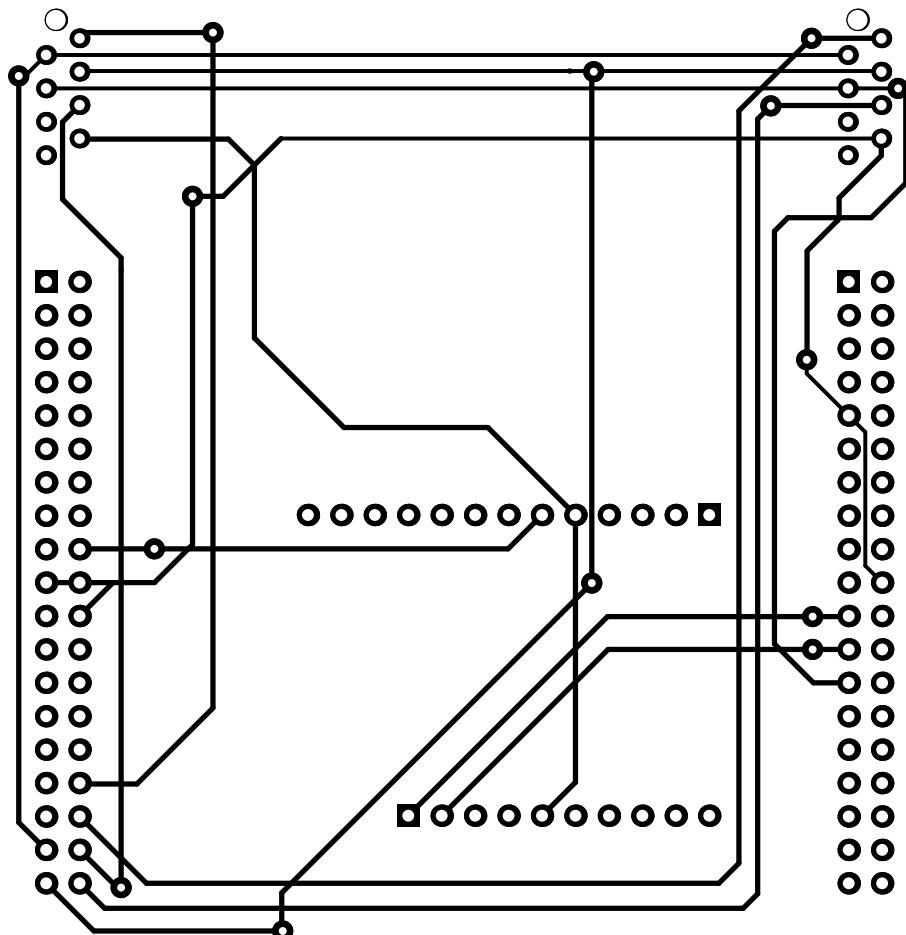




Biorobotics laboratory



MOUSE TREADMILL CONTROL

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Semester project description

Objectives and preliminary considerations The project consists of designing and manufacturing the electronics and control for a mouse treadmill. After that the system's performances are characterized. This work starts from [1]: in this paper a cardboard maze is used to test the mouse behaviour. This setup is quite simple and comes with some drawbacks (i.e. it is not possible to analyse the mouse gait or control its speed and direction). In [2] the setup do not allow for control on the mouse motion. These drawbacks are addressed by the treadmill design. The new design features closed-loop speed control, a user interface (with real-time plotting), data logging, moreover the system can be expanded easily thanks to the use of MAVLink.

System architecture For the system architecture one μ controller is used for the closed-loop control. This controller sends and receives data using a USB cable, UART 232 and the MAVLink messaging protocol. On the other side the PC can get the messages, log them and plot them. To measure the speed of the treadmill two optical sensors are used. These sensors are the same that can be found in gaming mouse. The sensors provide rich information which can be used not only to measure the speed of the surface of the treadmill, but also to estimate the quality of the measure itself. By using this information the control loop is aware of possible measuring problems and can therefore discard low quality information. Finally, to ease the user experience, a cross-platform graphical user interface as well as documentation, unit tests and a user manual are provided.

Testing and results Once the system is built the performances are verified, more precisely, the sensor noise is analysed as well as the speed of the control loop. To carry out an analysis of the total noise on the sensors (which is due to the sensor itself and the vibrations/imperfections of the machine), the treadmill is set to a constant speed setpoint, while data are logged. This procedure is repeated for different reference speeds. Figure

0.1 shows the distribution of the measured speed as a function of the setpoint. One can notice that it is not possible to reach the last setpoint due to saturation of the control signal. The minimum speed is always around $0 \frac{m}{s}$ due to some imperfections in the moving part that causes it to get slowed down periodically. On the other hand the maximum std is $< 0.008 \frac{m}{s}$, thus fulfilling the requirement of $\leq 0.02 \frac{m}{s}$. By integrating the speed it is possible to compute the position, doing so leads to a std on the position $\leq 0.045 \frac{mm}{s}$ fulfilling the requirement of $\leq 0.01 \frac{m}{s}$. Over a 60 [s] time no drift on the position can be measured. Finally the control loop is fast since it logs the speed measurements with a frequency of 200 [Hz] 97.3% of the time.

