3. SCLK is ignored if NCS is 1 (high). It is functional if NCS is 0 (low).
*4. MOSI is ignored if NCS is 1 (high). If NCS is 0 (low), any command present on the MOSI pin will be ignored except power-up command (writing 0x5a to register 0x3a).

Note:- There are long wakeup times from shutdown. These features should not be used for power management during normal mouse motion.

9.0 Lift cut off calibration

This chip has the capability to optimize its lift performance by tuning internal parameters to the surface. This “Lift cut off calibration” feature involves user interaction.

Take note that the Lift cut off calibration procedure that follows references registers of seven Lift cut off calibration related registers: (i) LiftCutoff_Tune1, (ii) LiftCutoff_Tune2, (iii) LiftCutoff_Tune3, (iv) LiftCutoff_Tune_Timeout, (v) LiftCutoff_Tune_Min_Length, (vi) Raw data_Threshold and (vii) Min_SQ_Run.

1. Ensure that the chip is powered up according to the Power Up Sequence.
2. Ensure that Lift cut off calibration SROM*[1] is downloaded.
3. Delay for 30ms.
4. Prompt the user that the "Lift cut off calibration" procedure is about to begin to ensure that the mouse is placed nominally on the surface (mouse is not lifted).
5. Start the calibration procedure by setting RUN_CAL register bit to 1. The calibration procedure can be started by a SW prompt to the user or user-initiated through a mouse-click event.
6. Poll CAL_STAT[2:0] to check the status of the calibration procedure. There are three ways to successfully stop the calibration procedure: set RUN_CAL register bit to 0 if either:
   - CAL_STAT[2:0] = 0x02,
   - CAL_STAT[2:0] = 0x02 and user initiates a stop through a mouse-click event, or,
   - CAL_STAT[2:0] = 0x03.

   If CAL_STAT[2:0] = 0x04, the calibration procedure needs to be re-started.
7. Stop the calibration procedure by ensuring that the RUN_CAL register bit is 0, then wait 1msec before reading the recommended “Raw data Threshold” register value, RPTH[6:0] (lower 7 bits of LiftCutoff_Tune2 register). RPTH[6:0] recommends a raw data threshold value that replaces the default value in the tracking SROM’s Raw_data_Threshold register to improve lift performance. The Raw_ data_Threshold register requires the Tracking SROM*[2] to be loaded.
8. Read the recommended “Min SQUAL Run” register value, RMSQ[7:0] (entire 8 bits of LiftCutoff_Tune3 register). RMSQ[7:0] recommends a Min SQUAL Run value that replaces the default value in the tracking SROM’s Min_SQ_Run register to improve lift performance. The Min_SQ_Run register requires the Tracking SROM*[2] to be downloaded.
9. The Lift cut off calibration procedure is complete.

Note:
**[1] Lift cut off calibration SROM: SROM 0x81 or above (4KB).*
**[2] Tracking SROM: SROM 0x03 or above (4KB).*

10.0 Registers Table

PMW3360DM-T2QU registers are accessible via the serial port. The registers are used to read motion data and status as well as to set the device configuration.

Address	Register	Access (R = Read / W = Write or Read/Write= RW)	Default Value
0x00	Product_ID	R	0x42
0x01	Revision_ID	R	0x01
0x02	Motion	RW	0x20
0x03	Delta_X_L	R	0x00
0x04	Delta_X_H	R	0x00
0x05	Delta_Y_L	R	0x00
0x06	Delta_Y_H	R	0x00
0x07	SQUAL	R	0x00
0x08	Raw_Data_Sum	R	0x00
0x09	Maximum_Raw_data	R	0x00
0x0A	Minimum_Raw_data	R	0x00
0x0B	Shutter_Lower	R	0x12
0x0C	Shutter_Upper	R	0x00
0x0D	Control	RW	0x02
0x0F	Config1	RW	0x31
0x10	Config2	RW	0x20
0x11	Angle_Tune	RW	0x00
0x12	Frame_Capture	RW	0x00
0x13	SROM_Enable	W	N/A
0x14	Run_Downshift	RW	0x32
0x15	Rest1_Rate_Lower	RW	0x00
0x16	Rest1_Rate_Upper	RW	0x00
0x17	Rest1_Downshift	RW	0x1F
0x18	Rest2_Rate_Lower	RW	0x63
0x19	Rest2_Rate_Upper	RW	0x00
0x1A	Rest2_Downshift	RW	0xBC
0x1B	Rest3_Rate_Lower	RW	0xF3
0x1C	Rest3_Rate_Upper	RW	0x01
0x24	Observation	RW	0x00
0x25	Data_Out_Lower	R	0x00
0x26	Data_Out_Upper	R	0x00
0x29	Raw_Data_Dump	RW	0x00
0x2A	SROM_ID	R	0x00
0x2B	Min_SQ_Run	RW	0x10
0x2C	Raw_Data_Threshold	RW	0x0A
0x2F	Config5	RW	0x31
0x3A	Power_Up_Reset	W	N/A
0x3B	Shutdown	W	N/A
0x3F	Inverse_Product_ID	R	0xBD
0x41	LiftCutoff_Tune3	RW	0x00
0x42	Angle_Snap	RW	0x00
0x4A	LiftCutoff_Tune1	RW	0x00
0x50	Motion_Burst	RW	0x00
0x58	LiftCutoff_Tune_Timeout	RW	0x27
0x5A	LiftCutoff_Tune_Min_Length	RW	0x09
0x62	SROM_Load_Burst	W	N/A
0x63	Lift_Config	RW	0x02
0x64	Raw_Data_Burst	R	0x00
0x65	LiftCutoff_Tune2	R	0x00

11.0 Registers Description

Register: 0x00								
Name: Product_ID								
Bit	7	6	5	4	3	2	1	0
Field	PID_7	PID_6	PID_5	PID_4	PID_3	PID_2	PID_1	PID_0
	Reset Value: 0x42							
Access: R/W	Read Only							
Data Type:	8-bit unsigned integer							
Usage	This value is a unique identification assigned to this model only. The value in this register does not change; it can be used to verify that the serial communications link is functional.							

