



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 [10] 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 [6] and higher lift to drag ratio [7]. 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 $2 [\frac{\partial C_r}{\partial \alpha}]$ for $\alpha \leq 8^\circ$) 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 ($\alpha < 8^\circ$), 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 ($C_r = 0.4519$ []).

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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

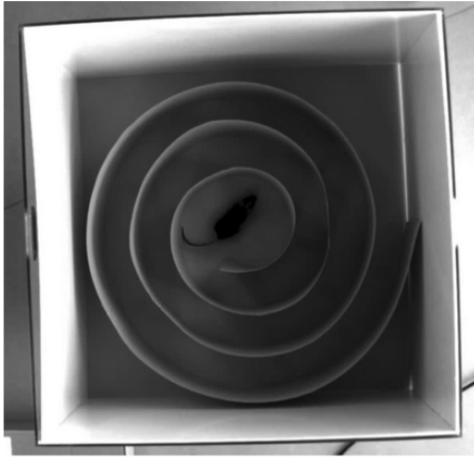


Figure 1.2 – The experimental setup used in [1].

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 4 describes the control strategy and shows some preliminary responses. Finally in section 5 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 and communication

In this section the architecture and the communication are explained and detailed.

2.1 System architecture

In this section the architecture and interfaces between the different components of the machine are detailed.

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 considered 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 a 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 3.3 – 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

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.

4 Control

5 Conclusion

References

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A MAVLink dialect description file

```

1 <?xml version="1.0"?>
2 <mavlink>
3   <version>3</version>
4   <dialect>2</dialect>
5   <enums>
6     <enum name="MOUSE_MODE">
7       <description>This enum defines the mode to be used</
8         description>
9       <entry value="0" name="MOUSE_MODE_STOP">
10        <description>All motion of mouse treadmill is stopped<
11          /description>
12        </entry>
13        <entry value="1" name="MOUSE_MODE_SPEED">
14          <description>Constanst speed is applied. Speed
15            selected by PC message SPEED_SETPOINT.</description>
16          </entry>
17        <entry value="2" name="MOUSE_MODE_AUTO_LOAD">
18          <description>Predefined speed profile is loaded</
19            description>
20          </entry>
21        <entry value="3" name="MOUSE_MODE_AUTO_RUN">

```

```

18         <description>Predefined speed profile is applied</
           description>
19     </entry>
20 </enum>
21 <enum name="MOUSE_ERROR">
22     <description>This enum defines the possible errors</
           description>
23     <entry value="0" name="MOTOR_ERROR">
24         <description>The motor driver flagged 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  ----- */
24 #ifndef __MAIN_H
25 #define __MAIN_H
26
27 #ifdef __cplusplus
28 extern "C" {
29 #endif
30
31 /* Includes
32  ----- */
33
34 /* Private includes
35  ----- */
36
37 /* USER CODE BEGIN Includes */
38 #include "mouseDriver.h"
39 #include "mavlink.h"
40 /* USER CODE END Includes */

```

```

39 /* Exported types
   -----
   */
40 /* USER CODE BEGIN ET */
41 typedef struct SENSOR{
42     GPIO_TypeDef * cs_port;
43     uint8_t cs_pin;
44     GPIO_TypeDef * pw_port;
45     uint8_t pw_pin;
46     uint8_t status;
47 } sensor_t;
48 /* USER CODE END ET */
49
50 /* Exported constants
   -----
   */
51 /* USER CODE BEGIN EC */
52
53 /* USER CODE END EC */
54
55 /* Exported macro
   -----
   */
56 /* USER CODE BEGIN EM */
57
58 /* USER CODE END EM */
59
60 void HAL_TIM_MspPostInit(TIM_HandleTypeDef *htim);
61
62 /* Exported functions prototypes
   -----*/
63 void Error_Handler(void);
64
65 /* USER CODE BEGIN EFP */
66 void main_transmit_buffer(uint8_t *outBuffer, uint16_t msg_size);
67 void main_stop_motors(void);
68 void main_set_motors_speed(mavlink_motor_setpoint_t motor );
69 int main_get_huart_tx_state(void);
70 void main_write_sensor(sensor_t sensor, uint8_t adress, uint8_t data);
71 uint8_t main_read_sensor(sensor_t sensor, uint8_t adress );
72 void main_transmit_spi(uint8_t data);
73 void main_wait_160us(void);
74 void main_wait_20us(void);
75 void main_write_sensor_burst(uint8_t data);
76 void main_read_sensor_motion_burst(uint8_t *data );
77 /*
78  * PW_0 is power pin for sensor X (PB_0)
79  * PW_1 is the power pin for sensor Y (PA_4)
80  * CS_0 is the chip select for sensor X (PC_0)
81  * CS_1 is the chip select for sensor Y (PC_1)
82  */
83
84 /* USER CODE END EFP */
85
86 /* Private defines
   -----
   */
87 #define DT_HEART 200

```



```

88 #define PRESCALER_HEART 1000
89 #define CLOCK_FREQ 8000000
90 #define COUNTER_PERIOD_HEART ((CLOCK_FREQ/(PRESCALER_HEART))*0.001*
    DT_HEART)
91 #define PRESCALER_PWM 9
92 #define COUNTER_PERIOD_PWM 255
93 #define PULSE_PWM 10
94 #define B1_Pin GPIO_PIN_13
95 #define B1_GPIO_Port GPIOC
96 #define CS_0_Pin GPIO_PIN_0
97 #define CS_0_GPIO_Port GPIOC
98 #define CS_1_Pin GPIO_PIN_1
99 #define CS_1_GPIO_Port GPIOC
100 #define USART_TX_Pin GPIO_PIN_2
101 #define USART_TX_GPIO_Port GPIOA
102 #define USART_RX_Pin GPIO_PIN_3
103 #define USART_RX_GPIO_Port GPIOA
104 #define PW_1_Pin GPIO_PIN_4
105 #define PW_1_GPIO_Port GPIOA
106 #define LD2_Pin GPIO_PIN_5
107 #define LD2_GPIO_Port GPIOA
108 #define PW_0_Pin GPIO_PIN_0
109 #define PW_0_GPIO_Port GPIOB
110 #define TMS_Pin GPIO_PIN_13
111 #define TMS_GPIO_Port GPIOA
112 #define TCK_Pin GPIO_PIN_14
113 #define TCK_GPIO_Port GPIOA
114 #define SWO_Pin GPIO_PIN_3
115 #define SWO_GPIO_Port GPIOB
116 /* USER CODE BEGIN Private defines */
117
118 /* USER CODE END Private defines */
119
120 #ifdef __cplusplus
121 }
122 #endif
123
124 #endif /* __MAIN_H */
125
126 /***** (C) COPYRIGHT STMicroelectronics *****/

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  #define TIMEOUT 2
37  /* USER CODE END PD */
38
39  /* Private macro
   -----
   */
40  /* USER CODE BEGIN PM */
41
42  /* USER CODE END PM */
43
44  /* Private variables
   -----
   */
45  SPI_HandleTypeDef hspi2;
46
47  TIM_HandleTypeDef htim1;
48  TIM_HandleTypeDef htim7;
49
50  UART_HandleTypeDef huart2;
51  DMA_HandleTypeDef hdma_usart2_tx;
52
53  /* USER CODE BEGIN PV */
54  static uint8_t inByte = 0;
55  /* USER CODE END PV */
56
57  /* Private function prototypes
   ----- */
58  void SystemClock_Config(void);
59  static void MX_GPIO_Init(void);
60  static void MX_USART2_UART_Init(void);
61  static void MX_TIM7_Init(void);
62  static void MX_TIM1_Init(void);

```

```

63 static void MX_DMA_Init(void);
64 static void MX_SPI2_Init(void);
65 /* USER CODE BEGIN PFP */
66 void main_wait_160us(void){
67     int i = 0;
68     i = 0;
69     while(i<900){
70         HAL_GPIO_TogglePin(GPIOA, GPIO_PIN_5);
71         i++;
72     }
73 }
74 void main_wait_20us(void){
75     int i = 0;
76     i = 0;
77     while(i<185){
78         HAL_GPIO_TogglePin(GPIOA, GPIO_PIN_5);
79         i++;
80     }
81 }
82 void main_wait_1us(void){
83     int i = 0;
84     i = 0;
85     while(i<25){
86         HAL_GPIO_TogglePin(GPIOA, GPIO_PIN_5);
87         i++;
88     }
89 }
90 int main_get_huart_tx_state(void){
91     return (HAL_DMA_GetState(&hdma_usart2_tx));
92 }
93 void main_transmit_buffer(uint8_t *outBuffer, uint16_t msg_size){
94     HAL_UART_Transmit_DMA(&huart2, outBuffer,msg_size);
95 }
96 void main_stop_motors(void)
97 {
98     HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_1);
99     HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_2);
100 }
101 void main_set_motors_speed(mavlink_motor_setpoint_t motor )
102 {
103
104     htim1.Instance->CCR1 = motor.motor_x;
105     htim1.Instance->CCR2 = motor.motor_y;
106
107     if (motor.motor_x == 0)
108         HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_1);
109     else
110         HAL_TIM_PWM_Start(&htim1, TIM_CHANNEL_1);
111
112     if (motor.motor_y == 0)
113         HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_2);
114     else
115         HAL_TIM_PWM_Start(&htim1, TIM_CHANNEL_2);
116
117 }
118 uint8_t main_read_sensor (const sensor_t sensor, uint8_t adress ){
119     uint8_t value = 0;
120     uint8_t adress_read = adress & 0x7F;

```

```

121
122 HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_RESET);
123 HAL_SPI_Transmit(&hspi2, &adress_read, 1, 100);
124 main_wait_160us();
125 HAL_SPI_Receive(&hspi2, &value, 1, 100);
126 main_wait_1us();
127 HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_SET);
128 main_wait_20us();
129 return (value);
130 }
131
132 void main_write_sensor (const sensor_t sensor, uint8_t adress, uint8_t data){
133     uint8_t value = data;
134     uint8_t adress_write = adress | 0x80;
135     uint8_t pack[2];
136     pack[0] = adress_write;
137     pack[1] = value;
138
139     HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_RESET);
140     HAL_SPI_Transmit(&hspi2, pack, 2, 10);
141     main_wait_20us();
142     HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_SET);
143     main_wait_160us();
144     main_wait_20us();
145 }
146 void main_write_sensor_burst(uint8_t data){
147     HAL_SPI_Transmit(&hspi2, &data, 1, 10);
148     main_wait_20us();
149 }
150 void main_read_sensor_motion_burst(uint8_t *data ){
151     HAL_SPI_Receive(&hspi2, data, 12, 100);
152     main_wait_1us();
153 }
154 void main_transmit_spi(uint8_t data){
155     uint8_t data_out = data;
156     HAL_SPI_Transmit(&hspi2, &data_out, 1, 10);
157 }
158 /* USER CODE END PFP */
159
160 /* Private user code
   -----
   */
161 /* USER CODE BEGIN 0 */
162
163 void TM7_IRQHandler(void){
164     HAL_TIM_IRQHandler(&htim7);
165
166 }
167
168 /* This callback is called by the HAL_UART_IRQHandler when the given number of bytes are
   received */
169 void HAL_UART_RxCpltCallback(UART_HandleTypeDef *huart){
170     HAL_NVIC_DisableIRQ(USART2_IRQn);
171     mavlink_message_t inmsg;
172     mavlink_status_t msgStatus;
173     if (huart->Instance == USART2){
174         /* Receive one byte in interrupt mode */
175         HAL_UART_Receive_IT(&huart2, &inByte, 1);

```

```

176     if(mavlink_parse_char(0, inByte, &inmsg, &msgStatus)){
177
178         mouseDriver_readMsg(inmsg);
179     }
180 }
181 HAL_NVIC_EnableIRQ(USART2_IRQn);
182 }
183
184 void HAL_TIM_PeriodElapsedCallback(TIM_HandleTypeDef *htim){
185     if (htim->Instance==TIM7){
186         mouseDriver_send_status_msg();
187     }
188 }
189 /* USER CODE END 0 */
190
191 /**
192  * @brief The application entry point.
193  * @retval int
194  */
195 int main(void)
196 {
197     /* USER CODE BEGIN 1 */
198
199     /* USER CODE END 1 */
200
201
202     /* MCU Configuration
203      *
204      * Reset of all peripherals, Initializes the Flash interface and the Systick. */
205     HAL_Init();
206
207     /* USER CODE BEGIN Init */
208
209     /* USER CODE END Init */
210
211     /* Configure the system clock */
212     SystemClock_Config();
213
214     /* USER CODE BEGIN SysInit */
215
216     /* USER CODE END SysInit */
217
218     /* Initialize all configured peripherals */
219     MX_GPIO_Init();
220     MX_USART2_UART_Init();
221     MX_TIM7_Init();
222     MX_TIM1_Init();
223     MX_DMA_Init();
224     MX_SPI2_Init();
225     /* USER CODE BEGIN 2 */
226     HAL_InitTick(0);
227     HAL_NVIC_SetPriority(USART2_IRQn,1,0);
228     HAL_NVIC_EnableIRQ(USART2_IRQn);
229     HAL_NVIC_SetPriority(TIM7_IRQn,2,0);
230     HAL_NVIC_EnableIRQ(TIM7_IRQn);
231     HAL_GPIO_WritePin(GPIOC, CS_0_Pin|CS_1_Pin, GPIO_PIN_SET);

```

```

232
233 HAL_UART_Receive_IT(&huart2, &inByte, 1);
234 HAL_TIM_Base_Start_IT(&htim7);
235 HAL_GPIO_WritePin(GPIOC, GPIO_PIN_0, GPIO_PIN_SET);
236
237 mouseDriver_init();
238
239 /* USER CODE END 2 */
240
241 /* Infinite loop */
242 /* USER CODE BEGIN WHILE */
243
244 while (1)
245 {
246     mouseDriver_idle();
247     /* USER CODE END WHILE */
248
249     /* USER CODE BEGIN 3 */
250 }
251 /* USER CODE END 3 */
252 }
253
254 /**
255  * @brief System Clock Configuration
256  * @retval None
257  */
258 void SystemClock_Config(void)
259 {
260     RCC_OscInitTypeDef RCC_OscInitStruct = {0};
261     RCC_ClkInitTypeDef RCC_ClkInitStruct = {0};
262     RCC_PeriphCLKInitTypeDef PeriphClkInit = {0};
263
264     /** Initializes the CPU, AHB and APB busses clocks
265     */
266     RCC_OscInitStruct.OscillatorType = RCC_OSCILLATORTYPE_HSI;
267     RCC_OscInitStruct.HSISState = RCC_HSI_ON;
268     RCC_OscInitStruct.HSICalibrationValue = RCC_HSICALIBRATION_DEFAULT;
269     RCC_OscInitStruct.PLL.PLLState = RCC_PLL_ON;
270     RCC_OscInitStruct.PLL.PLLSource = RCC_PLLSOURCE_HSI;
271     RCC_OscInitStruct.PLL.PLLM = 1;
272     RCC_OscInitStruct.PLL.PLLN = 10;
273     RCC_OscInitStruct.PLL.PLLP = RCC_PLLP_DIV7;
274     RCC_OscInitStruct.PLL.PLLQ = RCC_PLLQ_DIV2;
275     RCC_OscInitStruct.PLL.PLLR = RCC_PLLR_DIV2;
276     if (HAL_RCC_OscConfig(&RCC_OscInitStruct) != HAL_OK)
277     {
278         Error_Handler();
279     }
280     /** Initializes the CPU, AHB and APB busses clocks
281     */
282     RCC_ClkInitStruct.ClockType = RCC_CLOCKTYPE_HCLK|
        RCC_CLOCKTYPE_SYCLK
283         |RCC_CLOCKTYPE_PCLK1|RCC_CLOCKTYPE_PCLK2;
284     RCC_ClkInitStruct.SYSCLKSource = RCC_SYSCLKSOURCE_PLLCLK;
285     RCC_ClkInitStruct.AHBCLKDivider = RCC_SYSCLK_DIV1;
286     RCC_ClkInitStruct.APB1CLKDivider = RCC_HCLK_DIV1;
287     RCC_ClkInitStruct.APB2CLKDivider = RCC_HCLK_DIV1;
288