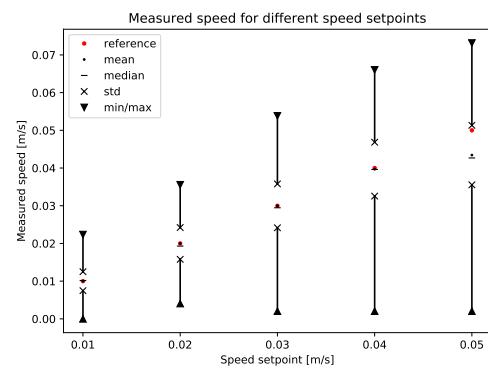


Figure 0.1 – Measured speed distribution as a function of the reference speed.

Drawbacks and future improvements The treadmill is an improvement of the previous designs since it provides solutions to many of the drawbacks. On the other hand not all the requirements are fulfilled yet (e.g. maximum speed), some improvements may include: new motors, which can provide the required speed and torque for better tracking and a camera to get information on the mouse position so that experiments with a free moving mouse can be performed. The main drawbacks of this design are the increased complexity, the higher cost and the need of a fixed-head mouse. No need to underline that the much richer information that can be retrieved using the new design as well as the possibility to solve the issues mentioned above in future iterations of this design outfaces all the drawbacks.

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1 Introduction

In section 1.1 the motivations for the project are given, then in section 1.2 the requirements are presented and finally in section 1.3 the overall structure of the report is shown.

1.1 Motivation

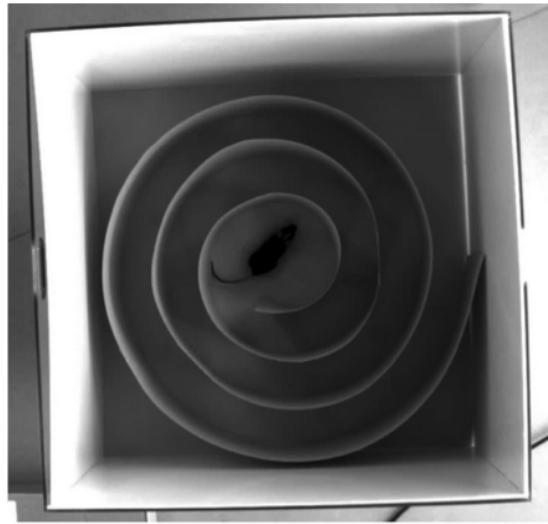


Figure 1.2 – The experimental setup used in [1].

The studies on mammal locomotion have driven more and more attention over the years, and especially experiments on mice, such as [1] or [2], have enhanced our understanding of the neuronal circuits that enable locomotion. The experimental setup in [1], is quite rudimental. As shown in 1.2 it only consists of a spiral maze made out of 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

A more advanced platform is used in [2]. In this case a rotating headpost allows 2-photon imaging in freely locomoting and rotating mice. This means that the measuring apparatus is fixed to the mouse head, while the mouse is free to move at his will. With such a setup it is possible to analyse the mouse gait, but it is not possible to control it, thus it is not the correct approach to use in the new design.

To assess the issues mentioned above 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.

1.2 Requirements

In this section the mechanical and functional requirements are stated. Table 1 summarizes the mechanical ones.

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 below.

- **Closed-loop control** The user can specify a 2D speed setpoint, the control is then able to measure the speed of the treadmill surface and adjust the motor signals 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 consists of 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. Section 2 describes the design decisions and the components' choices made. Section 3 describes the control strategy, while in section 4 the results are shown. Finally in section 5 the conclusion of the project is given. After that in section 6 the user manual for mouse treadmill is provided. The code and the data-sheets of the components are annexed. All the work done on the project can be downloaded from <https://github.com/DidierNegretto/3DMouseTreadmill>.

2 Design choices

In this section the design choices are explained and justified. First an overview of the system architecture is given in section 2.1, then the choices of: the board 2.2, the communication system 2.3 and the sensors 2.4 are analysed. Finally the calculations for the motor's dimensioning are shown 2.5.

2.1 System architecture overview

The overview of the system is given in figure 2.3.