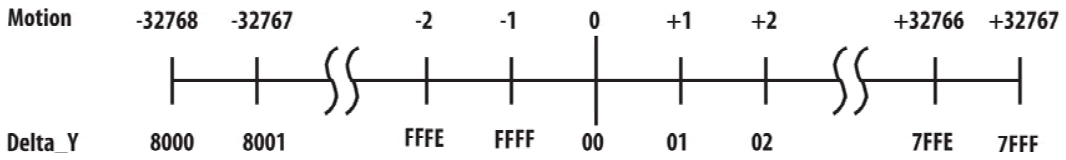
Register: 0x01								
Name: Revision_ID								
Bit	7	6	5	4	3	2	1	0
Field	RID_7	RID_6	RID_5	RID_4	RID_3	RID_2	RID_1	RID_0
	Reset Value: 0x01							
Access: R/W	Read Only							
Data Type:	8-bit unsigned integer							
Usage	This register contains the current IC revision, the revision of the permanent internal firmware. It is subject to change when new IC versions are released.							

Register: 0x02								
Name: Motion								
Bit	7	6	5	4	3	2	1	0
Field	MOT	Reserved	1	RData_1st	Lift_Stat	OP_MODE_1	OP_MODE_2	FRAME_RData_1st
	Reset Value: 0x20							
Access: R/W	Read/ Write							
Data Type:	8-bit Field							
Usage	This register allows the user to determine if motion has occurred since the last time it was read. The procedure to read the motion registers (Delta_X_L, Delta_X_H, Delta_Y_L and Delta_Y_H) is as follows: 1. Write any value to the Motion register. 2. Read the Motion register. This will freeze the Delta_X_L, Delta_X_H, Delta_Y_L and Delta_Y_H register values. 3. If the MOT bit is set, Delta_X_L, Delta_X_H, Delta_Y_L and Delta_Y_H registers should be read in the given sequence to get the accumulated motion. Note: if Delta_X_L, Delta_X_H, Delta_Y_L and Delta_Y_H registers are not read before the motion register is read for the second time, the data in Delta_X_L, Delta_X_H, Delta_Y_L and Delta_Y_H will be lost. 4. To read a new set of motion data (Delta_X_L, Delta_X_H, Delta_Y_L and Delta_Y_H), repeat from Step 2. 5. If any other register was read i.e. any other register besides Motion, Delta_X_L, Delta_X_H, Delta_Y_L and Delta_Y_H, then, to read a new set of motion data, repeat from Step 1 instead.							

Field Name	Description
MOT	Motion since last report or PD **0 = No motion** 1 = Motion occurred, data ready for reading in Delta_X_L, Delta_X_H, Delta_Y_L and Delta_Y_H registers
[6]	Reserved.
[5]	1
RData_1st	This bit is set when the Raw_Data_Grab register is written to or when a complete raw data array has been read, initiating an increment to raw data 0,0. **0 = Raw_Data_Grab data not from raw data 0,0** 1 = Raw_Data_Grab data is from raw data 0,0
Lift_Stat	Indicate the lift status of Chip, **0 = Chip on surface.** 1 = Chip lifted.
OP_Mode[1:0]	**00 – Run mode** 01 – Rest 1 10 – Rest 2 11 – Rest 3
FRAME_RData_1st	This bit is set to indicate first raw data in frame capture. **0 = Frame capture data not from raw data 0,0** 1 = Frame capture data is from raw data 0,0

Register: 0x03								
Name: Delta_X_L								
Bit	7	6	5	4	3	2	1	0
Field	X_7	X_6	X_5	X_4	X_3	X_2	X_1	X_0
	Reset Value: 0x00							
Access: R/W	Read Only							
Data Type:	16 bits 2's complement number. Lower 8 bits of Delta_X.							
Usage	X movement is counts since last report. Absolute value is determined by resolution. Reading it clears the register.							

Register: 0x04								
Name: Delta_X_H								
Bit	7	6	5	4	3	2	1	0
Field	X_{15}	X_{14}	X_{13}	X_{12}	X_{11}	X_{10}	X_9	X_8
	Reset Value: 0x04							
Access: R/W	Read Only							
Data Type:	16 bits 2's complement number. Lower 8 bits of Delta_X.							
Usage	Delta_X_H must be read after Delta_X_L to have the full motion data. Reading it clears the register.							

Register: 0x05								
Name: Delta_Y_L								
Bit	7	6	5	4	3	2	1	0
Field	Y_7	Y_6	Y_5	Y_4	Y_3	Y_2	Y_1	Y_0
	Reset Value: 0x00							
Access: R/W	Read Only							
Data Type:	16 bits 2's complement number. Lower 8 bits of Delta_Y.							
Usage	Y movement is counts since last report. Absolute value is determined by resolution. Reading it clears the register. 							