```

```

289 if (HAL_RCC_ClockConfig(&RCC_ClkInitStruct, FLASH_LATENCY_4) != HAL_OK)
290 {
291     Error_Handler();
292 }
293 PeriphClkInit.PeriphClockSelection = RCC_PERIPHCLK_USART2;
294 PeriphClkInit.Usart2ClockSelection = RCC_USART2CLKSOURCE_PCLK1;
295 if (HAL_RCCEx_PeriphCLKConfig(&PeriphClkInit) != HAL_OK)
296 {
297     Error_Handler();
298 }
299 /** Configure the main internal regulator output voltage
300 */
301 if (HAL_PWREx_ControlVoltageScaling(PWR_REGULATOR_VOLTAGE_SCALE1) !=
302     HAL_OK)
303 {
304     Error_Handler();
305 }
306
307 /**
308  * @brief SPI2 Initialization Function
309  * @param None
310  * @retval None
311  */
312 static void MX_SPI2_Init(void)
313 {
314
315     /* USER CODE BEGIN SPI2_Init 0 */
316     HAL_GPIO_DeInit(GPIOC, GPIO_PIN_3);
317
318     /*GPIO_InitTypeDef pin;
319     pin.Pin = GPIO_PIN_3;
320     pin.Mode = GPIO_MODE_OUTPUT_PP;
321     pin.Pull = GPIO_PULLDOWN;
322     pin.Speed = GPIO_SPEED_MEDIUM;
323     HAL_GPIO_Init(GPIOC, &pin);
324     HAL_GPIO_WritePin(GPIOC,GPIO_PIN_3, GPIO_PIN_RESET);*/
325
326     __HAL_RCC_SPI2_CLK_ENABLE();
327     __SPI2_CLK_ENABLE();
328     /* USER CODE END SPI2_Init 0 */
329
330     /* USER CODE BEGIN SPI2_Init 1 */
331
332     /* USER CODE END SPI2_Init 1 */
333     /* SPI2 parameter configuration*/
334     hspi2.Instance = SPI2;
335     hspi2.Init.Mode = SPI_MODE_MASTER;
336     hspi2.Init.Direction = SPI_DIRECTION_2LINES;
337     hspi2.Init.DataSize = SPI_DATASIZE_8BIT;
338     hspi2.Init.CLKPolarity = SPI_POLARITY_HIGH;
339     hspi2.Init.CLKPhase = SPI_PHASE_2EDGE;
340     hspi2.Init.NSS = SPI_NSS_SOFT;
341     hspi2.Init.BaudRatePrescaler = SPI_BAUDRATEPRESCALER_256;
342     hspi2.Init.FirstBit = SPI_FIRSTBIT_MSB;
343     hspi2.Init.TIMode = SPI_TIMODE_DISABLE;
344     hspi2.Init.CRCCalculation = SPI_CRCCALCULATION_DISABLE;
345     hspi2.Init.CRCPolynomial = 7;

```

```

346 hspi2.Init.CRCLength = SPI_CRC_LENGTH_DATASIZE;
347 hspi2.Init.NSSPMODE = SPI_NSS_PULSE_DISABLE;
348 if (HAL_SPI_Init(&hspi2) != HAL_OK)
349 {
350     Error_Handler();
351 }
352 /* USER CODE BEGIN SPI2_Init 2 */
353
354
355 /* USER CODE END SPI2_Init 2 */
356
357 }
358
359 /**
360  * @brief TIM1 Initialization Function
361  * @param None
362  * @retval None
363  */
364 static void MX_TIM1_Init(void)
365 {
366
367     /* USER CODE BEGIN TIM1_Init 0 */
368
369     /* USER CODE END TIM1_Init 0 */
370
371     TIM_ClockConfigTypeDef sClockSourceConfig = {0};
372     TIM_MasterConfigTypeDef sMasterConfig = {0};
373     TIM_OC_InitTypeDef sConfigOC = {0};
374     TIM_BreakDeadTimeConfigTypeDef sBreakDeadTimeConfig = {0};
375
376     /* USER CODE BEGIN TIM1_Init 1 */
377
378     /* USER CODE END TIM1_Init 1 */
379     htim1.Instance = TIM1;
380     htim1.Init.Prescaler = PRESCALER_PWM;
381     htim1.Init.CounterMode = TIM_COUNTERMODE_UP;
382     htim1.Init.Period = COUNTER_PERIOD_PWM;
383     htim1.Init.ClockDivision = TIM_CLOCKDIVISION_DIV1;
384     htim1.Init.RepetitionCounter = 0;
385     htim1.Init.AutoReloadPreload = TIM_AUTORELOAD_PRELOAD_DISABLE;
386     if (HAL_TIM_Base_Init(&htim1) != HAL_OK)
387     {
388         Error_Handler();
389     }
390     sClockSourceConfig.ClockSource = TIM_CLOCKSOURCE_INTERNAL;
391     if (HAL_TIM_ConfigClockSource(&htim1, &sClockSourceConfig) != HAL_OK)
392     {
393         Error_Handler();
394     }
395     if (HAL_TIM_PWM_Init(&htim1) != HAL_OK)
396     {
397         Error_Handler();
398     }
399     sMasterConfig.MasterOutputTrigger = TIM_TRGO_RESET;
400     sMasterConfig.MasterOutputTrigger2 = TIM_TRGO2_RESET;
401     sMasterConfig.MasterSlaveMode = TIM_MASTERSLAVEMODE_DISABLE;
402     if (HAL_TIMEx_MasterConfigSynchronization(&htim1, &sMasterConfig) != HAL_OK)
403     {

```



```

404     Error_Handler();
405 }
406 sConfigOC.OCMode = TIM_OCMode_PWM1;
407 sConfigOC.Pulse = PULSE_PWM;
408 sConfigOC.OCpolarity = TIM_OCPolarity_HIGH;
409 sConfigOC.OCNPolarity = TIM_OCNpolarity_HIGH;
410 sConfigOC.OCFastMode = TIM_OCFAST_DISABLE;
411 sConfigOC.OCIdleState = TIM_OCIdleState_RESET;
412 sConfigOC.OCNIdleState = TIM_OCNIdleState_RESET;
413 if (HAL_TIM_PWM_ConfigChannel(&htim1, &sConfigOC, TIM_CHANNEL_1) !=
    HAL_OK)
414 {
415     Error_Handler();
416 }
417 if (HAL_TIM_PWM_ConfigChannel(&htim1, &sConfigOC, TIM_CHANNEL_2) !=
    HAL_OK)
418 {
419     Error_Handler();
420 }
421 sBreakDeadTimeConfig.OffStateRunMode = TIM_OSSR_DISABLE;
422 sBreakDeadTimeConfig.OffStateIDLEMode = TIM_OSSI_DISABLE;
423 sBreakDeadTimeConfig.LockLevel = TIM_LOCKLEVEL_OFF;
424 sBreakDeadTimeConfig.DeadTime = 0;
425 sBreakDeadTimeConfig.BreakState = TIM_BREAK_DISABLE;
426 sBreakDeadTimeConfig.BreakPolarity = TIM_BREAKPolarity_HIGH;
427 sBreakDeadTimeConfig.BreakFilter = 0;
428 sBreakDeadTimeConfig.Break2State = TIM_BREAK2_DISABLE;
429 sBreakDeadTimeConfig.Break2Polarity = TIM_BREAK2Polarity_HIGH;
430 sBreakDeadTimeConfig.Break2Filter = 0;
431 sBreakDeadTimeConfig.AutomaticOutput = TIM_AUTOMATICOUTPUT_DISABLE;
432 if (HAL_TIMEx_ConfigBreakDeadTime(&htim1, &sBreakDeadTimeConfig) != HAL_OK)
433 {
434     Error_Handler();
435 }
436 /* USER CODE BEGIN TIM1_Init 2 */
437
438 /* USER CODE END TIM1_Init 2 */
439 HAL_TIM_MspPostInit(&htim1);
440
441 }
442
443 /**
444  * @brief TIM7 Initialization Function
445  * @param None
446  * @retval None
447  */
448 static void MX_TIM7_Init(void)
449 {
450
451     /* USER CODE BEGIN TIM7_Init 0 */
452
453     /* USER CODE END TIM7_Init 0 */
454
455     TIM_MasterConfigTypeDef sMasterConfig = {0};
456
457     /* USER CODE BEGIN TIM7_Init 1 */
458
459     /* USER CODE END TIM7_Init 1 */

```

```

460 htim7.Instance = TIM7;
461 htim7.Init.Prescaler = PRESCALER_HEART;
462 htim7.Init.CounterMode = TIM_COUNTERMODE_UP;
463 htim7.Init.Period = COUNTER_PERIOD_HEART;
464 htim7.Init.AutoReloadPreload = TIM_AUTORELOAD_PRELOAD_DISABLE;
465 if (HAL_TIM_Base_Init(&htim7) != HAL_OK)
466 {
467     Error_Handler();
468 }
469 sMasterConfig.MasterOutputTrigger = TIM_TRGO_RESET;
470 sMasterConfig.MasterSlaveMode = TIM_MASTERSLAVEMODE_DISABLE;
471 if (HAL_TIMEx_MasterConfigSynchronization(&htim7, &sMasterConfig) != HAL_OK)
472 {
473     Error_Handler();
474 }
475 /* USER CODE BEGIN TIM7_Init 2 */
476
477 /* USER CODE END TIM7_Init 2 */
478
479 }
480
481 /**
482  * @brief USART2 Initialization Function
483  * @param None
484  * @retval None
485  */
486 static void MX_USART2_UART_Init(void)
487 {
488
489     /* USER CODE BEGIN USART2_Init 0 */
490     /* DMA controller clock enable */
491     __DMA1_CLK_ENABLE();
492
493     /* Peripheral DMA init*/
494     hdma_usart2_tx.Init.Direction = DMA_MEMORY_TO_PERIPH;
495     hdma_usart2_tx.Init.PeriphInc = DMA_PINC_DISABLE;
496     hdma_usart2_tx.Init.MemInc = DMA_MINC_ENABLE;
497     hdma_usart2_tx.Init.PeriphDataAlignment = DMA_MDATAALIGN_BYTE;
498     hdma_usart2_tx.Init.MemDataAlignment = DMA_MDATAALIGN_BYTE;
499     hdma_usart2_tx.Init.Mode = DMA_NORMAL;
500     hdma_usart2_tx.Init.Priority = DMA_PRIORITY_LOW;
501     HAL_DMA_Init(&hdma_usart2_tx);
502
503     __HAL_LINKDMA(&huart2,hdmatx,hdma_usart2_tx);
504     /* USER CODE END USART2_Init 0 */
505
506     /* USER CODE BEGIN USART2_Init 1 */
507
508     /* USER CODE END USART2_Init 1 */
509     huart2.Instance = USART2;
510     huart2.Init.BaudRate = 230400;
511     huart2.Init.WordLength = UART_WORDLENGTH_8B;
512     huart2.Init.StopBits = UART_STOPBITS_1;
513     huart2.Init.Parity = UART_PARITY_NONE;
514     huart2.Init.Mode = UART_MODE_TX_RX;
515     huart2.Init.HwFlowCtl = UART_HWCONTROL_NONE;
516     huart2.Init.OverSampling = UART_OVERSAMPLING_16;
517     huart2.Init.OneBitSampling = UART_ONE_BIT_SAMPLE_DISABLE;

```

```

518 huart2.AdvancedInit.AdvFeatureInit = UART_ADVFEATURE_NO_INIT;
519 if (HAL_UART_Init(&huart2) != HAL_OK)
520 {
521     Error_Handler();
522 }
523 /* USER CODE BEGIN USART2_Init 2 */
524
525 /* USER CODE END USART2_Init 2 */
526
527 }
528
529 /**
530  * Enable DMA controller clock
531  */
532 static void MX_DMA_Init(void)
533 {
534
535     /* DMA controller clock enable */
536     __HAL_RCC_DMA1_CLK_ENABLE();
537
538     /* DMA interrupt init */
539     /* DMA1_Channel7_IRQn interrupt configuration */
540     HAL_NVIC_SetPriority(DMA1_Channel7_IRQn, 0, 0);
541     HAL_NVIC_EnableIRQ(DMA1_Channel7_IRQn);
542
543 }
544
545 /**
546  * @brief GPIO Initialization Function
547  * @param None
548  * @retval None
549  */
550 static void MX_GPIO_Init(void)
551 {
552     GPIO_InitTypeDef GPIO_InitStructure = {0};
553
554     /* GPIO Ports Clock Enable */
555     __HAL_RCC_GPIOC_CLK_ENABLE();
556     __HAL_RCC_GPIOH_CLK_ENABLE();
557     __HAL_RCC_GPIOA_CLK_ENABLE();
558     __HAL_RCC_GPIOB_CLK_ENABLE();
559
560     /*Configure GPIO pin Output Level */
561     HAL_GPIO_WritePin(GPIOC, CS_0_Pin|CS_1_Pin, GPIO_PIN_RESET);
562
563     /*Configure GPIO pin Output Level */
564     HAL_GPIO_WritePin(GPIOA, PW_1_Pin|LD2_Pin, GPIO_PIN_RESET);
565
566     /*Configure GPIO pin Output Level */
567     HAL_GPIO_WritePin(PW_0_GPIO_Port, PW_0_Pin, GPIO_PIN_RESET);
568
569     /*Configure GPIO pin : B1_Pin */
570     GPIO_InitStructure.Pin = B1_Pin;
571     GPIO_InitStructure.Mode = GPIO_MODE_IT_FALLING;
572     GPIO_InitStructure.Pull = GPIO_NOPULL;
573     HAL_GPIO_Init(B1_GPIO_Port, &GPIO_InitStructure);
574
575     /*Configure GPIO pins : CS_0_Pin CS_1_Pin */

```

```

576 GPIO_InitStruct.Pin = CS_0_Pin|CS_1_Pin;
577 GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;
578 GPIO_InitStruct.Pull = GPIO_NOPULL;
579 GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_LOW;
580 HAL_GPIO_Init(GPIOC, &GPIO_InitStruct);
581
582 /*Configure GPIO pins : PW_1_Pin LD2_Pin */
583 GPIO_InitStruct.Pin = PW_1_Pin|LD2_Pin;
584 GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;
585 GPIO_InitStruct.Pull = GPIO_NOPULL;
586 GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_LOW;
587 HAL_GPIO_Init(GPIOA, &GPIO_InitStruct);
588
589 /*Configure GPIO pin : PW_0_Pin */
590 GPIO_InitStruct.Pin = PW_0_Pin;
591 GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;
592 GPIO_InitStruct.Pull = GPIO_NOPULL;
593 GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_LOW;
594 HAL_GPIO_Init(PW_0_GPIO_Port, &GPIO_InitStruct);
595
596 }
597
598 /* USER CODE BEGIN 4 */
599
600 /* USER CODE END 4 */
601
602 /**
603  * @brief This function is executed in case of error occurrence.
604  * @retval None
605  */
606 void Error_Handler(void)
607 {
608     /* USER CODE BEGIN Error_Handler_Debug */
609     /* User can add his own implementation to report the HAL error return state */
610
611     /* USER CODE END Error_Handler_Debug */
612 }
613
614 #ifndef USE_FULL_ASSERT
615 /**
616  * @brief Reports the name of the source file and the source line number
617  *        where the assert_param error has occurred.
618  * @param file: pointer to the source file name
619  * @param line: assert_param error line source number
620  * @retval None
621  */
622 void assert_failed(char *file, uint32_t line)
623 {
624     /* USER CODE BEGIN 6 */
625     /* User can add his own implementation to report the file name and line number,
626        tex: printf("Wrong parameters value: file %s on line %d\r\n", file, line) */
627     /* USER CODE END 6 */
628 }
629 #endif /* USE_FULL_ASSERT */
630
631 /***** (C) COPYRIGHT STMicroelectronics *****END OF FILE*****/

```

B.2 Treadmill driver

```

1  /*! \file mouseDriver.c
2  \brief Implementation of the driver for the mouse treadmill 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 avoid spinning the motor too fast and
35 break it.
36 If this value is changed the motor might spin too fast and destroy itself or the gear box. Extreme
37 caution
38 needs to be taken if this value is modified.
39 */
40 #define MIN_MOTOR_SIGNAL 10
41 /*!
42 \def MIN_MOTOR_SIGNAL
43 \brief Min value for the motor signal. Any value lower than that will cause the motor to stop
44 */
45 #define MAX_MISSING_MEASURES 15
46 /*!
47 \def MAX_MISSING_MEASURES
48 \brief After MAX_MISSING_MEASURES non valid measures from sensors the motors are
49 stopped and mode goes
50 to stop.
51 */
52 #ifndef TEST
53 /*!
54 \var actual_mode
55 \brief Global variable defining the mode of the machine
56
57 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 amount 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 occurred
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 frequency.
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 with 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 void mouseDriver_initSetpoint(void){
167     actual_speed_setpoint.setpoint_x = 0;
168     actual_speed_setpoint.setpoint_y = 0;
169 }

```

```

170 void mouseDriver_initMode(void){
171     actual_mode = MOUSE_MODE_STOP;
172 }
173 void mouseDriver_initPoints(void){
174     for(int i=0; i<MAX_POINTS; i++){
175         points[i].duration = 0;
176         points[i].setpoint_x = 0;
177         points[i].setpoint_y = 0;
178         points[i].point_id = 0;
179     }
180     actual_point = 0;
181     actual_point_start_time = 0;
182 }
183 void mouseDriver_initMotorSignal(void){
184     actual_motor_signal.motor_x = 0;
185     actual_motor_signal.motor_y = 0;
186 }
187 void mouseDriver_init(void){
188     mouseDriver_initMode();
189     mouseDriver_initSetpoint();
190     mouseDriver_initPoints();
191     mouseDriver_initMotorSignal();
192
193     /* Init sensor as well */
194     sensorDriver_init();
195     main_stop_motors();
196 }
197 uint32_t mouseDriver_getTime (void){
198     return (HAL_GetTick());
199 }
200 void mouseDriver_send_status_msg(void){
201     send_msg = 1;
202 }
203 void mouseDriver_control_idle(void){
204     static int count = 0;
205     if (actual_speed_measure.valid == 0){
206         count ++;
207         if(count >= MAX_MISSING_MEASURES){
208             main_stop_motors();
209             mouseDriver_setMode(MOUSE_MODE_STOP);
210         }
211         return;
212     }
213     if (actual_mode == MOUSE_MODE_SPEED || actual_mode ==
        MOUSE_MODE_AUTO_RUN){
214         actual_motor_signal.time = mouseDriver_getTime();
215         actual_motor_signal.motor_x = (float)K*(actual_speed_setpoint.setpoint_x-
            actual_speed_measure.speed_x);
216         actual_motor_signal.motor_y = (float)K*(actual_speed_setpoint.setpoint_y-
            actual_speed_measure.speed_y);
217
218         if (actual_motor_signal.motor_x > MAX_MOTOR_SIGNAL){
219             actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL;
220         }
221         if (actual_motor_signal.motor_y > MAX_MOTOR_SIGNAL){
222             actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL;
223         }
224