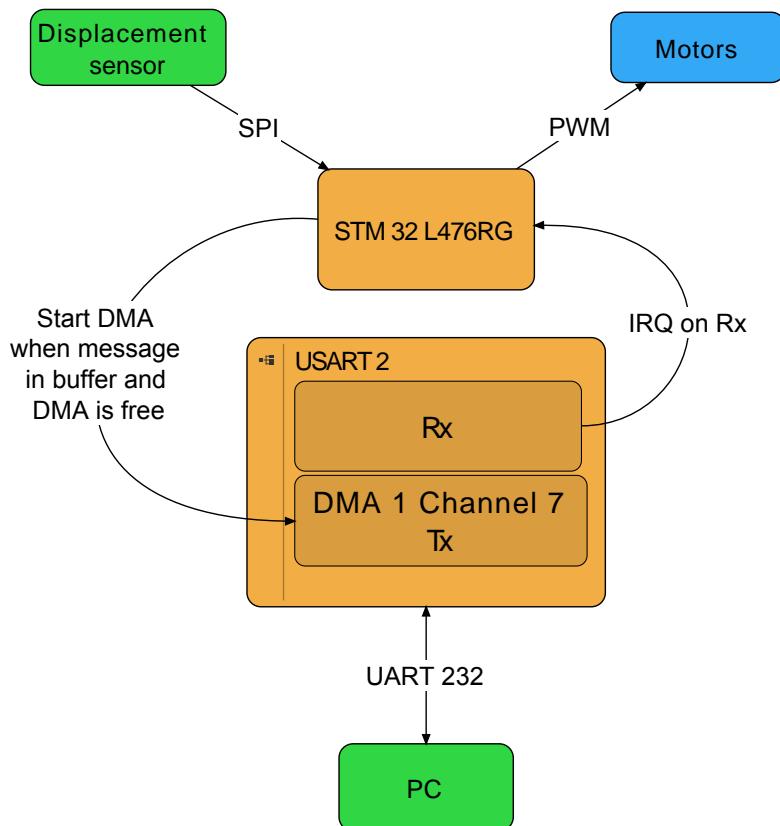


Figure 2.3 – Architecture for mouse treadmill project

The core of the system is the STM32L476RG, which can read from the sensors using the SPI interface and control the motors using PWM. Moreover it can communicate with the computer and the GUI for data logging and to receive the inputs from the user. The communication with the computer uses the DMA capabilities of the microcontroller to free the processor from waiting for the communication to end before being able to take care of other tasks. More detailed informations on how the treadmill works and can be used are given in section 6.

2.2 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 run 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 available.

Due to the constraints in the system the second category is considered for implementation. By comparing the Arduino and STM boards the choice of the STM is done, since it comes with much more and better features. 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 µcontrollers involved.

2.3 Communication

For the communication with the computer the UART 232 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. This protocol comes with the advantage that can be used to communicate with most of the PCs, but it comes with limited baud rate. The main settings for the UART protocol are reported in table 3.



Figure 2.4 – MAVLink logo

Parameter	Value	Unit
Baud rate	230400	[$\frac{Bits}{s}$]
Word length	8	[Bits]
Parity	None	—
Stop bits	1	[Bits]
MSB first	Disable	—

Table 3 – Table describing the main parameters of the UART communication protocol.

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

Being able to use the same messages in different programming languages is crucial to this project because the best solutions for graphical user interfaces are in python, while the μ controller is programmed in C. That's why on the PC a python script is running, while on the embedded system a C program is used. Thanks to MAVLink it is possible to use the same data structure on both and similar functions for parsing the incoming and sent data.

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. Thus it looks perfect for the expandability requirement.

Name	Description	Sender	Receiver	Type
HEARTBEAT	Verifies communication	STM32	PC	Status
SPEED_INFO	Measured speed	STM32	PC	Info
SPEED_SETPOINT	Speed setpoint	PC/STM32	STM32/PC	Status
MODE_SELECTION	Changes mode	PC	STM32	—
MOTOR_SETPOINT	Up time of PWM duty cycle	STM32	PC	Info
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	Status

Table 4 – List and description of the MAVLink messages. The Type indicates whatever the message is high frequency (Info), low frequency (Status) or none of the previous ones (—)

2.4 Sensor

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

- **Lift status** This bit in the motion register gives information about the status of the sensor and especially if the sensor detects a surface or not. This information is used to determine if the read value is valid or not.
- **Surface quality (SQUAL)** This register gives an information about how many features are detected on the surface. This value is used to verify the quality of the measurement, which is considered valid only if the number of detected features is above a given threshold.
- **Product ID** This register has a constant value and is read to verify that the SPI connection between the sensor and the board is connected correctly. If this value is not as expected the reading is flagged as non valid.
- **SROM ID** This value is read after the power up of the sensor to verify that the SROM of the sensor is uploaded correctly using the SPI interface. If this value is not as expected it means that the sensor is not initialized correctly and thus might not work properly.

The specifications of the sensor are summarized on table 5. For more details refer to E.1.

Description	Value	Unit
High speed detection	6.3	[$\frac{m}{s}$]
High acceleration detection	490	[$\frac{m}{s^2}$]
Default resolution	0.00508	[mm]
Resolution error of	1	[%]
4 wires SPI interface	1	—
Cost	29.99	[\\$]

Table 5 – PMW3660 main features.