Register: 0x06								
Name: Delta_Y_H								
Bit	7	6	Bit	7	6	Bit	7	6
Field	Y_{15}	Y_{14}	Y_{13}	Y_{12}	Y_{11}	Y_{10}	Y_9	Y_8
	Reset Value: 0x00							
Access: R/W	Read Only							
Data Type:	16 bits 2's complement number. Upper 8 bits of Delta_Y							
Usage	Delta_Y_H must be read after Delta_Y_L to have the full motion data. Reading it clears the register							

Register: 0x07								
Name: SQUAL								
Bit	7	6	5	4	3	2	1	0
Field	SQ_7	SQ_6	SQ_5	SQ_4	SQ_3	SQ_2	SQ_1	SQ_0
	Reset Value: 0x00							
Access: R/W	Read Only							
Data Type:	8-bit unsigned integer							
Usage	The SQUAL (Surface quality) register is a measure of the number of valid features visible by the chip in the current frame. Use the following formula to find the total number of valid features. Number of Features = SQUAL Register Value * 8 The maximum SQUAL register value is 0x80. Since small changes in the current frame can result in changes in SQUAL, variations in SQUAL when looking at a surface are expected. The graph below shows 883 sequentially acquired SQUAL values, while a chip was moved slowly over white paper. SQUAL values are only valid in run mode. Disable Rest mode before measuring SQUAL.							

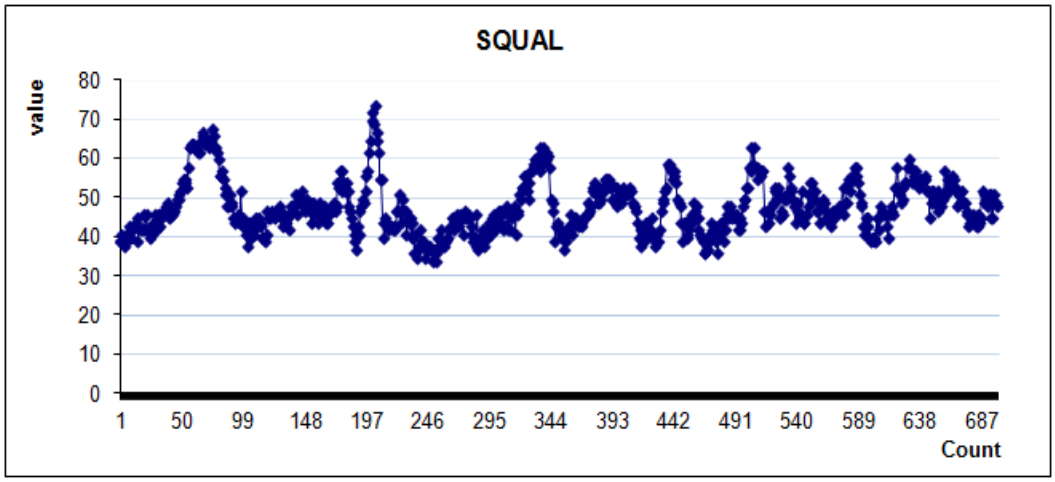


Figure 25. Average SQUAL on white paper

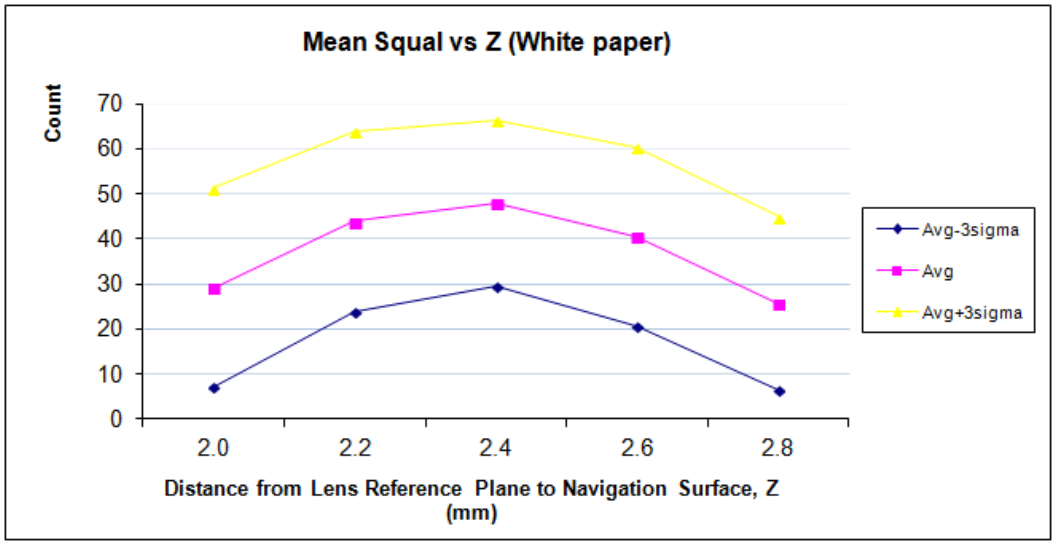


Figure 26. Mean SQUAL vs Z

Register: 0x08								
Name: Raw_Data_Sum								
Bit	7	6	5	4	3	2	1	0
Field	AP_7	AP_6	AP_5	AP_4	AP_3	AP_2	AP_1	AP_0
	Reset Value: 0x00							
Access: R/W	Read Only							
Data Type:	8-bit unsigned integer							
Usage	This register is used to find the average raw data value. It reports the upper byte of an 18-bit counter which sums all 1296 raw data in the current frame. To find the average raw data values follow the formula below. Average Raw Data = Register Value * 1024 / 1296 The maximum register value is 160(Dec) (0xA0) (127 * 1296 / 1024 truncated to an integer). The minimum register value is 0. The raw data sum value can change every frame							

Register: 0x09								
Name: Maximum_Raw_Data								
Bit	7	6	5	4	3	2	1	0
Field	MRD_7	MRD_6	MRD_5	MRD_4	MRD_3	MRD_2	MRD_1	MRD_0
	Reset Value: 0x00							
Access: R/W	Read Only							
Data Type:	8-bit unsigned integer							
Usage	Maximum Raw data value in current frame. Minimum value = 0, maximum value = 127. The maximum raw data value can change every frame							