```



```

225     main_set_motors_speed(actual_motor_signal);
226     count = 0;
227 }
228 else{
229     actual_motor_signal.motor_x = 0;
230     actual_motor_signal.motor_y = 0;
231     main_stop_motors();
232 }
233 }
234
235 void mouseDriver_setMode(uint8_t mode){
236     if (mode == MOUSE_MODE_STOP){
237         main_stop_motors();
238         actual_point = 0;
239         actual_mode = MOUSE_MODE_STOP;
240         mouseDriver_initMotorSignal();
241     }
242     if (mode == MOUSE_MODE_AUTO_LOAD){
243         actual_mode = mode;
244         mouseDriver_sendMsg(MAVLINK_MSG_ID_HEARTBEAT);
245     }
246     if (actual_mode == MOUSE_MODE_AUTO_LOAD && mode ==
        MOUSE_MODE_AUTO_RUN ){
247         actual_point = 0;
248         actual_point_start_time = mouseDriver_getTime();
249         actual_speed_setpoint.setpoint_x = points[0].setpoint_x;
250         actual_speed_setpoint.setpoint_y = points[0].setpoint_y;
251         actual_mode = mode;
252     }
253
254     if (actual_mode != MOUSE_MODE_AUTO_RUN)
255         actual_mode = mode;
256 }
257 void mouseDriver_sendMsg(uint32_t msgid){
258     mavlink_message_t msg;
259     static uint8_t outBuffer[MAX_BYTE_BUFFER_SIZE];
260     static uint16_t msg_size = 0;
261
262     while (main_get_huart_tx_state() == HAL_BUSY){
263         /*Wait for other messages to be sent*/
264         HAL_Delay(1);
265     }
266
267     switch(msgid){
268         case MAVLINK_MSG_ID_HEARTBEAT:
269             mavlink_msg_heartbeat_pack(SYS_ID,COMP_ID, &msg, actual_mode,
                mouseDriver_getTime());
270             msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
271             main_transmit_buffer(outBuffer, msg_size);
272             break;
273         case MAVLINK_MSG_ID_SPEED_SETPOINT:
274             mavlink_msg_speed_setpoint_encode(SYS_ID,COMP_ID, &msg, &
                actual_speed_setpoint);
275             msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
276             main_transmit_buffer(outBuffer, msg_size);
277             break;
278         case MAVLINK_MSG_ID_MOTOR_SETPOINT:
279             mavlink_msg_motor_setpoint_encode(SYS_ID,COMP_ID, &msg, &

```

```

actual_motor_signal);
280     msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
281     main_transmit_buffer(outBuffer, msg_size);
282     break;
283     case MAVLINK_MSG_ID_SPEED_INFO:
284         /* DEMO CODE INIT*/
285         actual_speed_measure.time_x = mouseDriver_getTime();
286         /* DEMO CODE END*/
287         mavlink_msg_speed_info_encode(SYS_ID,COMP_ID, &msg, &
actual_speed_measure);
288         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
289         main_transmit_buffer(outBuffer, msg_size);
290         break;
291     case MAVLINK_MSG_ID_ERROR:
292         mavlink_msg_error_encode(SYS_ID,COMP_ID,&msg,&actual_error);
293         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
294         main_transmit_buffer(outBuffer, msg_size);
295         break;
296     case MAVLINK_MSG_ID_POINT_LOADED:
297         mavlink_msg_point_loaded_pack(SYS_ID,COMP_ID,&msg,actual_point);
298         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
299         main_transmit_buffer(outBuffer, msg_size);
300         break;
301     case MAVLINK_MSG_ID_POINT:
302         mavlink_msg_point_encode(SYS_ID,COMP_ID,&msg,&points[actual_point]);
303         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
304         main_transmit_buffer(outBuffer, msg_size);
305         break;
306     case MAVLINK_MSG_ID_RAW_SENSOR:
307         mavlink_msg_raw_sensor_encode(SYS_ID,COMP_ID,&msg,&actual_raw_sensor
[0]);
308         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
309         main_transmit_buffer(outBuffer, msg_size);
310         while (main_get_huart_tx_state() == HAL_BUSY){
311             /*Wait for other messages to be sent*/
312             HAL_Delay(1);
313         }
314         mavlink_msg_raw_sensor_encode(SYS_ID,COMP_ID,&msg,&actual_raw_sensor
[1]);
315         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
316         main_transmit_buffer(outBuffer, msg_size);
317         break;
318     default:
319         break;
320 }
321 }
322 void mouseDriver_idle (void){
323     uint64_t difference = 0;
324     sensorDriver_motion_read_speed(actual_raw_sensor, &actual_speed_measure);
325     switch(actual_mode){
326     case MOUSE_MODE_STOP:
327         mouseDriver_initSetpoint();
328         mouseDriver_initMotorSignal();
329         actual_motor_signal.time = mouseDriver_getTime();
330         main_stop_motors();
331         mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_INFO);
332
333         break;

```

```

334 case MOUSE_MODE_SPEED:
335     mouseDriver_control_idle();
336     mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_INFO);
337     mouseDriver_sendMsg(MAVLINK_MSG_ID_MOTOR_SETPOINT);
338
339     break;
340 case MOUSE_MODE_AUTO_LOAD:
341     if (actual_point == 255){
342         actual_error.error = MOUSE_ROUTINE_TOO_LONG;
343         actual_error.time = mouseDriver_getTime();
344         mouseDriver_sendMsg(MAVLINK_MSG_ID_ERROR);
345     }
346     break;
347 case MOUSE_MODE_AUTO_RUN:
348     difference = mouseDriver_getTime() - actual_point_start_time;
349     if (difference >= points[actual_point].duration){
350         if (actual_point < MAX_POINTS-1){
351             actual_point++;
352
353             if(points[actual_point].duration == 0){
354                 actual_point = 0;
355             }
356             actual_speed_setpoint.setpoint_x = points[actual_point].setpoint_x;
357             actual_speed_setpoint.setpoint_y = points[actual_point].setpoint_y;
358             actual_point_start_time = mouseDriver_getTime();
359         }
360     }
361     if (actual_point == MAX_POINTS){
362         mouseDriver_setMode(MOUSE_MODE_AUTO_LOAD);
363     }
364     mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_INFO);
365     mouseDriver_sendMsg(MAVLINK_MSG_ID_MOTOR_SETPOINT);
366     mouseDriver_control_idle();
367     break;
368 default:
369     break;
370 }
371 if (send_msg == 1){
372     send_msg = 0;
373     mouseDriver_sendMsg(MAVLINK_MSG_ID_HEARTBEAT);
374     if(actual_mode != MOUSE_MODE_AUTO_LOAD){
375         mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_SETPOINT);
376         mouseDriver_sendMsg(MAVLINK_MSG_ID_RAW_SENSOR);
377         mouseDriver_sendMsg(MAVLINK_MSG_ID_MOTOR_SETPOINT);
378     }
379 }
380
381 }
382 void mouseDriver_readMsg(const mavlink_message_t msg){
383
384     switch(msg.msgid){
385
386     case MAVLINK_MSG_ID_MODE_SELECTION:
387         mouseDriver_setMode( mavlink_msg_mode_selection_get_mode(&msg));
388         break;
389
390     case MAVLINK_MSG_ID_SPEED_SETPOINT:
391         if (actual_mode == MOUSE_MODE_SPEED)

```

```

392     mavlink_msg_speed_setpoint_decode(&msg, &actual_speed_setpoint);
393     break;
394
395     case MAVLINK_MSG_ID_MOTOR_SETPOINT:
396         if (actual_mode == MOUSE_MODE_SPEED)
397             mavlink_msg_speed_setpoint_decode(&msg, &actual_speed_setpoint);
398         break;
399     case MAVLINK_MSG_ID_POINT:
400         if (actual_mode == MOUSE_MODE_AUTO_LOAD){
401             mavlink_msg_point_decode(&msg, &points[actual_point]);
402             if (actual_point == 255){
403                 actual_error.error = MOUSE_ROUTINE_TOO_LONG;
404                 actual_error.time = mouseDriver_getTime();
405                 mouseDriver_sendMsg(MAVLINK_MSG_ID_ERROR);
406             }
407             mouseDriver_sendMsg(MAVLINK_MSG_ID_POINT_LOADED);
408             actual_point++;
409         }
410         break;
411     default:
412         break;
413 };
414 };
415 }
416 #endif

```

```

1  /*! \file mouseDriver.h
2  \brief Header of the driver for the mouse treadmill 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 \def COMP_ID
37 \brief Component ID for MAVLink
38 */
39 #define COMP_ID 0
40 /* maximum size of the trasmit buffer */
41 /*!
42 \def MAX_BYTE_BUFFER_SIZE
43 \brief MAX size of transmit buffer in bytes
44 */
45 #define MAX_BYTE_BUFFER_SIZE 500
46
47 /*!
48 \def MAX_POINTS
49 \brief MAX amount of points that can be defined in AUTO mode
50 */
51 #define MAX_POINTS 255
52
53
54 /*!
55 \fn mouseDriver_init
56 \brief Function that initializes the driver of the mouse treadmill.
57
58 This functions initialites the mouse treadmill driver. It initializes the sensors as well.
59 */
60 void mouseDriver_init(void);
61
62
63
64 /*!
65 \fn mouseDriver_control_idle
66 \brief Function doing the control on the motors.
67 \attention This function is in charge of generating the control signals for the
68 motors. If it is modified, make sure to respect the specifications of the motor
69 to avoid damaging or destroying them !!
70
71 This function is called periodically to update the control signal for the motors.
72 */
73 void mouseDriver_control_idle(void);
74
75 /*!
76 \fn mouseDriver_send_status_msg
77 \brief Function generating the signal for sending messages.
78
79 This function is called periodically to set the flag for sending status messages.
80 */
81 void mouseDriver_send_status_msg(void);
82
83 /*!
84 \fn mouseDriver_readMsg(const mavlink_message_t msg)
85 \param msg MAVLink message to be decoded
86 \brief Function that reads one message.
87
88 This function is called in main.c. Depending on the received message different actions are taken.
89 */
90 void mouseDriver_readMsg(const mavlink_message_t msg);
```

```

91
92 /*!
93 \fn mouseDriver_getTime
94 \return The actual time in ms from boot of the system.
95 \brief Function that gets the time of the system from boot.
96 */
97 uint32_t mouseDriver_getTime (void);
98
99 /*!
100 \fn mouseDriver_idle
101 \brief Idle function for the mouse treadmill driver.
102 \note This function needs to be called periodically to ensure a correct behaviour.
103
104 This is the idle function of the mouse treadmill. It reads values from the sensors,
105 calls \ref mouseDriver_control_idle, and sends high frequency messages (not the status ones).
106 */
107 void mouseDriver_idle (void);
108
109
110 #endif

```

B.3 Sensor driver

```

1 /*
2 * sensorDriver.c
3 *
4 * Created on: Nov 11, 2019
5 * Author: Didier
6 */
7
8 #include "sensorDriver.h"
9
10 /*!
11 \var sensor_x
12 \brief variable for storing data for the x sensor.
13 */
14 static sensor_t sensor_x = {CS_0_GPIO_Port,CS_0_Pin,PW_0_GPIO_Port,PW_0_Pin
15 ,0};
16
17 /*!
18 \var sensor_y
19 \brief variable for storing data for the y sensor.
20 */
21 static sensor_t sensor_y = {CS_1_GPIO_Port,CS_1_Pin,PW_1_GPIO_Port,PW_1_Pin
22 ,0};
23
24 /*!
25 \fn sensorDriver_powerup(sensor_t sensor)
26 \param sensor sensor structure of the sensor to be powered up
27 \brief This function turns off and the on the sensor. It then performs the power up routine
28 \note This routine is time consuming and done only at start up.
29
30 After Flashing the SROM the SROM_ID register is read to confirm that the
31 SROM have been flashed correctly.
32 */
33 void sensorDriver_powerup(sensor_t * sensor);
34
35 /*!

```

```

34 \fn sensorDriver_motion_read_raw(uint8_t sensor_id, mavlink_raw_sensor_t * sensor_data
    )
35 \param sensor_id 0 for sensor x, 1 for sensor y
36 \param sensor_data pointer to a structure for storing the raw sensor value
37 \brief This function reads raw data from the sensor given its ID and puts the result in the
    pointer.
38 */
39 void sensorDriver_motion_read_raw(uint8_t sensor_id, mavlink_raw_sensor_t * sensor_data
    );
40
41 void sensorDriver_powerup(sensor_t * sensor){
42     /* Disable the sensor */
43     HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_SET);
44
45     /* Make sure all sensor is switched off */
46     HAL_GPIO_WritePin(sensor->pw_port, sensor->pw_pin, GPIO_PIN_RESET);
47     main_write_sensor(*sensor, 0x00, 0x00);
48     HAL_Delay(100);
49
50     /* Gives voltage to sensors */
51     HAL_GPIO_WritePin(sensor->pw_port, sensor->pw_pin , GPIO_PIN_SET);
52     HAL_Delay(300);
53
54     /* Reset SPI port */
55     HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_SET);
56     HAL_Delay(5);
57     HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_RESET);
58     HAL_Delay(5);
59     HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_SET);
60     HAL_Delay(5);
61
62     /* Write to Power_up_Reset register */
63     main_write_sensor(*sensor, Power_Up_Reset, 0x5A);
64
65     /* Wait at least 50 ms */
66     HAL_Delay(50);
67
68     /* Read from data registers */
69     main_read_sensor(*sensor, 0x02);
70     main_read_sensor(*sensor, 0x03);
71     main_read_sensor(*sensor, 0x04);
72     main_read_sensor(*sensor, 0x05);
73     main_read_sensor(*sensor, 0x06);
74
75     /* Start ROM Download */
76     main_write_sensor(*sensor, Config2, 0x20);
77     main_write_sensor(*sensor, SROM_Enable, 0x1d);
78     HAL_Delay(10);
79     main_write_sensor(*sensor, SROM_Enable, 0x18);
80     main_wait_160us();
81     main_wait_20us();
82
83     /* Burst start with adress */
84     HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_RESET);
85     main_write_sensor_burst(SROM_Load_Burst|0x80);
86     for (int i = 0; i < firmware_length; i++) {
87         main_write_sensor_burst(firmware_data[i]);
88     }

```

```

89 HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_SET);
90 main_wait_160us();
91 main_wait_20us();
92 main_wait_20us();
93
94 /* Read SROM_ID for verification */
95 sensor->status = main_read_sensor(*sensor, SROM_ID);
96
97 /* Write to Config2 for wired mouse */
98 main_write_sensor(*sensor, Config2, 0x00);
99 }
100 void sensorDriver_init(void){
101     sensorDriver_powerup(&sensor_x);
102     sensorDriver_powerup(&sensor_y);
103 }
104 void sensorDriver_motion_read_raw(uint8_t sensor_id, mavlink_raw_sensor_t * sensor_data
    ){
105     uint8_t data[12];
106     int16_t temp = 0;
107     sensor_t sensor;
108
109     if (sensor_id == SENSOR_X) sensor = sensor_x;
110     else if (sensor_id == SENSOR_Y) sensor = sensor_y;
111     else return;
112     sensor_data->sensor_id = sensor_id;
113
114     /* write to motion burst address */
115     main_write_sensor(sensor, Motion_Burst, 0xbb);
116
117     /* Prepare for burst */
118     HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_RESET);
119     sensor_data->time = mouseDriver_getTime();
120     main_write_sensor_burst(Motion_Burst);
121     /* Start burst */
122     main_read_sensor_motion_burst(data);
123     HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_SET);
124     /* END of burst */
125     main_wait_20us();
126
127     /* Read other register for stopping burst mode */
128     sensor_data->product_id = main_read_sensor(sensor, Product_ID);
129
130     /* TWO's Complement */
131     temp = (data[DELTA_X_H]<<8) | (data[DELTA_X_L]);
132     temp = ~temp + 1;
133     sensor_data->delta_x = temp;
134     temp = (data[DELTA_Y_H]<<8) | (data[DELTA_Y_L]);
135     temp = ~temp + 1;
136     sensor_data->delta_y = temp;
137
138     sensor_data->squal = data[SQUAL_READ];
139     sensor_data->lift = (data[MOTION] & 0x08) >> 3;
140     sensor_data->srom_id = sensor.status;
141 }
142 void sensorDriver_motion_read_speed(mavlink_raw_sensor_t sensor_data[2],
    mavlink_speed_info_t * speed_info){
143     mavlink_raw_sensor_t raw_values[2];
144     uint32_t old_time[2];

```



```

145
146     speed_info->valid = 0;
147     old_time[0] = speed_info->time_x;
148     old_time[1] = speed_info->time_y;
149
150     sensorDriver_motion_read_raw(SENSOR_X, &raw_values[0]);
151     sensorDriver_motion_read_raw(SENSOR_Y, &raw_values[1]);
152
153     speed_info->speed_x = (float)raw_values[0].delta_x*(float)INCH2METER/(float)
        RESOLUTION;
154     speed_info->speed_x /= (float)(raw_values[0].time-old_time[0])/(float)1000;
155     speed_info->time_x = raw_values[0].time;
156     speed_info->speed_y = (float)raw_values[1].delta_x*(float)INCH2METER/(float)
        RESOLUTION;
157     speed_info->speed_y /= (float)(raw_values[1].time-old_time[1])/(float)1000;
158     speed_info->time_y = raw_values[1].time;
159     sensor_data[0] = raw_values[0];
160     sensor_data[1] = raw_values[1];
161
162     if((raw_values[0].lift == 0) && (raw_values[1].lift == 0) &&
163        (raw_values[0].squal >= SQUAL_THRESH) && (raw_values[0].squal >=
        SQUAL_THRESH) &&
164        (raw_values[0].product_id == 66) && (raw_values[1].product_id == 66)){
165         speed_info->valid = 1;
166     }
167     else{
168         speed_info->valid = 0;
169     }
170 }