2.5 Motor

In this section one motor proposition B ¹ is shown with all the calculations used to justify such a choice. 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
5. Negligible rotor and gearbox inertia

The data given are:

¹This motors are not used in the actual version of the treadmill, but might be used for a future iteration.

- $m_s = 2 \text{ [kg]}$ mass of the sphere
- $r_s = 0.2 \text{ [m]}$ radius of the sphere
- $m_w = 0.0114 \text{ [kg]}$ mass of the wheel
- $r_w = 0.03 \text{ [m]}$ radius of the wheel
- $M_{max} = 0.11 \text{ [Nm]}$ maximum torque provided by the motor-gearbox
- $\omega_{max} = 1000 \text{ [rpm]}$ maximum angular speed of the motor-gearbox

It is therefore possible to estimate the maximum continuous acceleration and speed of the sphere. The maximum continuous speed can be computed using equation 1:

$$v_{max} = \omega_{max} \frac{r_s}{60} \quad (1)$$

For the acceleration first the inertia of the wheel J_w and of the sphere J_s as seen by the motor can be computed using equations 2 and 3 respectively:

$$J_w = m_w r_w^2 \quad (2)$$

$$J_s = \frac{2}{3} m_s r_s^2 * \frac{r_w}{r_s} \quad (3)$$

Finally the maximum acceleration can be computed using equation 4:

$$a_{max} = \frac{M_{max} r_w}{J_w + J_s} \quad (4)$$

Using the equations above we get $v_{max} = 3.16 \text{ [m/s]}$ and $a_{max} = 2.74 \text{ [m/s}^2]$, which are values within the requirements. The motors shown in B are not used in the current version of the treadmill, but the calculations used to choose them are shown since they might be useful for an improved version.

3 Control

In this section the main aspects of the control are discussed. For the closed-loop control a simple PI controller is used. This can be improved in future works to allow for faster and better performance control. The implementation of the controller is done in CodeSTM32/mouseDrive.c in the function void mouseDriver_control_idle(void). In 3.1 the inputs and outputs of the control loop are explained, in section 3.2 the control logic is shown.

3.1 Inputs/Outputs

In this section the signal definitions are described. The control diagram is shown in figure 3.5. The signals are defined as follow:

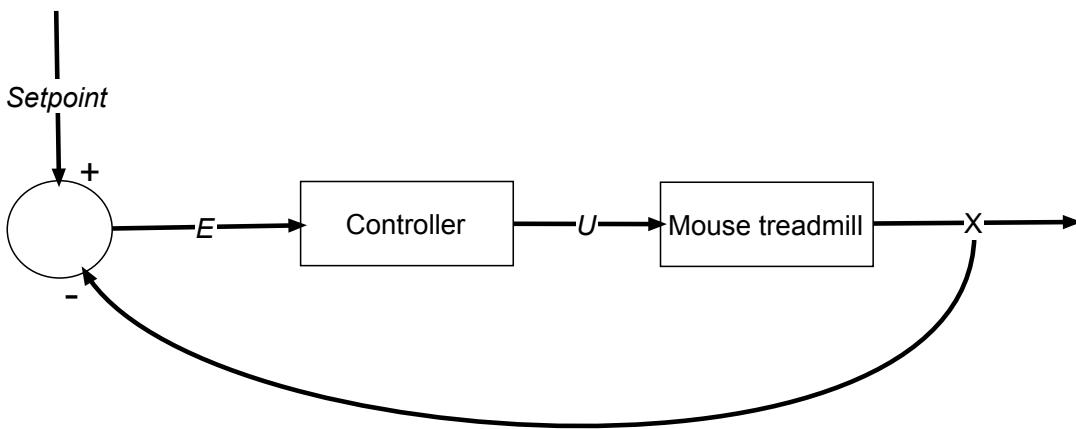


Figure 3.5 – Control diagram

- $X = \begin{bmatrix} v_x \\ v_y \end{bmatrix}$: is the measured v_x and v_y speeds. This measure is done using the optical sensors, which means that the raw values are as defined in the datasheet of the sensors (see E.1). In short words the sensor runs a navigation program, which does the correlation between two images as fast as possible and finds out of how many counts the two images are displaced in the x and y direction of the sensor. Those displacements are then integrated up to when the motion burst read is performed. Since two sensors are used, only one axis of each sensor is meaningful for the control (since the other one is always reading 0). Therefore the information that can be retrieved from one sensor is the number of counts along one axis that the ball has moved since the last read. This can then be translated in meters by knowing the resolution of the sensor (which is given in counts per inch). Finally the speed can be computed by keeping track of when the last measure is taken, and the actual time, thus knowing the dt between two measures. The time measurement is done using time from boot expressed in [ms].
- $E = \begin{bmatrix} e_x \\ e_y \end{bmatrix}$: is the error, id est the difference between the setpoint and the measured speed.
- $U = \begin{bmatrix} u_x \\ u_y \end{bmatrix}$: is the control signal, which is the up time of the duty cycle of the PWM signal controlling the X and Y directions. The parameters of this signal can be modified by using the PRESCALER_PWM and COUNTER_PERIOD_PWM. This two values allow for defining the frequency and number of possible values of the PWM signal.