Register: 0x0A								
Name: Minimum_Raw_Data								
Bit	7	6	5	4	3	2	1	0
Field	$MinRD_7$	$MinRD_6$	$MinRD_5$	$MinRD_4$	$MinRD_3$	$MinRD_2$	$MinRD_1$	$MinRD_0$
	Reset Value: 0x00							
Access: R/W	Read Only							
Data Type:	8-bit unsigned integer							
Usage	Minimum Raw data value in current frame. Minimum value = 0, maximum value = 127. The minimum raw data value can change every frame							

Register: 0x0B								
Name: Shutter_Lower								
Bit	7	6	5	4	3	2	1	0
Field	S_7	S_6	S_5	S_4	S_3	S_2	S_1	S_0
	Reset Value: 0x12							
Access: R/W	Read Only							
Data Type:	16-bit unsigned number							
Usage	Lower byte of the 16bit Shutter register							

Register: 0x0C								
Name: Shutter_Upper								
Bit	7	6	5	4	3	2	1	0
Field	S_{15}	S_{14}	S_{13}	S_{12}	S_{11}	S_{10}	S_9	S_8
	Reset Value: 0x00							
Access: R/W	Read Only							
Data Type:	16-bit unsigned number							
Usage	Units are clock cycles of the internal oscillator. Read Shutter_Upper first, then Shutter_Lower. They should be read consecutively. The shutter is adjusted to keep the average raw data values within normal operating ranges. The shutter value is checked and automatically adjusted to a new value if needed on every frame when operating in default mode.							

<table>
<tr><th colspan="9">Register: 0x0D</th></tr>
<tr><td colspan="9">Name: Control</td></tr>
<tr><td>Bit</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">Field</td><td>CTRL1$_7$</td><td>CTRL1$_6$</td><td>CTRL1$_5$</td><td>Reserved</td><td>Reserved</td><td>Reserved</td><td>Reserved</td><td>Reserved</td></tr>
<tr><td colspan="8">Reset Value: 0x02</td></tr>
<tr><td>Access: R/W</td><td colspan="8">Read Write</td></tr>
<tr><td>Data Type:</td><td colspan="8">8-bit unsigned integer</td></tr>
<tr><td>Usage</td><td colspan="8">This register defines programmable invert able of XY register scheme.
<table>
<tr><th>Field Name</th><th>Description</th></tr>
<tr><td>CTRL1$_{[7:5]}$</td><td>000 - 0 degree
110 - 90 degree
011 – 180 degree
101 – 270 degree</td></tr>
<tr><td>Reserved$_{[4:0]}$</td><td>Reserved</td></tr>
</table>
Note: For CTRL1$_{[7:5]}$ please use 0 degree for best performance</td></tr>
</table>

<table>
<tr><th colspan="9">Register: 0x0F</th></tr>
<tr><td colspan="9">Name: Config1</td></tr>
<tr><td>Bit</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">Field</td><td>RES_7</td><td>RES 1_6</td><td>RES_5</td><td>RES_4</td><td>RES_3</td><td>RES_2</td><td>RES_1</td><td>RES_0</td></tr>
<tr><td colspan="8">Reset Value: 0x31</td></tr>
<tr><td>Access: R/W</td><td colspan="8">Read/ Write</td></tr>
<tr><td>Data Type:</td><td colspan="8">Bit Field</td></tr>
<tr><td>Usage</td><td colspan="8">This register allows the user to change the X & Y or Y only resolution of the chip. Shown below are the bits, their default values, and optional values. The CPI of X & Y or Y only setting in this register depends on the Rpt_Mod register bit (refer to the description for Config2 register).
<table>
<tr><th>Field Name</th><th>Description</th></tr>
<tr><td>RES[7:0]</td><td>Set resolution with CPI step of 100 cpi
0x00: 100 cpi (Minimum cpi)
0x01: 200 cpi
0x02: 300 cpi
:
:
0x31: 5000 cpi (default cpi)
:
:
0x77: 12000 cpi (maximum cpi)</td></tr>
</table></td></tr>
</table>

Register: 0x10								
Name: Config2								
Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	Rest_En	Reserved	Reserved	Rpt_Mod	Reserved	O
	Reset Value: 0x20							
Access: R/W	Read/ Write							
Data Type:	Bit Field							

Usage

Field Name	Description
[7:6]	Reserved
Rest_En	0 = Normal operation without REST mode. **1 = REST mode enable.**
[4:3]	Reserved
Rpt_Mod	Select the X and Y CPI reporting mode. **= 0: Normal CPI setting affects both delta X and Y.** = 1: CPI setting for delta Y is defined by Config1 (address 0x0F). CPI setting for delta X is defined by Config5 (address 0x2F)
1	Reserved
Bit[0]	Must be set to 0

Register: 0x11								
Name: Angle_Tune								
Bit	7	6	5	4	3	2	1	0
Field	$Angle_7$	$Angle_6$	$Angle_5$	$Angle_4$	$Angle_3$	$Angle_2$	$Angle_1$	$Angle_0$
	Reset Value: 0x00							
Access: R/W	Read/ Write							
Data Type:	Bit Field							

Usage

Field Name	Description
Angle[7:0]	0xE2 -30 degree 0xF6 -10 degree **0x00 0 degree (default)** 0x0F +15 degree 0x1E +30 degree

Register: 0x12								
Name: Frame_Capture								
Bit	7	6	5	4	3	2	1	0
Field	FC_7	FC_6	FC_5	FC_4	FC_3	FC_2	FC_1	FC_0
	Reset Value: 0x12							
Access: R/W	Read Only							
Data Type:	8-bit unsigned integer							
Usage	Used to capture the next available complete 1 frame of raw data values to be stored to RAM. Writing to this register will cause any firmware loaded to be overwritten and stops navigation. A hardware reset and SROM download are required to restore normal operation for motion reading. Refer to the Frame Capture section for use details.							