```

```

1  #pragma once
2
3  #ifndef SENSORDRIVER_H_
4  #define SENSORDRIVER_H_
5
6  #ifndef TEST
7  #include "main.h"
8  #include "mavlink.h"
9  #include "sensorSROM.h"
10 #endif
11
12 /* BEGIN DEFINES FOR SENSOR INTERNAL REGISTERS */
13 #define Product_ID 0x00
14 #define Revision_ID 0x01
15 #define Motion 0x02
16 #define Delta_X_L 0x03
17 #define Delta_X_H 0x04
18 #define Delta_Y_L 0x05
19 #define Delta_Y_H 0x06
20 #define SQUAL 0x07
21 #define Raw_Data_Sum 0x08
22 #define Maximum_Raw_data 0x09
23 #define Minimum_Raw_data 0x0A
24 #define Shutter_Lower 0x0B
25 #define Shutter_Upper 0x0C
26 #define Control 0x0D
27 #define Config1 0x0F
28 #define Config2 0x10

```

```

29 #define Angle_Tune 0x11
30 #define Frame_Capture 0x12
31 #define SROM_Enable 0x13
32 #define Run_Downshift 0x14
33 #define Rest1_Rate_Lower 0x15
34 #define Rest1_Rate_Upper 0x16
35 #define Rest1_Downshift 0x17
36 #define Rest2_Rate_Lower 0x18
37 #define Rest2_Rate_Upper 0x19
38 #define Rest2_Downshift 0x1A
39 #define Rest3_Rate_Lower 0x1B
40 #define Rest3_Rate_Upper 0x1C
41 #define Observation 0x24
42 #define Data_Out_Lower 0x25
43 #define Data_Out_Upper 0x26
44 #define Raw_Data_Dump 0x29
45 #define SROM_ID 0x2A
46 #define Min_SQ_Run 0x2B
47 #define Raw_Data_Threshold 0x2C
48 #define Config5 0x2F
49 #define Power_Up_Reset 0x3A
50 #define Shutdown 0x3B
51 #define Inverse_Product_ID 0x3F
52 #define LiftCutoff_Tune3 0x41
53 #define Angle_Snap 0x42
54 #define LiftCutoff_Tune1 0x4A
55 #define Motion_Burst 0x50
56 #define LiftCutoff_Tune_Timeout 0x58
57 #define LiftCutoff_Tune_Min_Length 0x5A
58 #define SROM_Load_Burst 0x62
59 #define Lift_Config 0x63
60 #define Raw_Data_Burst 0x64
61 #define LiftCutoff_Tune2 0x65
62 /* END DEFINES FOR SENSOR INTERNAL REGISTERS */
63
64 #include <mavlink_msg_raw_sensor.h>
65 #include <stdint.h>
66
67 /* DEFINES FOR BURST READ (only usefull data) */
68 #define MOTION 0
69 #define OBSERVATION 1
70 #define DELTA_X_L 2
71 #define DELTA_X_H 3
72 #define DELTA_Y_L 4
73 #define DELTA_Y_H 5
74 #define SQUAL_READ 6
75
76 /*!
77 \def SQUAL_THRESH
78 \brief Threshold value on SQUAL to consider the measure valid.
79 */
80 #define SQUAL_THRESH 16
81
82 /*!
83 \def RESOLUTION
84 \brief Resolution of the sensor in Count per Inch (CPI)
85 \note This value needs to be updated if the resolution of the sensors is changed,
86

```

```

87 This value is used to convert the raw sensor value in counts to meter per second.
88 */
89 #define RESOLUTION 5000
90
91 /*!
92 \def INCH2METER
93 \brief Conversion factor to convert inches in meters.
94 */
95 #define INCH2METER 0.0254
96
97 /*!
98 \fn sensorDriver_init
99 \brief Initializes all sensors.
100
101 This functions powers down the sensor and does the powering up routine.
102 \note This routine takes a long time, so it is done only at start up.
103 */
104 void sensorDriver_init(void);
105
106 /*!
107 \fn sensorDriver_motion_read_speed(mavlink_raw_sensor_t sensor_data[2],
108     mavlink_speed_info_t * speed_info)
109 \param sensor_data[2] array for the raw values of the 2 sensors
110 \param speed_info pointer to a mavlink_speed_info_t
111 \brief Function for reading the raw data and speed measures from the sensors.
112 \attention The speed_info.time_x/y is used to compute speed. This value should NOT BE
113     MODIFIED by
114 the caller function
115
116 This function reads values from the sensors and puts them in the given pointers.
117 It also flags invalid readings, so that \ref mouseDriver_control_idle do not use them.
118 */
119 void sensorDriver_motion_read_speed(mavlink_raw_sensor_t sensor_data[2],
120     mavlink_speed_info_t * speed_info);
121
122 #endif

```

B.4 Code for unit tests

```

1  /*
2  * display.h
3  *
4  * Created on: Nov 24, 2019
5  * Author: Didier
6  */
7
8  #ifndef DISPLAY_H_
9  #define DISPLAY_H_
10
11 #define RED    "\x1b[31m"
12 #define GREEN  "\x1b[32m"
13 #define END    "\x1b[0m"
14
15 #include <stdio.h>
16 #include <stdbool.h>
17 #include <stdlib.h>
18
19 #ifdef COLOR

```

```

20 static inline bool display (bool correct, const char *name){
21     if(correct == 1){
22         printf("    [GREEN \"OK\" END] ");
23         printf(name);
24         printf(GREEN " DONE SUCCESSFULLY\\n" END);
25         return 1;
26     }
27     else{
28         printf("[\"RED \"NO\" END]    ");
29         printf(name);
30         printf(RED " PERFORMED INCORRECTLY OR NOT AT ALL\\n" END);
31         return 0;
32     }
33     return 0;
34 }
35 #else
36
37 static inline bool display (bool correct, const char *name){
38     if(correct == 1){
39         printf("    [OK] ");
40         printf("%s", name);
41         printf(" DONE SUCCESSFULLY\\n");
42         return 1;
43     }
44     else{
45         printf("[NO]    ");
46         printf("%s", name);
47         printf(" PERFORMED INCORRECTLY OR NOT AT ALL\\n");
48         return 0;
49     }
50     return 0;
51 }
52 #endif
53 #endif /* DISPLAY_H_ */

1  /*
2  * main.c
3  *
4  * Created on: Nov 24, 2019
5  * Author: Didier
6  */
7
8 #include "test_mouseDriver.h"
9 #include "test_sensorDriver.h"
10
11 int main(void){
12
13     bool test = 1;
14
15     printf("
=====\\n");
16     printf("*****TESTING CODE FOR MOUSE TREADMILL *****\\n");
17     printf("
=====\\n");
18     printf("
=====\\n");

```

```

    n");
19 printf("TESTING mouseDriver.c\n");
20 printf("TESTING mouseDriver_init()\n");
21 test &= test_mouseDriver_init();
22 printf("TESTING mouseDriver_idle()\n");
23 test &= test_mouseDriver_idle();
24 printf("TESTING mouseDriver_getTime()\n");
25 test &= test_mouseDriver_getTime();
26 printf("TESTING mouseDriver_send_status_msg()\n");
27 test &= test_mouseDriver_send_status_msg();
28 printf("TESTING mouseDriver_control_idle()\n");
29 test &= test_mouseDriver_control_idle();
30 /*printf
   ("-----\n");
31 printf("TESTING mouseDriver.c\n");
32 if (! test_mouseDriver_init()) printf(RED"ERRORS IN mouseDriver_init\n"END);*/
33
34
35 if (test == 1){
36     printf("ALL TEST PASSED SUCCESSFULLY\n");
37 }
38 else{
39     printf("
=====
n");
40     printf("!!!!!!!!!!!! SOME TESTS NOT PASSED !!!!!!!!!!!!!\n");
41     printf("
=====
n\n");
42
43 }
44 return test;
45 }

1 /*
2 * mock_mouseDriver.h
3 *
4 * Created on: Nov 24, 2019
5 * Author: Didier
6 */
7
8 #ifndef MOCK_MOUSEDRIVER_H_
9 #define MOCK_MOUSEDRIVER_H_
10
11 #define HAL_BUSY 0
12 #define SYS_ID 0
13 #define COMP_ID 0
14 #define MAX_BYTE_BUFFER_SIZE 500
15 #define MAX_POINTS 255
16
17
18 static int stop_motor = 0;
19 static int sensor_init = 0;
20 static int sensor_read_x = 0;
21 static int sensor_read_y = 0;
22
23 /* 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){
43     stop_motor = 0;};
44 static inline void main_stop_motors(void){stop_motor = 1;};
45 static inline int main_get_huart_tx_state(void){return 1;};
46 static inline void HAL_Delay(int delay){};
47 static inline void main_transmit_buffer(uint8_t * outbuffer, int msg_size){};
48 static inline void sensorDriver_motion_read_speed(mavlink_raw_sensor_t actual_raw_sensor
49     [2], mavlink_speed_info_t * actual_speed_measure){
50     sensor_read_x = 1;
51     sensor_read_y = 1;
52     actual_raw_sensor[0].delta_x = 0;
53     actual_raw_sensor[1].delta_y = 0;
54     actual_speed_measure->speed_x = 0;
55     actual_speed_measure->speed_y = 0;
56 };
57 #endif /* MOCK_MOUSEDRIVER_H_ */

```

```

1 /*
2  * mock_sensorDriver.h
3  *
4  * Created on: Nov 25, 2019
5  * Author: Didier
6  */
7
8 #ifndef MOCK_SENSORDRIVER_H_
9 #define MOCK_SENSORDRIVER_H_
10
11 typedef struct SENSOR{
12     int cs_port;
13     uint8_t cs_pin;
14     int pw_port;
15     uint8_t pw_pin;
16     uint8_t status;
17 } sensor_t;
18
19 #define CS_0_GPIO_Port 0
20 #define CS_0_Pin 0
21 #define PW_0_GPIO_Port 0

```

```

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

```

```

1 /*
2  * test_sensorDriver.h
3  *
4  * Created on: Nov 25, 2019
5  * Author: Didier

```

```

6  */
7
8  #ifndef TEST_SENSORDRIVER_H_
9  #define TEST_SENSORDRIVER_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 test functions */
18 bool test_sensorDriver_init(void);
19
20 #endif /* TEST_SENSORDRIVER_H_ */

```

```

1  /*
2  * test_mouseDriver.c
3  *
4  * Created on: Nov 24, 2019
5  * Author: Didier
6  */
7  #include "test_mouseDriver.h"
8  #include "mock_mouseDriver.h"
9  #include "display.h"
10 #include "mouseDriver.c"
11
12
13 bool test_mouseDriver_init(void){
14
15     bool test = 1;
16
17     actual_mode = 5;
18     for(int i = 0; i < MAX_POINTS; i++){
19         points[i].duration = i;
20         points[i].setpoint_x = i;
21         points[i].setpoint_y = i;
22         points[i].point_id = i;
23     }
24     actual_point = 10;
25     actual_point_start_time = 10;
26     actual_speed_setpoint.setpoint_x = 10;
27     actual_speed_setpoint.setpoint_y = 10;
28     actual_motor_signal.motor_x = 10;
29     actual_motor_signal.motor_y = 10;
30
31     sensor_init = 0;
32     stop_motor = 0;
33
34     mouseDriver_init();
35
36     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
49                == 0), "actual_motor_signal initialization");
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
123         == 0), "actual_motor_signal reset");
124     test &= display(stop_motor == 1, "motor stop");
125
126     /* Case actual mode == SPEED */
127     actual_mode = MOUSE_MODE_SPEED;
128     stop_motor = 1;
129     actual_speed_setpoint.setpoint_y = 0;
130     actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
131     actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
132     actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
133     printf("if (actual_mode == MOUSE_MODE_SPEED)\n");
134     mouseDriver_control_idle();
135     test &= display(stop_motor == 0, "motor_x speed changed");
136     for(int i = 0; i < 100; i++)
137         mouseDriver_control_idle();
138     test &= display(actual_motor_signal.motor_x <= MAX_MOTOR_SIGNAL, "motor_x
139         with MAX_MOTOR_SIGNAL limit");
140
141     stop_motor = 1;
142     actual_speed_setpoint.setpoint_x = 0;
143     actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
144     actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
145     actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
146     mouseDriver_control_idle();
147     test &= display(stop_motor == 0, "motor_y speed changed");
148     for(int i = 0; i < 100; i++)
149         mouseDriver_control_idle();
150     test &= display(actual_motor_signal.motor_y <= MAX_MOTOR_SIGNAL, "motor_y
151         with MAX_MOTOR_SIGNAL limit");
152
153     actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
154     actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
155     actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
156     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/
7  echo COMPILING TESTS
8  make all -C ../../CodeSTM32/test/Debug/
9  echo RUNNING TESTS
10 ../../CodeSTM32/test/Debug/test