3.2 Controller

In this section the internal structure of the controller is described. The inputs in the controller are the errors on the speed setpoint in X and Y. The control signal is defined as in equation 5.

$$U = \begin{bmatrix} u_x \\ u_y \end{bmatrix} = K * \begin{bmatrix} e_x \\ e_y \end{bmatrix} + I * \begin{bmatrix} i_x \\ i_y \end{bmatrix} \quad (5)$$

Where K and I are constant scalar values and $\begin{bmatrix} i_x \\ i_y \end{bmatrix}$ is a vector containing the sum of the errors over all the past measures where the motor signal U is not the maximum allowed. This condition is taken to avoid wind up and overshoot in the controller.

Moreover the control is done only if the measures taken are valid. Which means that the SQUAL measure is bigger than SQUAL_THRESH, the sensors are not lifted, and the PRODUCT_ID is equal 66. If those conditions are met it means that the surface quality is good, the sensor "sees" correctly the surface and the communication is done correctly. If the measures are not valid for more than MAX_MISSING_MEASURES the motors are stopped and the mode goes to STOP mode to avoid damage to the machine.

4 Results

In this section the results of a first test of the machine are presented. The experiment consisted in making the control slowly reach a target speed and then measure whatever the desired speed is reached and with which precision (section 4.1). Then, by analysing the log files it is studied if it is possible to recover the position of the ball relative to the starting point (section 4.2). This test is then repeated for different speed setpoints (0.01, 0.02, 0.03, 0.04 and 0.05 [$\frac{m}{s}$]). The visual display of the information is inspired by [3].

4.1 Speed measure

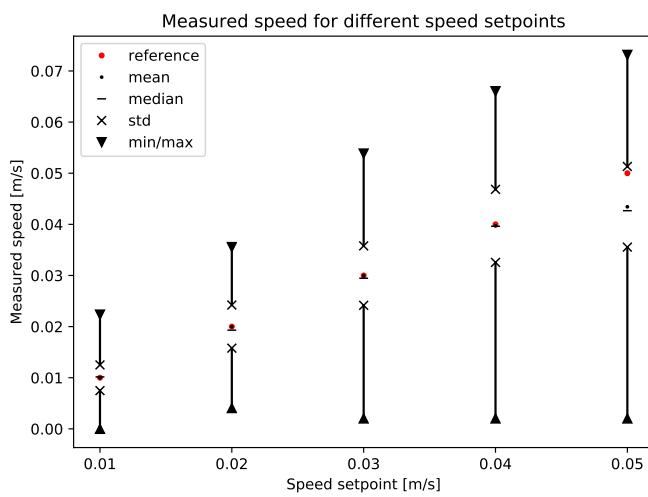


Figure 4.6 – Measured speed as a function of the reference speed.

One can notice that the minimum speed is always 0 [$\frac{m}{s}$], this is due to the friction that causes the ball to get periodically blocked, as said before. Moreover the last speed reference of 0.05 [$\frac{m}{s}$] is not reached because of the saturation of the control signal. On the other hand the median value is close to the mean, which is the case when the distribution is close to Gaussian. Finally a sensible increase in the standard deviation can be noticed when the reference speed is increased, this is probably due the sensor behaviour, but it might also be caused by more vibrations in the mechanical construction.

When it will be possible to reach higher speeds it will be interesting to see if the sensor's performances are degraded, probably the standard deviation will increase and then saturate for high speeds. It is expected, from the sensor's data-sheet, that the requirements are met for the full speed range of the final version of the treadmill (up to 3 [$\frac{m}{s}$]) even if it was not possible to test this situation.

The time series of the speed error are shown in figure 4.8. The noise distribution is close to Gaussian for every speed reference, the parameters to model the noise are given in table 6. One can notice that in every time-series there is a high frequency noise given by the sensor and a low frequency one. The low frequency noise is due to the imperfections on the ball. The ball gets periodically slowed down by some regions with higher friction. To better understand how the noise on the sensors varies with the increase of the reference speed figure 4.6 is shown. In this figure the reference speed is compared with the measured one.