Register: 0x13								
Name: SROM_Enable								
Bit	7	6	5	4	3	2	1	0
Field	SE_7	SE_6	SE_5	SE_4	SE_3	SE_2	SE_1	SE_0
	Reset Value: N/A							
Access: R/W	Write Only							
Data Type:	8-bit unsigned integer							
Usage	Write to this register to start either SROM download or SROM CRC test. See SROM Download section for details. SROM CRC test can be performed to check if SROM download was successful. Navigation is halted and the SPI port should not be used during this SROM CRC test. Registers will be reset to default value after completion of CRC test. SROM CRC read procedure is as below: 1. Write 0x15 to SROM_Enable register. 2. Wait for at least 10ms. 3. Read register Data_Out_Upper and register Data_Out_Lower .							

Register: 0x14								
Name: Run_Downshift								
Bit	7	6	5	4	3	2	1	0
Field	RD_7	RD_6	RD_5	RD_4	RD_3	RD_2	RD_1	RD_0
	Reset Value: 0x32							
Access: R/W	Read/ Write							
Data Type:	8-bit unsigned integer							
Usage	This register set the Run to Rest1 downshift time. Default value is 500ms. Use the formula below for calculation. The minimum register value is 0x01. A value of 0x00 will be internally clipped to 0x01. Run Downshift time (ms) = RD[7:0] x 10 ms Default = 50 x 10 = 500ms Max = 255x10 = 2550ms = 2.55s All the above values are expected to have a +40% and -20% of tolerance.							

Register: 0x15								
Name: Res1_Rate_Lower								
Bit	7	6	5	4	3	2	1	0
Field	$R1R_7$	$R1R_6$	$R1R_5$	$R1R_4$	$R1R_3$	$R1R_2$	$R1R_1$	$R1R_0$
	Reset Value: 0x00							
Access: R/W	Read/Write							
Data Type:	16-bit unsigned integer							
Usage	Lower byte of the Rest1 frame rate register.							

Register: 0x16								
Name: Rest1_Rate_Upper								
Bit	7	6	5	4	3	2	1	0
Field	$R1R_{15}$	$R1R_{14}$	$R1R_{13}$	$R1R_{12}$	$R1R_{11}$	$R1R_{10}$	$R1R_{9}$	$R1R_{8}$
	Reset Value: 0x00							
Access: R/W	Read/Write							
Data Type:	16-bit unsigned integer							
Usage	Upper byte of the Rest1 frame rate register. This register sets the Rest1 frame rate duration. Default value is 1 ms. To write to the registers, write Lower first, followed by Upper. Register read can be in any order but must be consecutive. R1R[15:0] value must not exceed 0x09B0, otherwise an internal watchdog will trigger a reset. Use the formula below for calculation. Rest1 frame rate duration = (R1R[15:0] + 1) x 1 ms Default = (0 + 1) x 1 = 1 ms All the above values are expected to have a +40% and -20% of tolerance.							

Register: 0x17								
Name: Rest1_Downshift								
Bit	7	6	5	4	3	2	1	0
Field	$R1D_{7}$	$R1D_{6}$	$R1D_{5}$	$R1D_{4}$	$R1D_{3}$	$R1D_{2}$	$R1D_{1}$	$R1D_{0}$
	Reset Value: 0x1F							
Access: R/W	Read/Write							
Data Type:	8-bit unsigned integer							
Usage	This register set the Rest1 to Rest2 downshift time. Default value is 9.92 sec. Use the formula below for calculation. The minimum register value is 0x01. A value of 0x00 will be internally clipped to 0x01. The default multiplier value is defined through SROM. Rest1 Downshift time = R1D[7:0] x 320 x Rest1_Rate. Default = Rest1_Downshift x 320 x Rest1_Rate = 9.92s (default multiplier value is 320) All the above values are expected to have a +40% and -20% of tolerance.							

Register: 0x18								
Name: Rest2_Rate_Lower								
Bit	7	6	5	4	3	2	1	0
Field	$R2R_7$	$R2R_6$	$R2R_5$	$R2R_4$	$R2R_3$	$R2R_2$	$R2R_1$	$R2R_0$
	Reset Value: 0x63							
Access: R/W	Read/Write							
Data Type:	16-bit unsigned integer							
Usage	Lower byte of the Rest2 frame rate register.							

Register: 0x19								
Name: Rest2_Rate_Upper								
Bit	7	6	5	4	3	2	1	0
Field	$R2R_{15}$	$R2R_{14}$	$R2R_{13}$	$R2R_{12}$	$R2R_{11}$	$R2R_{10}$	$R2R_9$	$R2R_8$
	Reset Value: 0x00							
Access: R/W	Read/Write							
Data Type:	16-bit unsigned integer							
Usage	Upper byte of the Rest2 frame rate register. This register sets the Rest2 frame rate duration. Default value is 100 ms. To write to the registers, write Lower first, followed by Upper. Register read can be in any order but must be consecutive. R2R[15:0] value must not exceed 0x09B0, otherwise an internal watchdog will trigger a reset. Use the formula below for calculation. Rest2 frame rate duration = (R2R[15:0] + 1) x 1 ms Default = (99 + 1) x 1 = 100 ms All the above values are expected to have a +40% and -20% of tolerance.							