```

C Code for PC

C.1 GUI

```

1 import serial
2 import os
3 import sys
4 import numpy as np
5 #import matplotlib as plt
6 from appJar import gui
7 import time
8 import json
9 from tqdm import tqdm
10 import routine as mouseRoutine
11 from pymavlink.dialects.v20 import mouse as mouseController
12
13 """
14 PATH
15
16 /Users/Didier/Desktop/EPFL/Secondo_master/SemesterProject2019/GITRepository/3
    DMouseTreadmill/MouseTreadmillPC/python
17 """
18 SENSOR_STATUS_MSG = ["SENSOR STATUS", "ID 66 = ", "LIFT 0 = ", "SQUAL > 20 = ", "ROM 4 = "]
19 MODES = ["STOP", "SPEED", "AUTO", "RUNNING"]
20 MODES_NUM = {"STOP": int(0), "SPEED": int(1), "AUTO": int(2), "RUNNING": int(3) }
21 DATA = { "HEARTBEAT": {"time": [], "mode": []},
22           "SPEED_SETPOINT": {"time": [], "setpoint_x": [], "setpoint_y": [], "start": 0},
23           "SPEED_INFO": {"time": [], "speed_x": [], "speed_y": [], "start": 0},
24           "MOTOR_SETPOINT": {"time": [], "motor_x": [], "motor_y": [], "start": 0}
25         }
26 LOG = []
27 MAX_SAMPLES_ON_SCREEN = 200
28 print(mouseController.MAVLink_speed_info_message.fieldnames)
29 port = "/dev/cu.usbmodem14102"
30
31 class MyApplication():
32     actualMode = 0
33     actualTime = 0
34     actualSpeedSetpoint = [None, None]
35     actualMotorSetpoint = [None, None]
36     actualSpeedInfo = [None, None]
37     connection = serial.Serial(port, baudrate = 230400, timeout = 50)
38     mavlink = mouseController.MAVLink(file = connection )
39     setpointX = 0.0
40     setpointY = 0.0
41
42     def commSTM32 (self):
43         # Init variables
44         m = None
45         while(self.connection.in_waiting>0):
46             # 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 amount 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         ")]))
158         while(self.connection.out_waiting > 0):
159             time.sleep(0.001)
160         time.sleep(0.001)
161         if self.actualMode == mouseController.MOUSE_MODE_STOP:
162             self.setpointX = 0
163             self.setpointY = 0
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["
190             setpoint_x"])>254 or len(mouseRoutine.ROUTINE["setpoint_y"])>254):
191                 raise ValueError("mouseRoutine too long")
192             if not (len(mouseRoutine.ROUTINE["duration"]) == len(mouseRoutine.ROUTINE["
193             setpoint_x"]) == len(mouseRoutine.ROUTINE["setpoint_y"])):
194                 raise ValueError("not all components of mouseRoutine have the same lenght")
195
196         # TODO add verification on max speed and min speed
197
198         for i in tqdm(range(len(mouseRoutine.ROUTINE["duration"]))):
199             self.mavlink.point_send(mouseRoutine.ROUTINE["duration"][i],i,mouseRoutine.
200             ROUTINE["setpoint_x"][i], mouseRoutine.ROUTINE["setpoint_y"][i])
201             stop = True
202             while(self.connection.in_waiting>0 or stop):
203                 # Recive messages
204                 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

[illegible]

C.3 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 12000dpi with 100dpi 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:

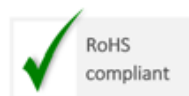
- Wired and Wireless Optical gaming mice
- Integrated input devices
- Battery-powered input devices

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 dpi
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



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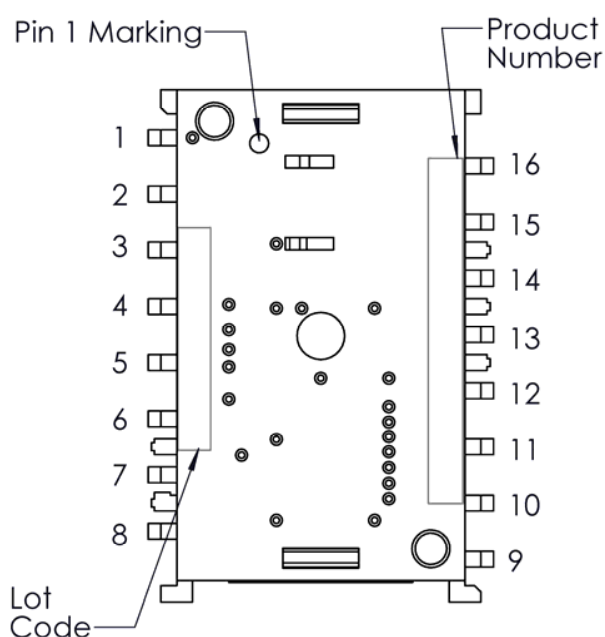
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1.0 System Level Description

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

1.1 Pin Configuration



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)

Figure 1. Device output pins

Table 1. PMW3360DM-T2QU Pin Description

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

1.2 Package Outline Drawing

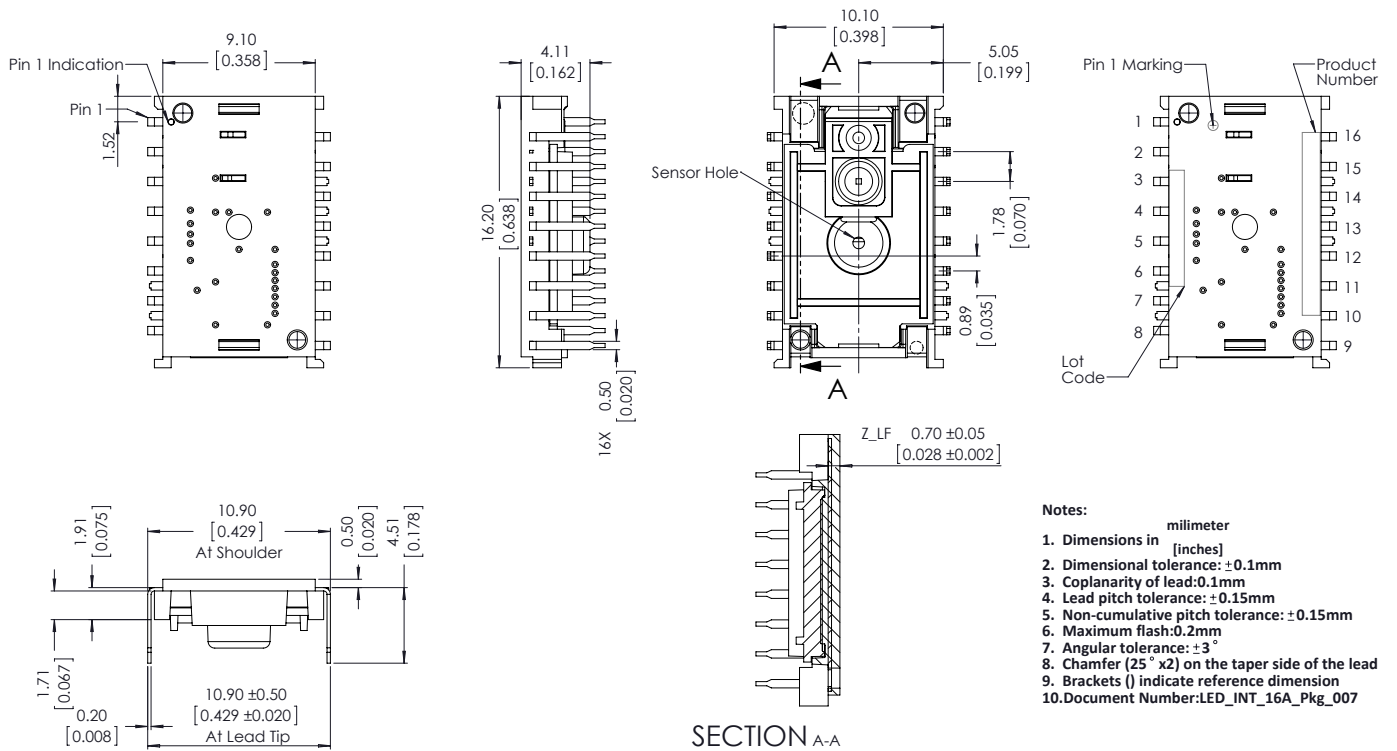


Figure 2. Package Outline Drawing

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

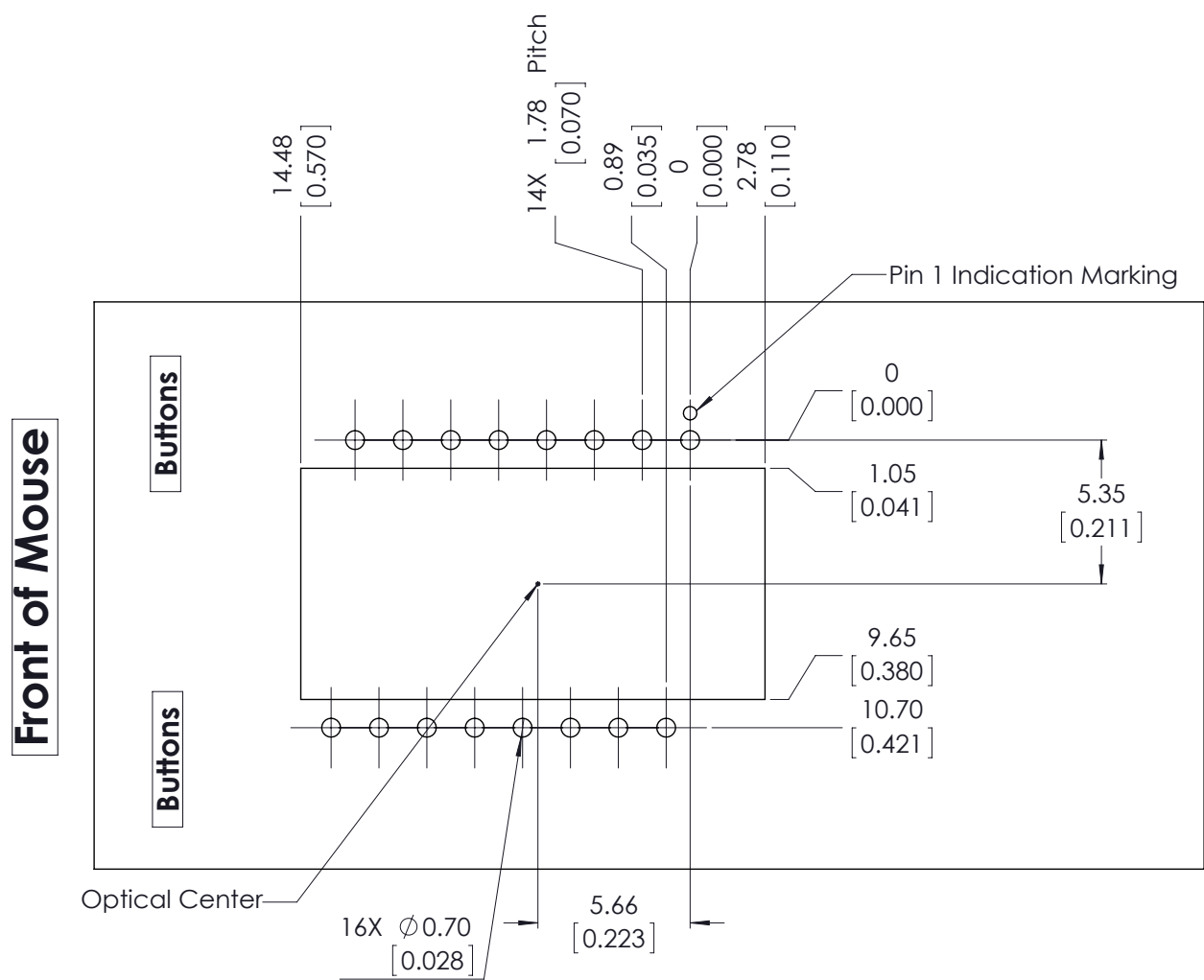


Figure 3. Recommended chip orientation, mechanical cutouts and spacing (Top View)

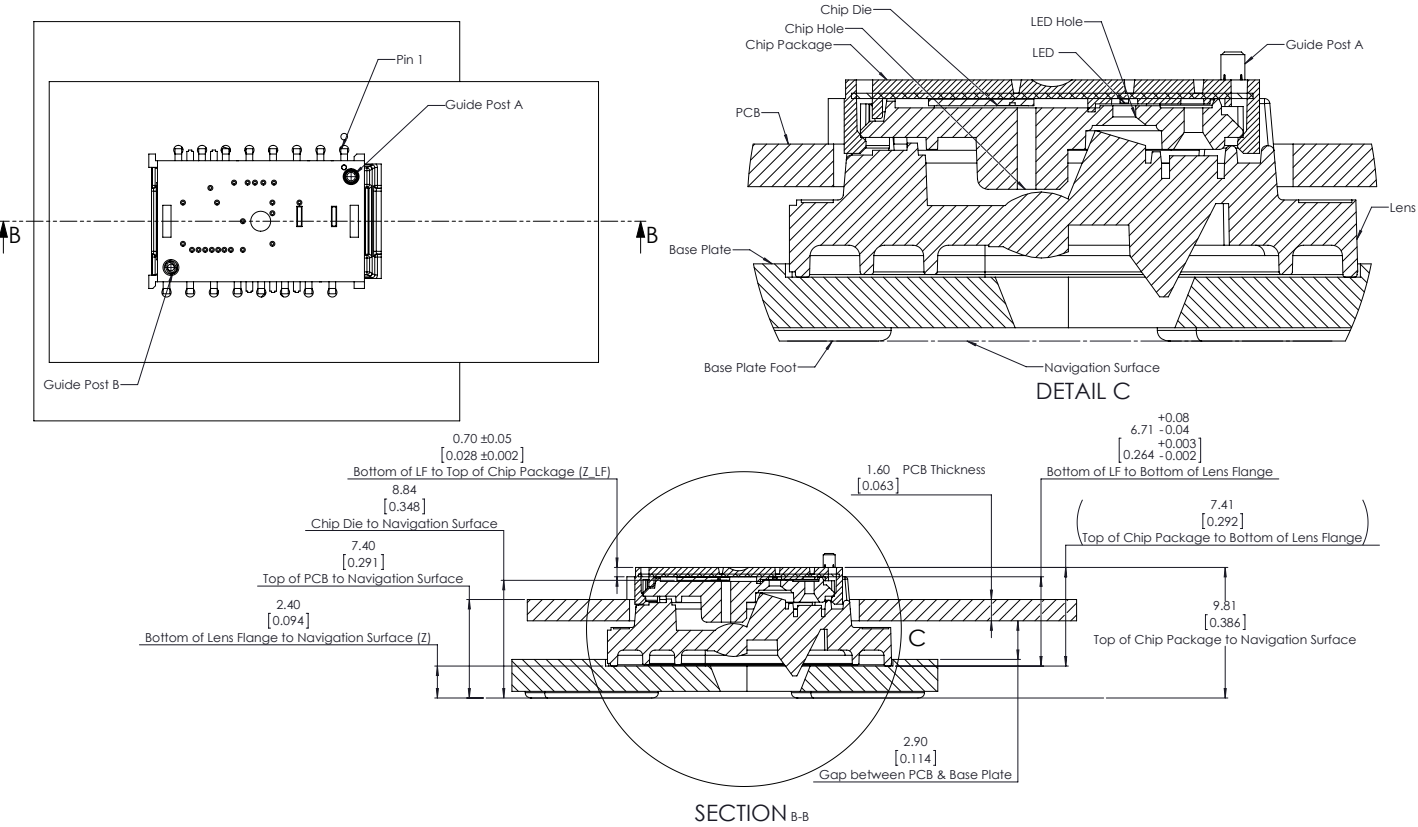


Figure 4. Assembly drawing of PMW3360DM-T2QU and distance from lens reference plane to tracking surface (Z)

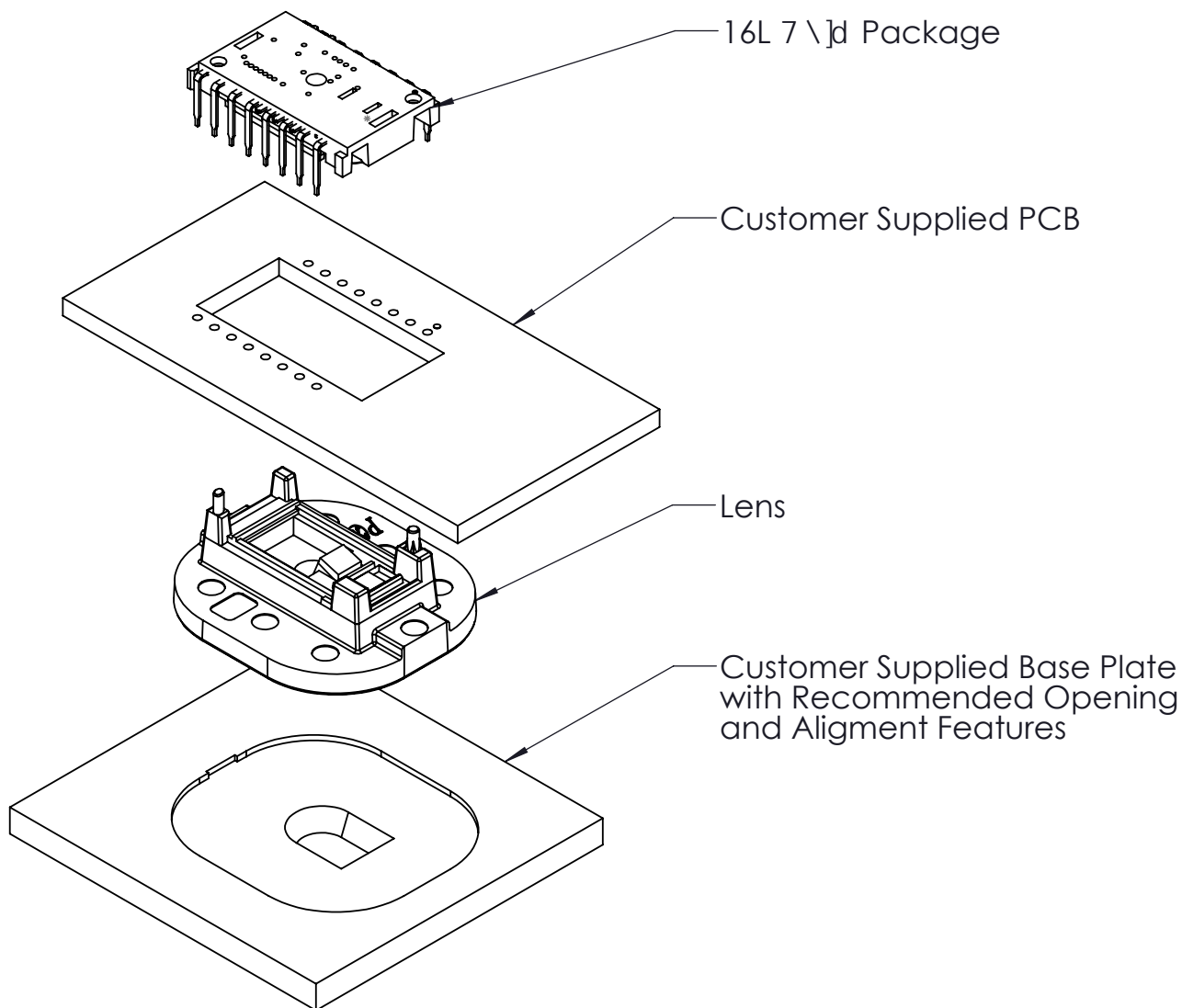
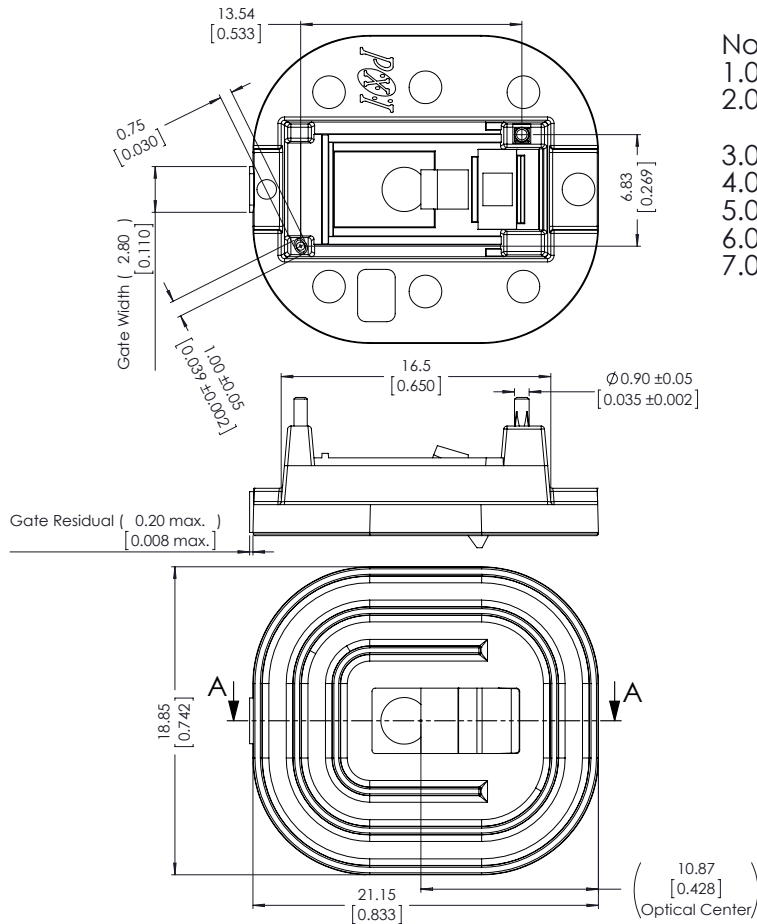


Figure 5. Exploded Assembly View



Notes:

- 1.0 Dimension in millimeters / [inches]
- 2.0 General dimension tolerance: $\pm 0.10\text{mm}$ unless specified otherwise