One can notice that the minimum speed is

Reference	mean	median	std	min	max	unit
0.01	0.0100	0.0102	0.0025	-0.0000	0.0224	[$\frac{m}{s}$]
0.02	0.0200	0.0193	0.0042	0.0041	0.0356	[$\frac{m}{s}$]
0.03	0.0300	0.0295	0.0058	0.0020	0.0538	[$\frac{m}{s}$]
0.04	0.0397	0.0396	0.0071	0.0020	0.0660	[$\frac{m}{s}$]
0.05	0.0434	0.0427	0.0079	0.0020	0.0732	[$\frac{m}{s}$]

Table 6 – Noise parameters on speed for different speed references.

4.2 Position measurement

The time series of the position error are shown in figure 4.9. The noise distribution is close to Gaussian for every speed reference, the parameters to model the noise are given in table 7. One can notice that the position is not drifting from the expected one, or at least is drifting so slowly that on a time scale of 60 [s] it is not possible to measure it. This means that the optical sensors are very good and are able to compensate for the drift.

To better understand how the noise on the position varies with the increase of the reference speed figure 4.7 is shown. No surprise to see that the worst case it at $0.05 \frac{m}{s}$, which is the case in which the motor signal saturates.

The accuracy in position is impressive $\leq 4.4e-5 [m]$ for the reference speeds tested, this seems to deteriorate with higher speeds but should be within the requirements even for very high speeds. This high accuracy is expected from the sensors, since in the data sheet a similar result is presented. One question might arise at this point, why the speed is so less accurate if the position can be determined so precisely? This might be due to the precision in the time reference in the μ controller, which is set to 1 [ms]. Trying to use a more precise beat might improve the speed accuracy quite a lot, despite the little effort.

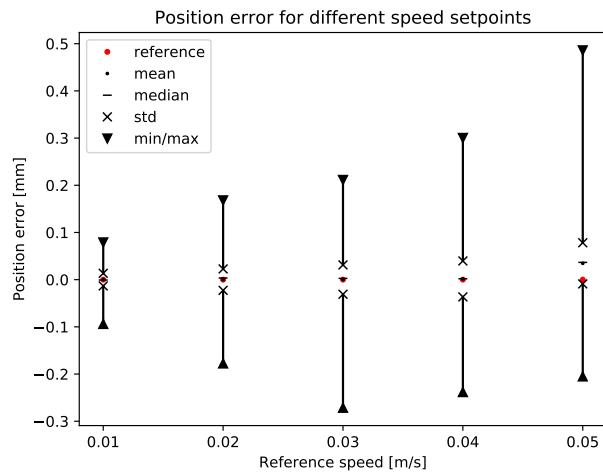


Figure 4.7 – Position error as a function of the reference speed.

Reference	mean	median	std	min	max	unit
$0.01 \frac{m}{s}$	6.4960e-08	-8.0000e-07	1.3375e-05	-9.3840e-05	7.8880e-05	[m]
$0.02 \frac{m}{s}$	3.3333e-08	3.4800e-06	2.2692e-05	-1.7752e-04	1.6792e-04	[m]
$0.03 \frac{m}{s}$	1.4768e-07	2.6800e-06	3.1088e-05	-2.7136e-04	2.1124e-04	[m]
$0.04 \frac{m}{s}$	1.5460e-06	1.8800e-06	3.8120e-05	-2.3820e-04	3.0028e-04	[m]
$0.05 \frac{m}{s}$	3.4602e-05	3.6640e-05	4.3614e-05	-2.0504e-04	4.8584e-04	[m]

Table 7 – Noise parameters on position for different speed references.