Register: 0x1A								
Name: Rest2_Downshift								
Bit	7	6	5	4	3	2	1	0
Field	$R2D_7$	$R2D_6$	$R2D_5$	$R2D_4$	$R2D_3$	$R2D_2$	$R2D_1$	$R2D_0$
	Reset Value: 0xBC							
Access: R/W	Read/Write							
Data Type:	8-bit unsigned integer							
Usage	This register set the Rest2 to Rest3 downshift time. Default value is 601.6s. Use the formula below for calculation. The minimum register value is 0x01. A value of 0x00 will be internally clipped to 0x01. Rest2 Downshift time = R2D[7:0] x 32 x Rest2_Rate. Default = 188 x 32 x 100 = 601.6s = 10mins All the above values are expected to have a +40% and -20% of tolerance.							

Register: 0x1B								
Name: Rest3_Rate_Lower								
Bit	7	6	5	4	3	2	1	0
Field	$R3R_7$	$R3R_6$	$R3R_5$	$R3R_4$	$R3R_3$	$R3R_2$	$R3R_1$	$R3R_0$
	Reset Value: 0xF3							
Access: R/W	Read/Write							
Data Type:	16-bit unsigned integer							
Usage	Lower byte of the Rest3 frame rate register.							

Register: 0x1C								
Name: Res3_Rate_Upper								
Bit	7	6	5	4	3	2	1	0
Field	$R3R_{15}$	$R3R_{14}$	$R3R_{13}$	$R3R_{12}$	$R3R_{11}$	$R3R_{10}$	$R3R_{9}$	$R3R_{8}$
	Reset Value: 0x01							
Access: R/W	Read/Write							
Data Type:	16-bit unsigned integer							
Usage	Upper byte of the Rest3 frame rate register. This register sets the Rest3 frame rate duration. Default value is 500 ms. To write to the registers, write Lower first, followed by Upper. Register read can be in any order but must be consecutive. R3R[15:0] value must not exceed 0x09B0, otherwise an internal watchdog will trigger a reset. Use the formula below for calculation. Rest3 frame rate duration = (R3R[15:0] + 1) x 1 ms Default = (499 + 1) x 1 = 500 ms All the above values are expected to have a +40% and -20% of tolerance.							

Register: 0x24								
Name: Observation								
Bit	7	6	5	4	3	2	1	0
Field	Reserved	OB_6	OB_5	OB_4	OB_3	OB_2	OB_1	OB_0
	Reset Value: 0x00							
Access: R/W	Read/Write							
Data Type:	Bit Field							
Usage	The user must clear the register by writing 0x00, wait for minimum T_{dly_obs} msec, and read the register. The active process will have set their corresponding bit. The register may be used as part of recovery scheme to detect a problem caused by EFT/B or ESD. T_{dly_obs} is defined as the longest frame period + 0.5msec. The longest frame period is Rest3. Clock tolerance need to be taken into account. For e.g. if the default Rest3 rate of 500msec is used, then T_{dly_obs} = (500x1.4) + 0.5 = 700.5msec.							

Field Name	Description
OB6	SROM_RUN: Indicates whether SROM is running. **0 = SROM not running** 1 = SROM running
OB[5:0]	Set once per frame

Register: 0x25								
Name: Data_Out_Lower								
Bit	7	6	5	4	3	2	1	0
Field	DO_7	DO_6	DO_5	DO_4	DO_3	DO_2	DO_1	DO_0
	Reset Value: 0x00							
Access: R/W	Read Only							
Data Type:	16-bit unsigned integer							
Usage	Lower byte of the Data_Out register							

Register: 0x26								
Name: Data_Out_Upper								
Bit	7	6	5	4	3	2	1	0
Field	DO_{15}	DO_{14}	DO_{13}	DO_{12}	DO_{11}	DO_{10}	DO_9	DO_8
	Reset Value: 0x00							
Access: R/W	Read Only							
Data Type:	16-bit unsigned integer							
Usage	Data in these registers come from the SROM CRC test. The data can be read out in any order. The SROM CRC test is initiated by writing 0x15 to SROM_Enable register.							

CRC Result	Data_Out_Upper	Data_Out_Lower
SROM CRC test	0xBE	0xEF

Register: 0x29								
Name: Raw_Data_Grab								
Bit	7	6	5	4	3	2	1	0
Field	Valid	RD_D_6	RD_D_5	RD_D_4	RD_D_3	RD_D_2	RD_D_1	RD_D_0
	Reset Value: 0x00							
Access: R/W	Read / Write							
Data Type:	8-bit unsigned integer							
Usage	Write any value to this register to initialize the raw data output. Read motion register to check if first raw data is ready, and then read data from this register for the raw data. 1. Write 0 to Bit [5] of register 0x10 (Config2) to disable Rest mode. 2. Write any value to Raw_Data_Grab register to reset the register. 3. Read MOTION register 0x02 & check for Bit [4] for first raw data in raw data grab to be ready. 4. Then continuously reading Raw_Data_Grab register for raw data for 1296 times. Ensure Bit [7] is valid for each raw data read. 5. Write 1 to Bit [5] of register 0x10 (Config2) to enable rest mode if required.							

Register: 0x2A								
Name: SROM_ID								
Bit	7	6	5	4	3	2	1	0
Field	SR_7	SR_6	SR_5	SR_4	SR_3	SR_2	SR_1	SR_0
	0x00							
Access: R/W	Read Only							
Data Type:	8-bit unsigned integer							
Usage	Contains the revision of the downloaded Shadow ROM (SROM) firmware. If the firmware has been successfully downloaded and the chip is operating out of SROM, this register will contain the SROM firmware revision; otherwise it will contain 0x00.							

Register: 0x2B								
Name: Min_SQ_Run								
Bit	7	6	5	4	3	2	1	0
Field	$MSQR_7$	$MSQR_6$	$MSQR_5$	$MSQR_4$	$MSQR_3$	$MSQR_2$	$MSQR_1$	$MSQR_0$
	Reset Value: 0x10							
Access: R/W	Read/Write							
Data Type:	Bit Field							
Usage	This register defines the minimum Squal threshold below which the chip will produce motion delta values of zero. Typically, the default value of this register should only be modified as a result of Lift cut off calibration SROM. Min_SQ_Run is only available for Tracking SROM and above.							