- 3.0 Angular tolerance: $\pm 3.0^\circ$
- 4.0 Maximum flash: 0.20mm
- 5.0 Bracket () indicates reference dimension
- 6.0 Optical details removed
- 7.0 Document Number: PNLR-019-LSI-G8_011

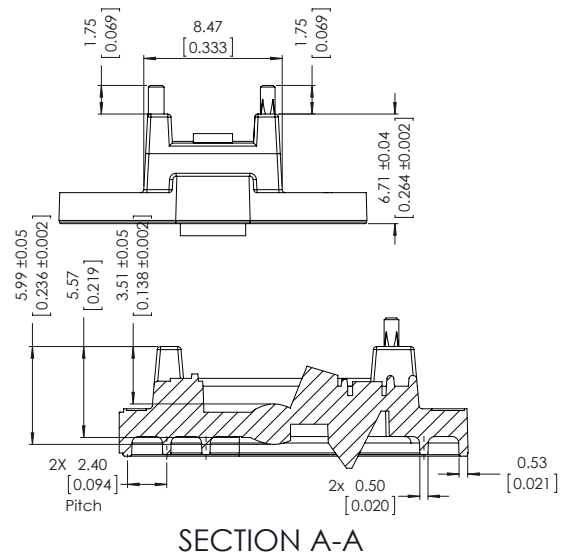


Figure 6. Lens Outline Drawing

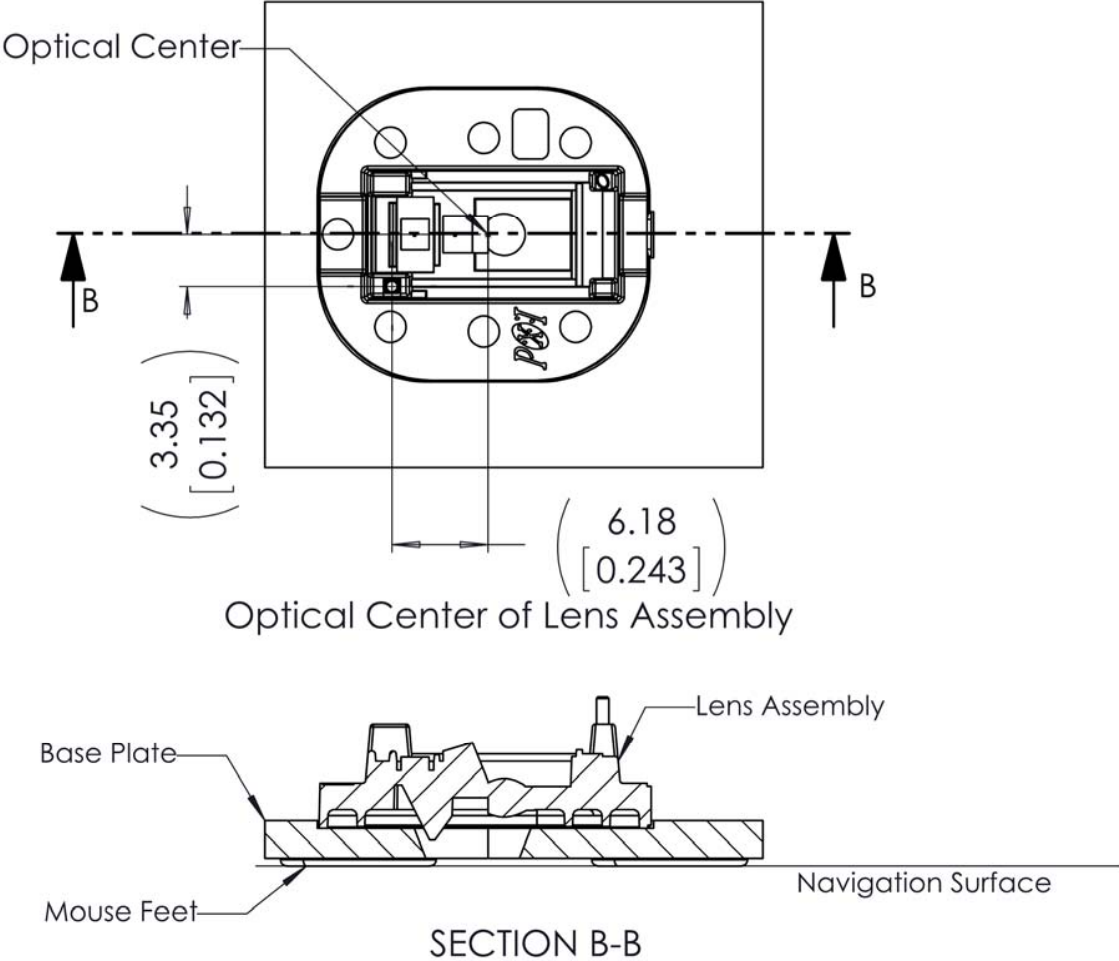


Figure 7. Cross section view of lens assembly

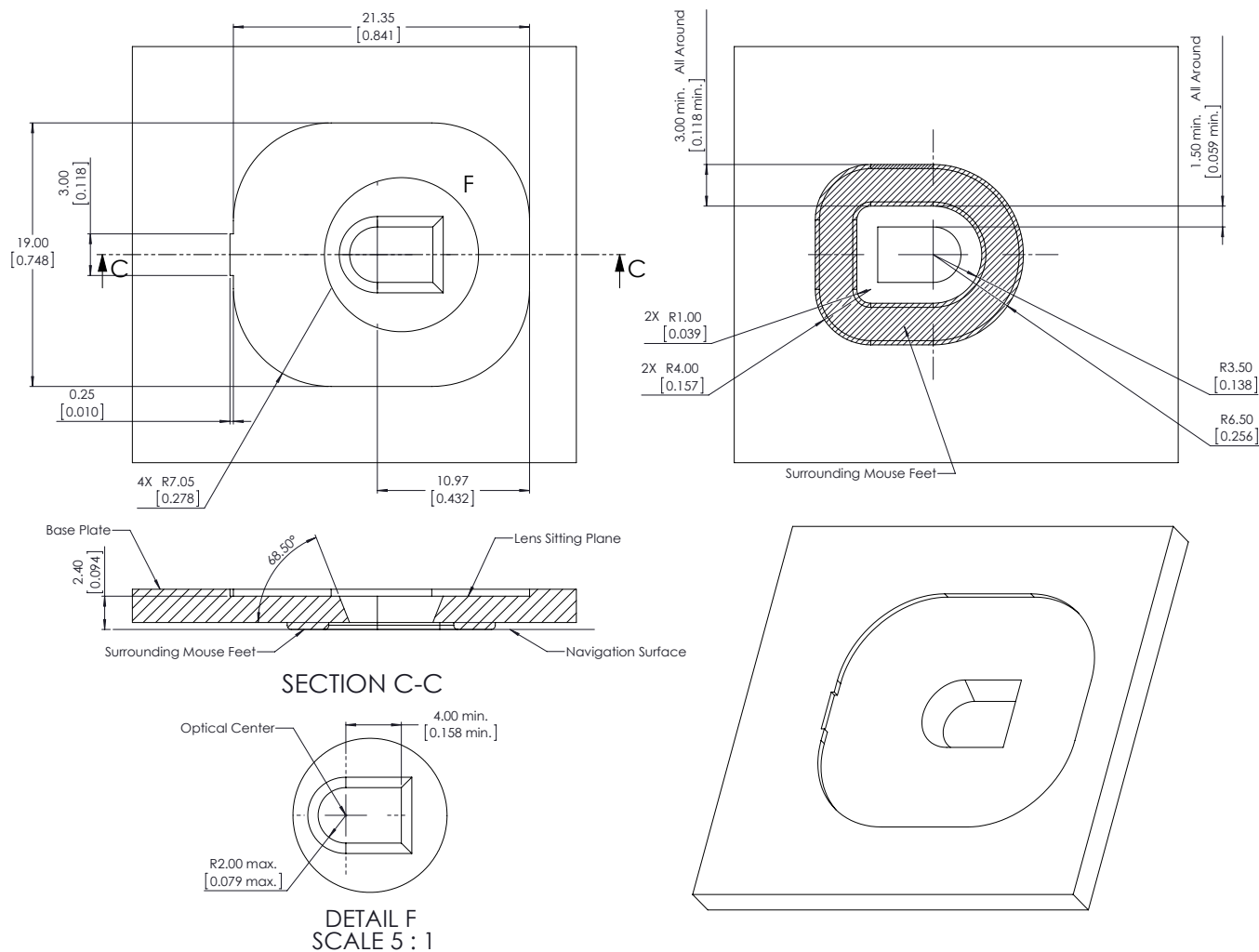


Figure 8. Recommended Base Plate Opening

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.

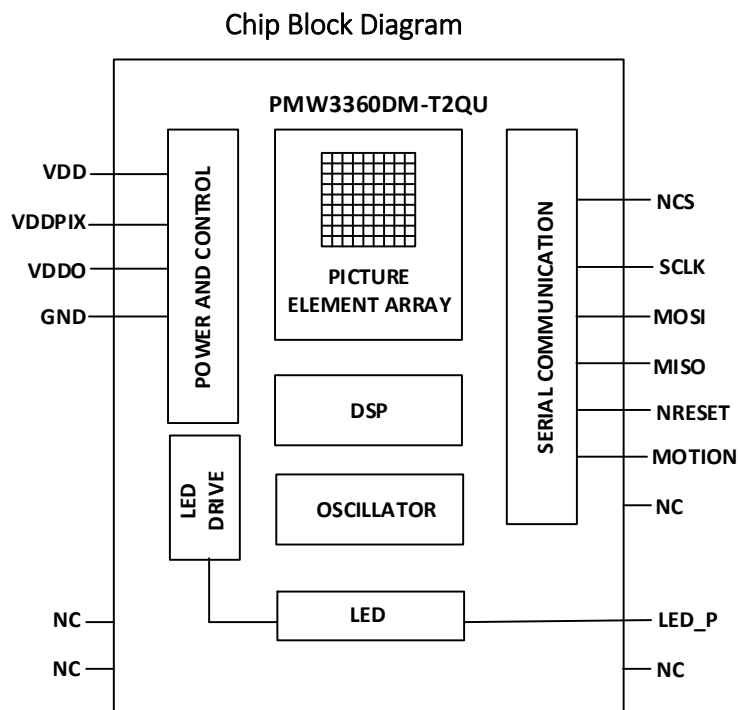


Figure 9. Block diagram of PMW3360DM-T2QU

1.5 Reference Schematics

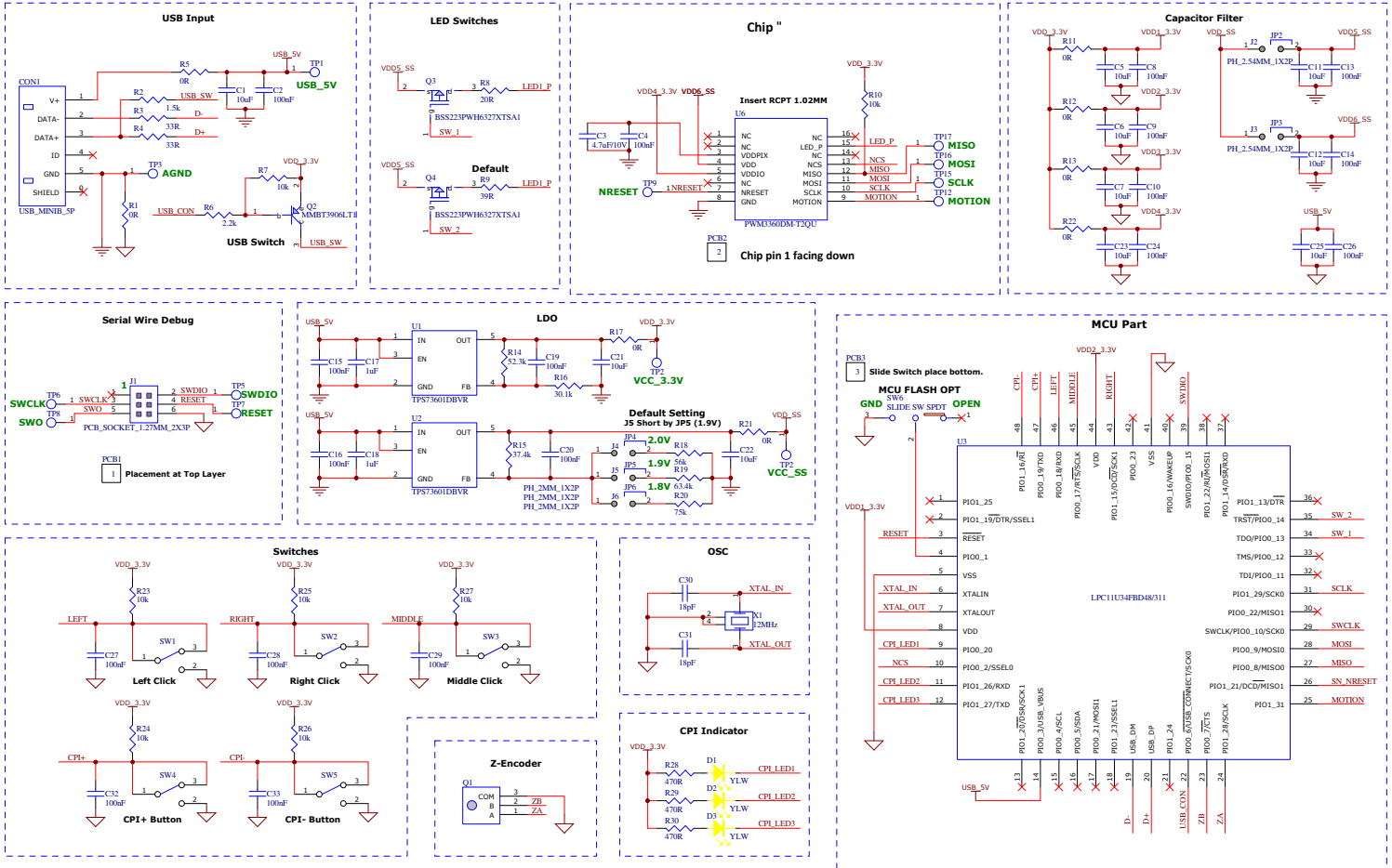


Figure 10. Schematic diagram for interface between PMW3360DM-T2QU and microcontroller on a wired solution

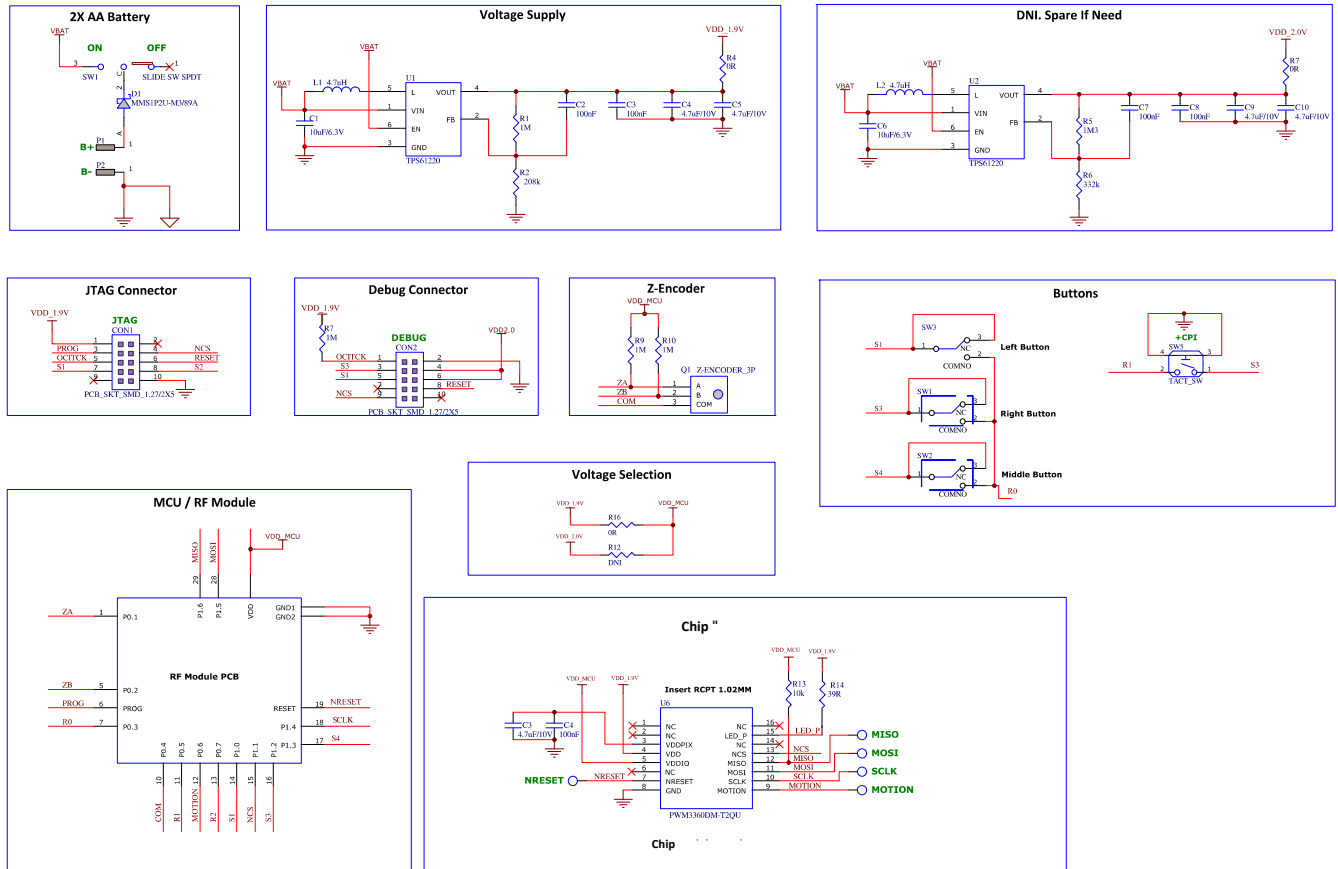


Figure 11. Schematic diagram for interface between PMW3360DM-T2QU and microcontroller on a wireless solution

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_{resErr}		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, $V_{DD} = 1.9\text{ V}$, $V_{DDIO} = 1.9\text{ V}$.

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Motion Delay After Reset	$t_{\text{MOT-RST}}$	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 $t_{\text{MOT-RST}}$
MISO Rise Time	$t_{\text{r-MISO}}$		50		ns	$C_L = 100\text{pF}$
MISO Fall Time	$t_{\text{f-MISO}}$		50		ns	$C_L = 100\text{pF}$
MISO Delay After SCLK	$t_{\text{DLY-MISO}}$			90	ns	From SCLK falling edge to MISO data valid, no load conditions
MISO Hold Time	$t_{\text{hold-MISO}}$	200			ns	Data held until next falling SCLK edge
MOSI Hold Time	$t_{\text{hold-MOSI}}$	200			ns	Amount of time data is valid after SCLK rising edge
MOSI Setup Time	$t_{\text{setup-MOSI}}$	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	$t_{\text{SRAD_MOTBR}}$	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	$t_{\text{NCS-SCLK}}$	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)	$t_{\text{SCLK-NCS}}$	120			ns	From last SCLK rising edge to NCS rising edge, for valid MISO data transfer
SCLK To NCS Inactive (For Write Operation)	$t_{\text{SCLK-NCS}}$	35			μs	From last SCLK rising edge to NCS rising edge, for valid MOSI data transfer
NCS To MISO High-Z	$t_{\text{NCS-MISO}}$			500	ns	From NCS rising edge to MISO high-Z state
MOTION Rise Time	$t_{\text{r-MOTION}}$		50		ns	$C_L = 100\text{pF}$
MOTION Fall Time	$t_{\text{f-MOTION}}$		50		ns	$C_L = 100\text{pF}$
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 μs 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 μs 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, $V_{\text{DD}} = 1.9\text{V}$, $V_{\text{DDIO}} = 1.9\text{V}$, LED current at 12mA, 70MHz (internal), and 1.1kHz (slow clock).

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

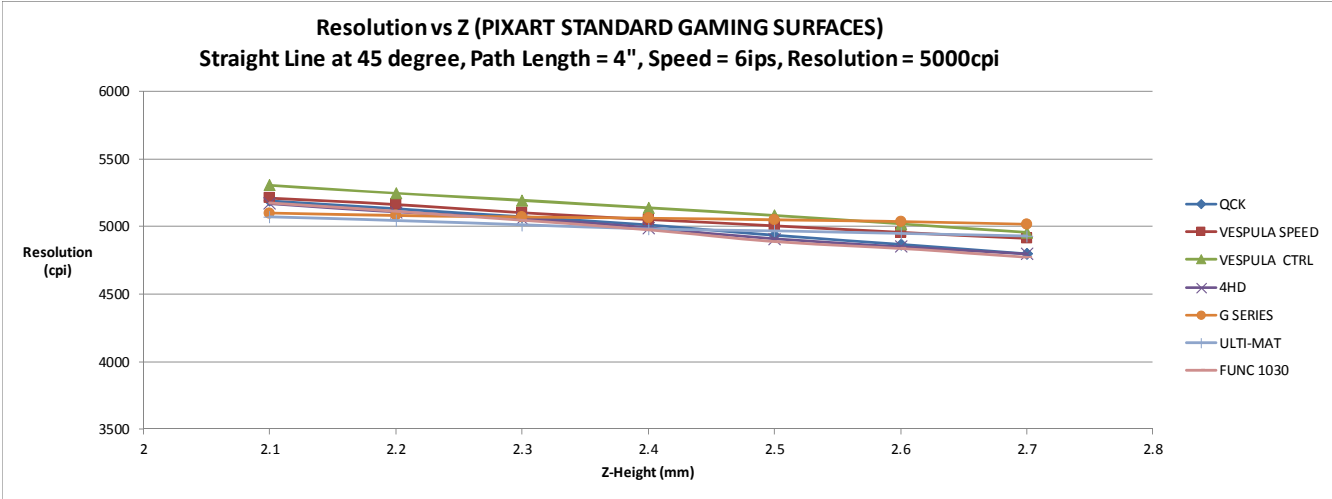


Figure 12 Mean Resolution vs. Z at default resolution at 5000cpi

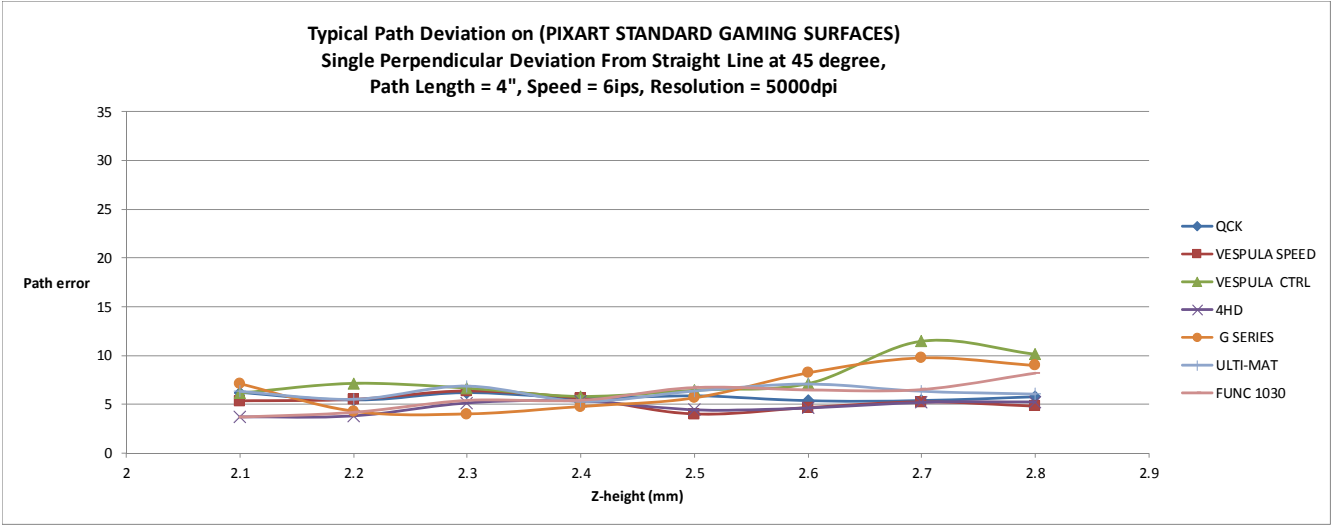


Figure 13 Path error vs. Z-height at default resolution at 5000cpi (mm)

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.

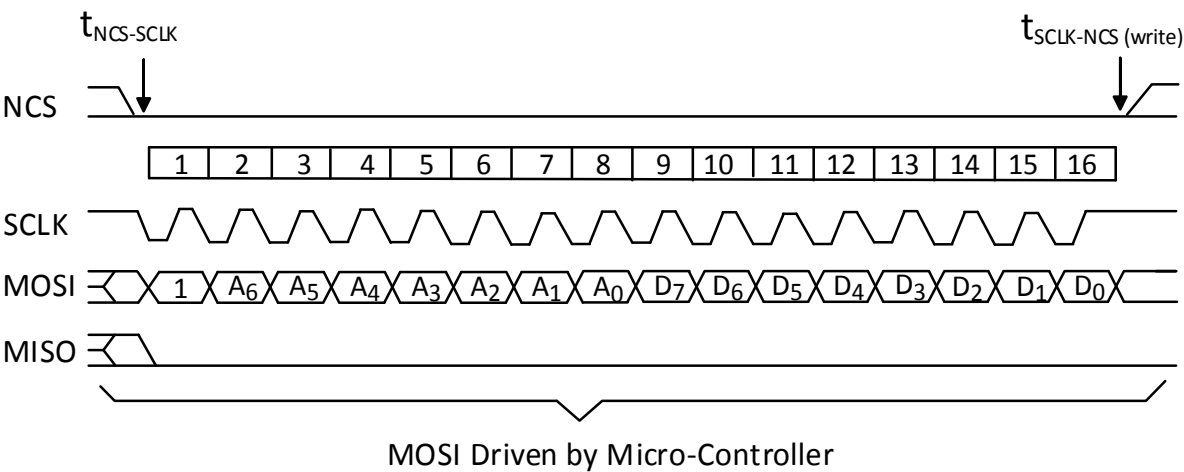


Figure 14. Write operation

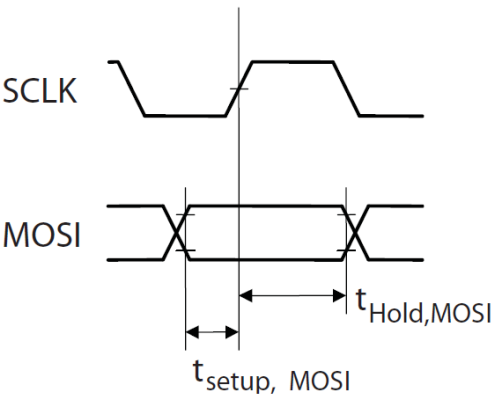


Figure 15. MOSI setup and hold time

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.

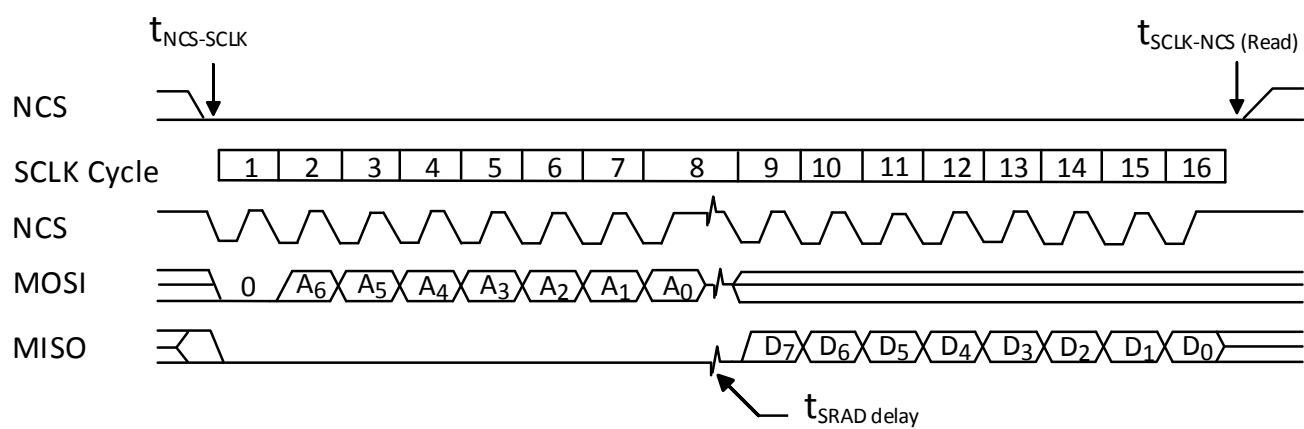


Figure 16. Read operation

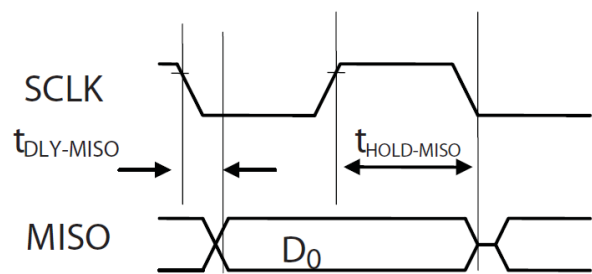


Figure 17. MISO Delay and hold time

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 (t_{sxx})

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

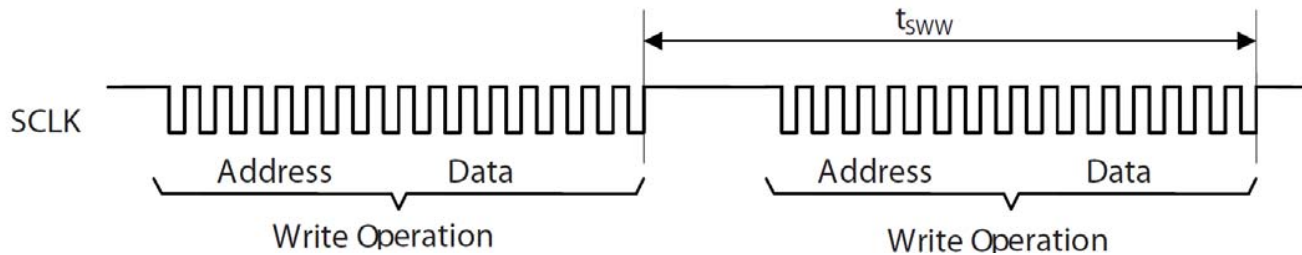


Figure 18. Timing between two write commands

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.

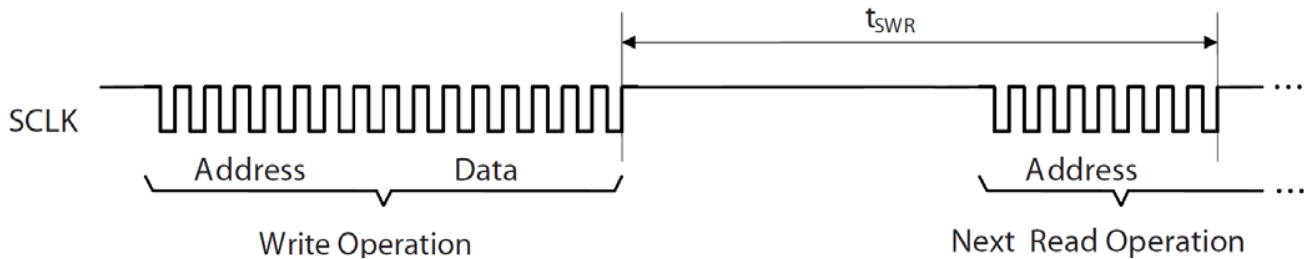


Figure 19. Timing between write and either write or subsequent read commands

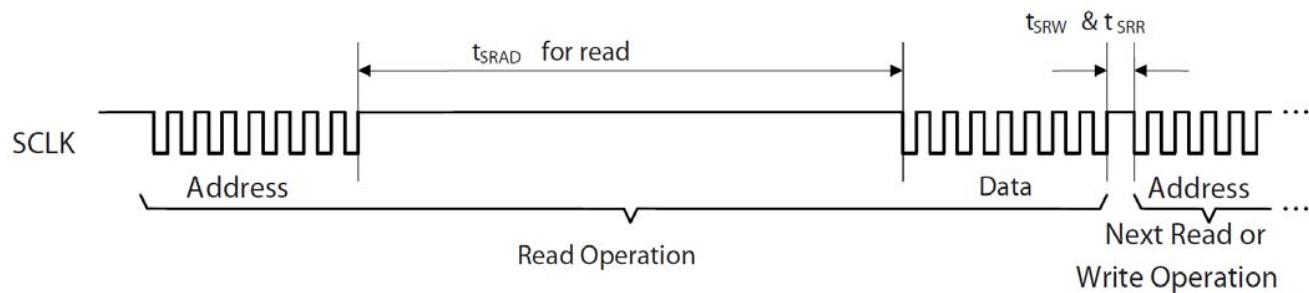


Figure 20. Timing between read and either write or subsequent read commands

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.

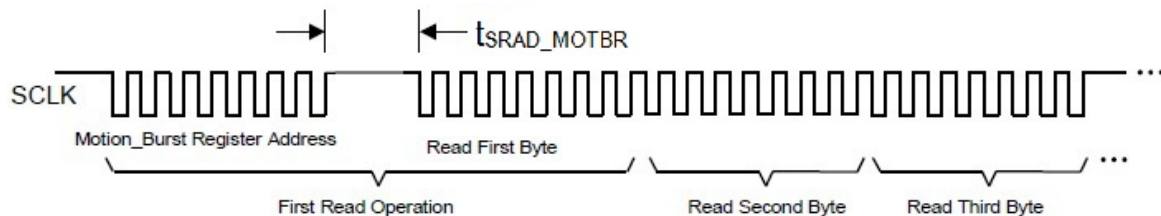


Figure 21. Motion Read sequence for step 3 to 5

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.

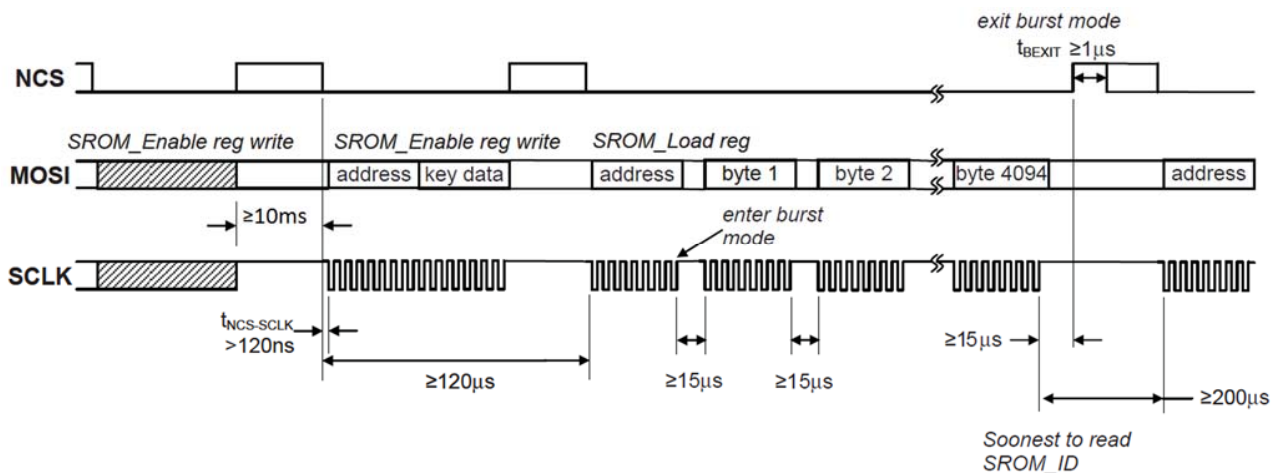


Figure 22. SROM Download Burst Mode

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.

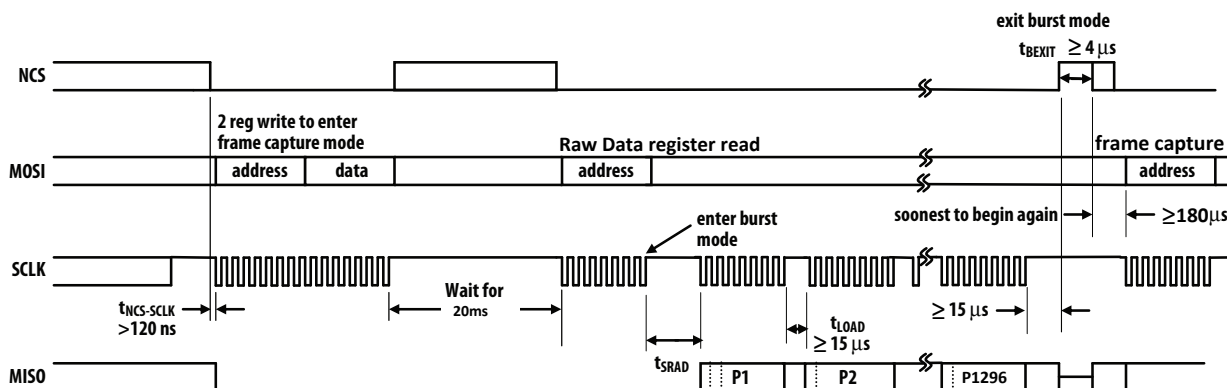
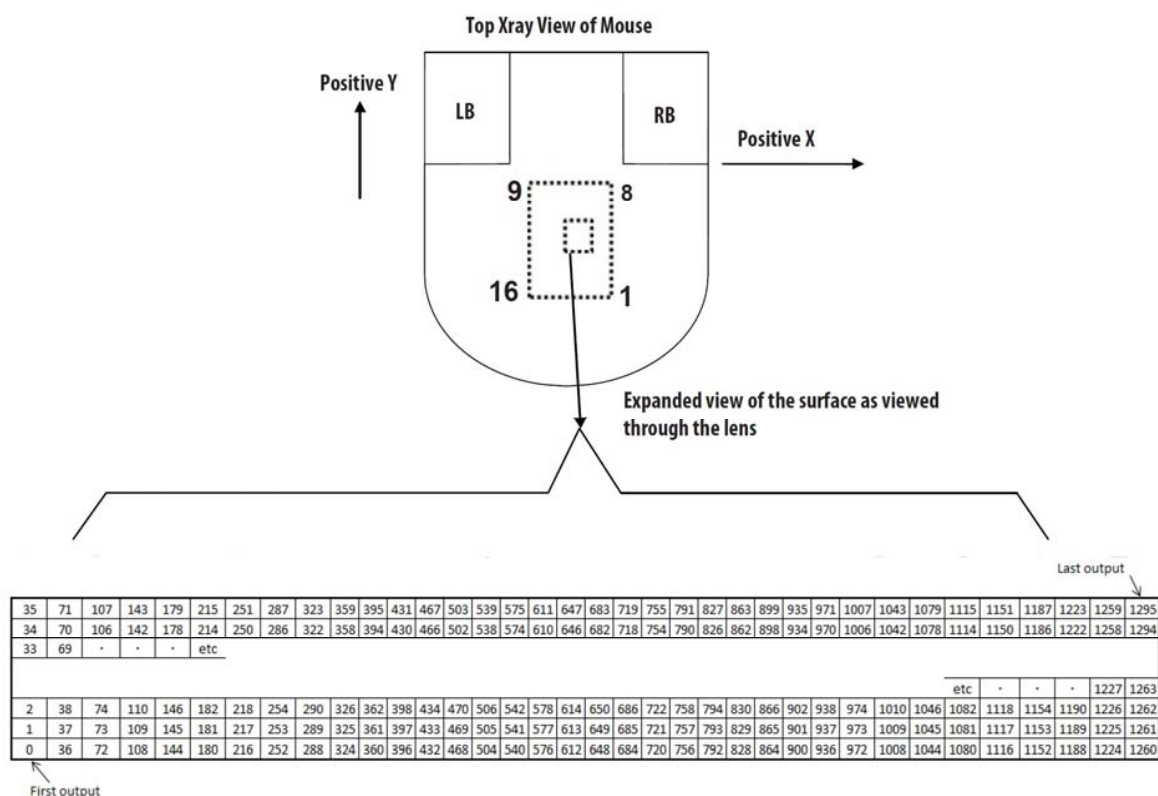


Figure 23. Frame Capture Burst Mode



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:
 - o CAL_STAT[2:0] = 0x02,
 - o CAL_STAT[2:0] = 0x02 and user initiates a stop through a mouse-click event, or,