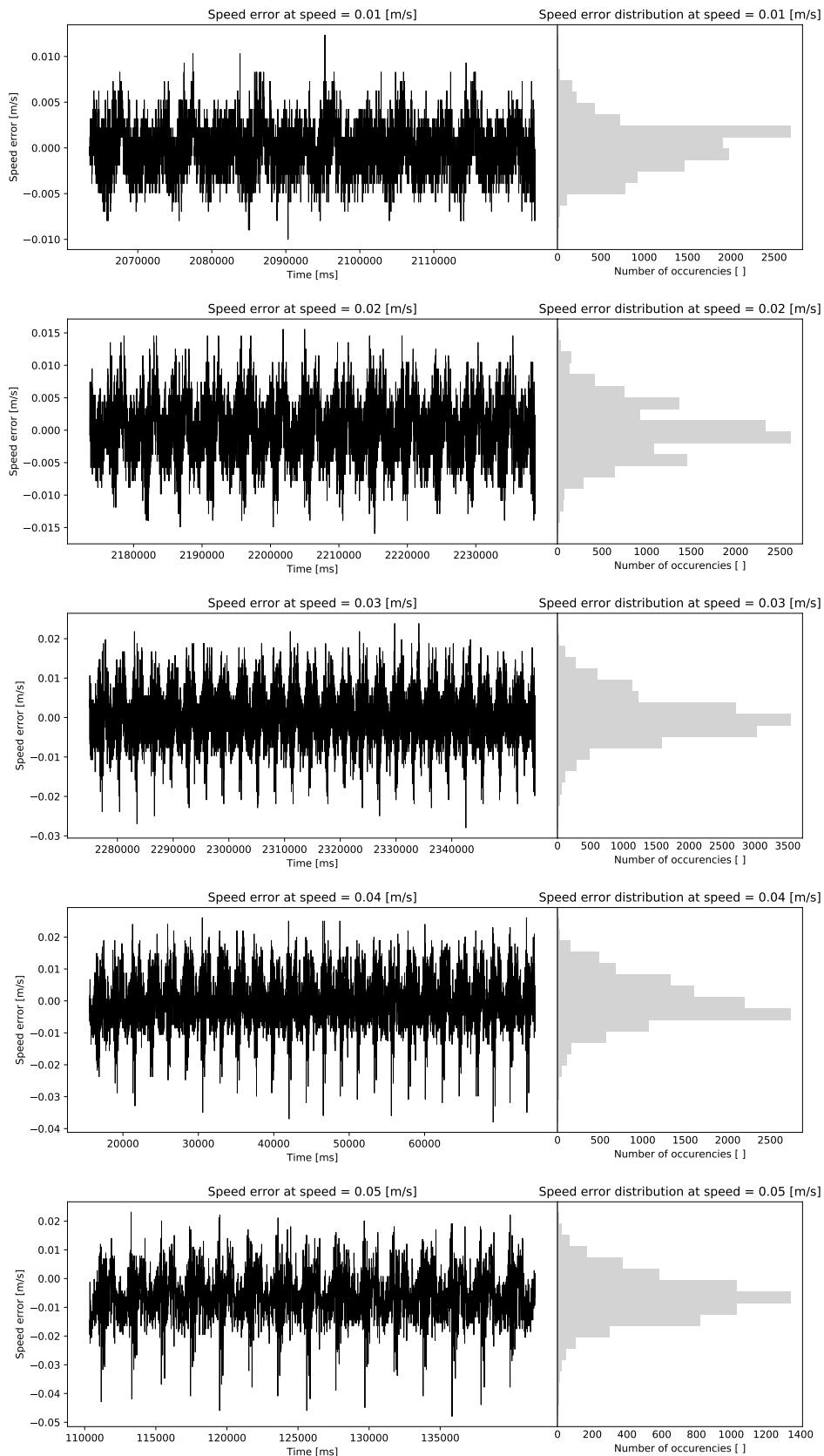


Figure 4.8 – Time-series of the speed error (measured speed-reference) for different reference speeds. On the right the number of occurrences is shown to study the distribution of the error.