Register: 0x2C								
Name: Raw_Data_Threshold								
Bit	7	6	5	4	3	2	1	0
Field	$RDTH_7$	$RDTH_6$	$RDTH_5$	$RDTH_4$	$RDTH_3$	$RDTH_2$	$RDTH_1$	$RDTH_0$
	Reset Value: 0x0A							
Access: R/W	Read/ Write							
Data Type:	Bit Field							
Usage	This register affects the SQUAL value register value. The SQUAL is a measure of the number of valid features. The raw data threshold register defines what is considered a valid feature. A low threshold value will make it easier for a feature to be considered valid. Therefore, a low raw data threshold will increase SQUAL since more features will be considered valid and vice versa. If raw data threshold is set too high, it will invalidate features that are actually trackable, thus making SQUAL too low and degrades tracking. If raw data threshold is set too low, it will validate features that are not trackable. Typically, the default value of this register should only be modified as the result of Lift cut off calibration SROM. Raw_Data_Threshold is only available with tracking SROM.							

Register: 0x2F								
Name: Config5								
Bit	7	6	5	4	3	2	1	0
Field	$RESX_7$	$RESX_6$	$RESX_5$	$RESX_4$	$RESX_3$	$RESX_2$	$RESX_1$	$RESX_0$
	Reset Value: 0x31							
Access: R/W	Read/ Write							
Data Type:	Bit Field							
Usage	This register allows the user to change the X-axis resolution when the chip is configured to have independent X-axis and Y-axis resolution reporting mode via Rpt_Mod bit = 1 in Config2 register. The setting in this register will be inactive if Rpt_Mod bit = 0.Shown below are the bits, their default values, and optional values.							

Field Name	Description
RESX [7:0]	Set resolution with CPI step of 100 cpi 0x00: 100 cpi (Minimum cpi) 0x01: 200 cpi 0x02: 300 cpi : : **0x31: 5000 cpi (default cpi)** : : 0x77: 12000 cpi (maximum cpi)

Register: 0x3A								
Name: Power_Up_Reset								
Bit	7	6	5	4	3	2	1	0
Field	PUR_7	PUR_6	PUR_5	PUR_4	PUR_3	PUR_2	PUR_1	PUR_0
	Reset Value: N/A							
Access: R/W	Write Only							
Data Type:	8-bit unsigned integer							
Usage	Write 0x5a to this register to reset the chip. All settings will revert to default values. Reset is required after recovering from shutdown mode and to restore normal operation after Frame Capture							

Register: 0x3B								
Name: Shutdown								
Bit	7	6	5	4	3	2	1	0
Field	SD_7	SD_6	SD_5	SD_4	SD_3	SD_2	SD_1	SD_0
	Reset Value: N/A							
Access: R/W	Write Only							
Data Type:	8-bit unsigned integer							
Usage	Write 0xB6 to set the chip to shutdown mode. Refer to the Shutdown section for more details and on the recovery procedure.							

Register: 0x3F								
Name: Inverse_Product_ID								
Bit	7	6	5	4	3	2	1	0
Field	PID_7	PID_6	PID_5	PID_4	PID_3	PID_2	PID_1	PID_0
	Reset Value: 0xBD							
Access: R/W	Read Only							
Data Type:	Bit Field							
Usage	This value is the inverse of the Product_ID. It is used to test the SPI port hardware							

Register: 0x41								
Name: LiftCuttoff_Tune3								
Bit	7	6	5	4	3	2	1	0
Field	$RMSQ_7$	$RMSQ_6$	$RMSQ_5$	$RMSQ_4$	$RMSQ_3$	$RMSQ_3$	$RMSQ_1$	$RMSQ_0$
	Reset Value: 0x00							
Access: R/W	Read/Write							
Data Type:	Bit Field							
Usage	This register is valid only if the calibration procedure is stopped successfully. RMSQ[7:0] recommends a minimum Squal run value that replaces the default value in the Min_SQ_Run register to improve lift performance. LiftCutoff_Tune3 is only available if Lift cut off calibration SROM is used for Lift cut off calibration.							

Register: 0x42								
Name: Angle_Snap								
Bit	7	6	5	4	3	2	1	0
Field	AS_EN	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved
	Reset Value: 0x00							
Access: R/W	Read/Write							
Data Type:	Bit Field							
Usage	The AS_EN bit in this register enables or disables the Angle Snap feature. AS_EN = 0 (Angle snap disabled. This is the default value.) AS_EN = 1 (Angle snap enabled with 5° snap setting.)							

Register: 0x4A								
Name: LiftCuttoff_Tune1								
Bit	7	6	5	4	3	2	1	0
Field	RUN_CAL	Reserved	Reserved	Reserved	Reserved	CAL_STAT2	CAL_STAT1	CAL_STAT0
	Reset Value: 0x00							
Access: R/W	Read/Write							
Data Type:	Bit Field							

Usage

This register is used to start either the Shutter Calibration or the SQUAL Calibration Lift cut off calibration procedure. It is also used to check the status of either procedure. Refer to the Lift cut off calibration section for more details.