 - o 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	<p>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:</p> <ol style="list-style-type: none"> 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.							
	<div> <div>Motion</div> <div> <div>-32768</div> <div>-32767</div> <div>-2</div> <div>-1</div> <div>0</div> <div>+1</div> <div>+2</div> <div>+32766</div> <div>+32767</div> </div> <div> <div>8000</div> <div>8001</div> <div>FFFE</div> <div>FFFF</div> <div>00</div> <div>01</div> <div>02</div> <div>7FFE</div> <div>7FFF</div> </div> </div>							

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	<p>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.</p> $\text{Number of Features} = \text{SQUAL Register Value} * 8$ <p>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.</p> <p>SQUAL values are only valid in run mode. Disable Rest mode before measuring SQUAL.</p>							

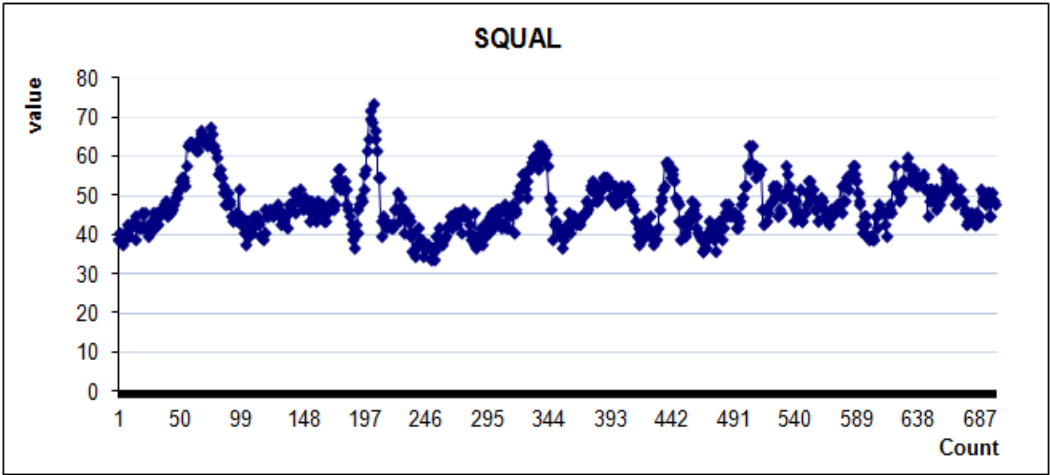


Figure 25. Average SQUAL on white paper

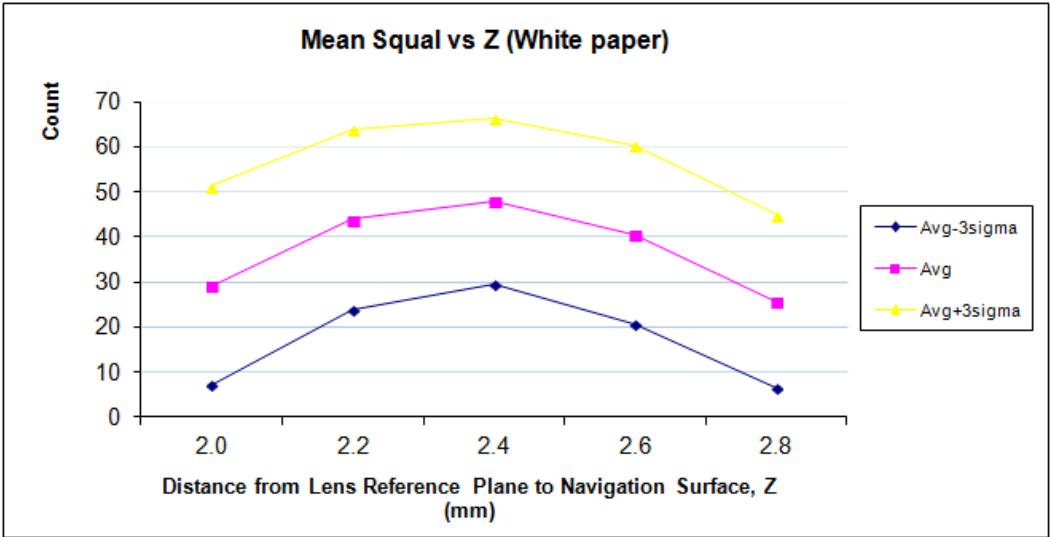


Figure 26. Mean SQUAL vs Z

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	<p>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.</p> $\text{Average Raw Data} = \text{Register Value} * 1024 / 1296$ <p>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</p>							

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.							

Register: 0x0D														
Name: Control														
Bit	7	6	5	4	3	2	1	0						
Field	CTRL1 ₇	CTRL1 ₆	CTRL1 ₅	Reserved	Reserved	Reserved	Reserved	Reserved						
	Reset Value: 0x02													
Access: R/W	Read Write													
Data Type:	8-bit unsigned integer													
Usage	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>								Field Name	Description	CTRL1 _[7:5]	000 - 0 degree 110 - 90 degree 011 – 180 degree 101 – 270 degree	Reserved _[4:0]	Reserved
	Field Name	Description												
	CTRL1 _[7:5]	000 - 0 degree 110 - 90 degree 011 – 180 degree 101 – 270 degree												
	Reserved _[4:0]	Reserved												
Note: For CTRL1 _[7:5] please use 0 degree for best performance														

Register: 0x0F												
Name: Config1												
Bit	7	6	5	4	3	2	1	0				
Field	RES ₇	RES 1 ₆	RES ₅	RES ₄	RES ₃	RES ₂	RES ₁	RES ₀				
	Reset Value: 0x31											
Access: R/W	Read/ Write											
Data Type:	Bit Field											
Usage	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><thead><tr><th>Field Name</th><th>Description</th></tr></thead><tbody><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></tbody></table>								Field Name	Description	RES[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)
	Field Name	Description										
RES[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: 0x10								
Name: Config2								
Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	Rest_En	Reserved	Reserved	Rpt_Mod	Reserved	0
	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	<p>Write to this register to start either SROM download or SROM CRC test. See SROM Download section for details.</p> <p>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.</p> <p>SROM CRC read procedure is as below:</p> <ol style="list-style-type: none"> 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	<p>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.</p> <p>Run Downshift time (ms) = RD[7:0] x 10 ms Default = 50 x 10 = 500ms Max = 255x10 = 2550ms = 2.55s</p> <p>All the above values are expected to have a +40% and -20% of tolerance.</p>							

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	<p>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.</p> <p>R1R[15:0] value must not exceed 0x09B0, otherwise an internal watchdog will trigger a reset. Use the formula below for calculation.</p> <p>Rest1 frame rate duration = (R1R[15:0] + 1) x 1 ms Default = (0 + 1) x 1 = 1 ms</p> <p>All the above values are expected to have a +40% and -20% of tolerance.</p>							

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	<p>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.</p> <p>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)</p> <p>All the above values are expected to have a +40% and -20% of tolerance.</p>							

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	<p>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.</p> <p>R2R[15:0] value must not exceed 0x09B0, otherwise an internal watchdog will trigger a reset. Use the formula below for calculation.</p> <p>Rest2 frame rate duration = (R2R[15:0] + 1) x 1 ms Default = (99 + 1) x 1 = 100 ms</p> <p>All the above values are expected to have a +40% and -20% of tolerance.</p>							

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	<p>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.</p> <p>Rest2 Downshift time = R2D[7:0] x 32 x Rest2_Rate. Default = 188 x 32 x 100 = 601.6s = 10mins</p> <p>All the above values are expected to have a +40% and -20% of tolerance.</p>							

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	<p>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.</p> <p>R3R[15:0] value must not exceed 0x09B0, otherwise an internal watchdog will trigger a reset. Use the formula below for calculation.</p> <p>Rest3 frame rate duration = (R3R[15:0] + 1) x 1 ms</p> <p>Default = (499 + 1) x 1 = 500 ms</p> <p>All the above values are expected to have a +40% and -20% of tolerance.</p>							

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	<p>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.</p> <p>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 $T_{dly_obs} = (500 \times 1.4) + 0.5 = 700.5\text{msec}$.</p>							
	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.													
	<table><tr><th>CRC Result</th><th>Data_Out_Upper</th><th>Data_Out_Lower</th></tr><tr><td>SROM CRC test</td><td>0xBE</td><td>0xEF</td></tr></table>								CRC Result	Data_Out_Upper	Data_Out_Lower	SROM CRC test	0xBE	0xEF
	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.							
	<ol style="list-style-type: none"> Write 0 to Bit [5] of register 0x10 (Config2) to disable Rest mode. Write any value to Raw_Data_Grab register to reset the register. Read MOTION register 0x02 & check for Bit [4] for first raw data in raw data grab to be ready. Then continuously reading Raw_Data_Grab register for raw data for 1296 times. Ensure Bit [7] is valid for each raw data read. 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	<p>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.</p> <p>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.</p> <p>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.</p>							

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.							

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: LiftCutoff_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	<p>The AS_EN bit in this register enables or disables the Angle Snap feature.</p> <p>AS_EN = 0 (Angle snap disabled. This is the default value.)</p> <p>AS_EN = 1 (Angle snap enabled with 5° snap setting.)</p>							

Register: 0x4A												
Name: LiftCutoff_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.											
	<table><tr><th>Field Name</th><th>Description</th></tr><tr><td>RUN_CAL</td><td>0 = Stop Shutter Calibration procedure (default) 1 = Start Shutter Calibration procedure</td></tr></table>								Field Name	Description	RUN_CAL	0 = Stop Shutter Calibration procedure (default) 1 = Start Shutter Calibration procedure
	Field Name	Description										
	RUN_CAL	0 = Stop Shutter Calibration procedure (default) 1 = Start Shutter Calibration procedure										
	<table><tr><td>Bit [6:3]</td><td>Reserved</td></tr></table>								Bit [6:3]	Reserved		
	Bit [6:3]	Reserved										
<table><tr><td>CAL_STAT[2:0]</td><td>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</td></tr></table>								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			
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: LiftCutoff_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	<p>This register sets the minimum Lift cut off calibration timeout threshold.</p> <p>Timeout (sec) = (TIMEOUT[7:0] + 1) x 0.5 sec Default = (39 + 1) x 0.5 = 20 sec</p> <p>Allowed TIMEOUT[7:0] range is 0x00 (0.5 sec) to 0xF9 (125 sec).</p> <p>All the above values are expected to have a +40% and -20% of tolerance.</p>							

Register: 0x5A								
Name: LiftCutoff_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	<p>This register sets the minimum Lift cut off calibration length threshold.</p> <p>Minimum Length (inches) = (MINL[7:0] + 1) x 2 inches Default = (9 + 1) x 2 = 20 inches</p> <p>Allowed MINL [7:0] range is 0x00 (2 inches) to 0xF9 (500 inches).</p> <p>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%.</p>							

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: LiftCutoff_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.											
	<table><tr><th>Field Name</th><th>Description</th></tr><tr><td>RPTH[6:0]</td><td>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.</td></tr></table>								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.
	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 30ms
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