Field Name	Description
RUN_CAL	0 = Stop Shutter Calibration procedure (default) 1 = Start Shutter Calibration procedure
Bit [6:3]	Reserved
CAL_STAT[2:0]	0x00 = Reserved 0x01 = Calibration in progress. 0x02 = Calibration successfully completed (minimum length met). Surface data collection continues until timeout. Registers LiftCutoff_Tune_Min_Length and LiftCutoff_Tune_Timeout define the minimum length threshold and timeout respectively. 0x03 = Calibration successfully completed (minimum length met) and timeout has triggered. Surface data collection stops automatically. 0x04 = Calibration unsuccessful (minimum length not met) and timeout has triggered. 0x05 - 0x07 = Reserved

Register: 0x50								
Name: Motion_Burst								
Bit	7	6	5	4	3	2	1	0
Field	MB_7	MB_6	MB_5	MB_4	MB_3	MB_2	MB_1	MB_0
	Reset Value: 0x00							
Access: R/W	Read/Write							
Data Type:	8-Bit unsigned integer							
Usage	The Motion_Burst register is used for high-speed access of up to 12 register bytes. See the Burst Mode-Motion Read section for full details of operation.							

Register: 0x58								
Name: LiftCuttoff_Tune_Timeout								
Bit	7	6	5	4	3	2	1	0
Field	$RMSQ_7$	$RMSQ_6$	$RMSQ_5$	$RMSQ_4$	$RMSQ_3$	$RMSQ_3$	$RMSQ_1$	$RMSQ_0$
	Reset Value: 0x27							
Access: R/W	Read/Write							
Data Type:	Bit Field							
Usage	This register sets the minimum Lift cut off calibration timeout threshold. Timeout (sec) = (TIMEOUT[7:0] + 1) x 0.5 sec Default = (39 + 1) x 0.5 = 20 sec Allowed TIMEOUT[7:0] range is 0x00 (0.5 sec) to 0xF9 (125 sec). All the above values are expected to have a +40% and -20% of tolerance.							

Register: 0x5A								
Name: LiftCuttoff_Tune_Min_Length								
Bit	7	6	5	4	3	2	1	0
Field	$MINL_7$	$MINL_6$	$MINL_5$	$MINL_4$	$MINL_3$	$MINL_3$	$MINL_1$	$MINL_0$
	Reset Value: 0x09							
Access: R/W	Read/Write							
Data Type:	Bit Field							
Usage	This register sets the minimum Lift cut off calibration length threshold. Minimum Length (inches) = (MINL[7:0] + 1) x 2 inches Default = (9 + 1) x 2 = 20 inches Allowed MINL [7:0] range is 0x00 (2 inches) to 0xF9 (500 inches). Actual distance is expected to have a tolerance that is strongly dependent on MINL. The tolerance is approximately 40% for MINL = 0x04 (10 inches) and above. It is not recommended to set a MINL that is lower because the tolerance can potentially increase to 100%.							

Register: 0x62								
Name: SROM_Load_Burst								
Bit	7	6	5	4	3	2	1	0
Field	SL_7	SL_6	SL_5	SL_4	SL_3	SL_2	SL_1	SL_0
	Reset Value: N/A							
Access: R/W	Write Only							
Data Type:	8-Bit unsigned integer							
Usage	The SROM_Load_Burst register is used for high-speed programming SROM from an external PROM or microcontroller. See the SROM Download section for use details.							

Register: 0x63								
Name: Lift_Config								
Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	LIFC1	LIFC0
	Reset Value: 0X02							
Access: R/W	Read/Write							
Data Type:	Bit Field							
Usage	This register defines the lift detection height threshold. The lift status bit is asserted when the chip is above the threshold.							

LIFC[1:0]	Description
00	Reserved
10	Lift detection height = nominal height + 2 mm (default value).
11	Lift detection height = nominal height + 3 mm.

Register: 0x64								
Name: Raw_Data_Burst								
Bit	7	6	5	4	3	2	1	0
Field	RDB_7	RDB_6	RDB_5	RDB_4	RDB_3	RDB_2	RDB_1	RDB_0
	Reset Value: 0X00							
Access: R/W	Read Only							
Data Type:	8-Bit unsigned integer							
Usage	The Raw_Data_Burst register is used for high-speed access to all the raw data values for one complete frame capture, without having to write to the register address to obtain each raw data. The data pointer is automatically incremented after each read so all 1296 raw data values may be obtained by reading this register 1296 times. See the Frame Capture section for details. **Note**: Maximum raw data value is 127. PB7 is always zero.							

Register: 0x65								
Name: LiftCuttoff_Tune2								
Bit	7	6	5	4	3	2	1	0
Field	Reserved	$RPTH_6$	$RPTH_5$	$RPTH_4$	$RPTH_3$	$RPTH_3$	$RPTH_1$	$RPTH_0$
	Reset Value:0x00							
Access: R/W	Read Only							
Data Type:	Bit Field							
Usage	This register provides Lift cut off calibration related readout registers. See the Lift cut off calibration section for more details. **Field Name** — **Description** RPTH[6:0] — These bits are valid only if calibration procedure is stopped successfully. RPTH[6:0] recommends a raw data threshold value that replaces the default value in the Raw_Data_Threshold register to improve lift performance.							

12.0 Document Revision History

Revision Number	Date	Description
1.00	19 Aug 2014	- Initial creation
1.10	26 Nov 2015	- pg8 update Fig6 Lens Outline Drawing - pg10 update Fig8 Recommended Base Plate Opening - pg28 add item #3 Delay for 30mis
1.20	25 Feb 2016	- pg23 add point #8 Write 0x00 to Config2 register for wired mouse or 0x20 for wireless mouse design
1.30	6 Apr 2016	- pg47 add Register 0x29 Pix_Grab information
1.40	3 Aug 2016	- pg55 modify Register 0x63 Lift_Config register information. Removed setting 0x00
1.50	26 Sep 2016	- Update document. Change “sensor” to “chip”& “pixel” to “raw data” - Change PixArt RoH Logo - Change Image Array to Picture Element Array