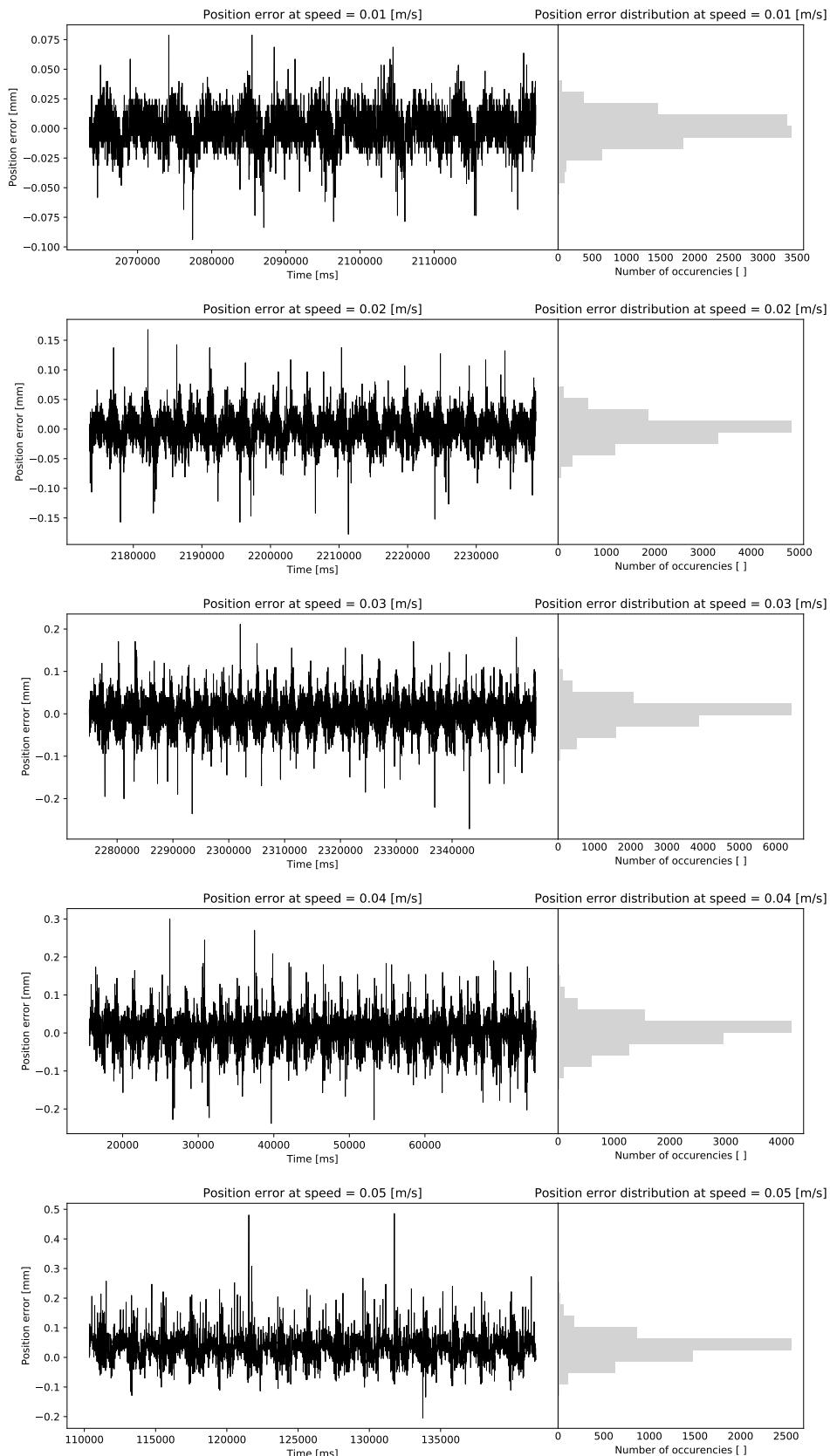


Figure 4.9 – Time-series of the position error (reference position- measured) for different reference speeds. On the right the number of occurrences is shown to study the distribution of the error.

5 Conclusion

In the first part of the section a comparison between requirements and achievements is done, then the conclusions are taken.

In the end the proposed system performs well in terms of accuracy, even if it is lacking on other requirements. Table 8 shows which requirements are achieved and which are not².

Description	Required	Obtained	Unit	Achieved
Dimensions of the moving surface	0.5	—	[m ²]	—
Course	∞	∞	[m]	YES
Maximum speed	3	≤ 0.05	[m/s]	NO
Maximum acceleration	2	—	[m/s ²]	—
Position resolution	0.01	≤ 4.4e - 5	[m]	YES
Speed resolution	0.02	≤ 0.008	[m/s]	YES
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)	feasible	([m],[s])	YES

Table 8 – Comparison between the requirements and the achieved performances. The slots marked with — are not measured or part of the mechanical design.

One can notice that the position and speed can be determined with really high resolution, this means that it is possible to achieve precise position control on the ball if required, moreover the time-series for the position do not show drift from the expected value except when it is not possible to reach it due to saturation in the control signals. For the functional requirements it is possible to say that:

- **Closed-loop control** The closed-loop control works correctly even if it is tested only for low speeds and accelerations, in a more advanced version it will be possible to have higher performances on the control by using some advanced control and better motors. It will also be possible to do position control on the ball if needed.
- **Speed routines** All the necessary code for generating, uploading and running speed routines is available, due to some problems in the mechanical build of the machine it was not possible to test and improve this feature.
- **User interface** One user interface is provided, this interface allows the full control of the machine. Improvements can be done to make it more "user-friendly".
- **Data logging** The data are logged correctly to the computer. On the performance side the logging speed for the info messages (see table 4) reaches 200 [Hz] for 97.3% of the time, which is a quite high frequency.
- **Expandability of the system** It is possible to expand and modify the system for future uses, an interesting expansion is to add some cameras to track the position of the mouse and use it to control the speed or position of the machine.

In conclusion all the functional requirements are met by the current design even if some of them can be improved and others need more testing.

²The position and speed resolution/accuracy depends on the speed setpoint, the surface quality and others, only extensive tests for different dynamics can provide good knowledge of these values.

The goal of designing a mouse treadmill able to solve the drawbacks of the ones used in [1] and [2] is achieved. Unfortunately, not all the requirements for the new design are met, which means that steps to improve the machine needs to be taken. This report try to underline the good performances achieved, as well as the things that are not to show the way for improving the design. One crucial step to take is the improvement of the motors, the ones on the prototype are too noisy and slow to be used for testing with a real mouse. In this report one suggestion for the new motors is done, so that for the next iteration it is possible to start from a solid starting point. No need to underline that a different choice can be made, especially since the motors are controlled using PWM, which is a very common technique used by most motor drivers.

Working on this project was a great opportunity to practice many different skills and improve my knowledge on the field. The most interesting part was to implement a functional embedded system and its interface with the PC, the sensors and the motors. A true and complete robotic project from A to Z !

I thanks the professor for this opportunity and the assistant for his help throughout the project. I also thanks Maxime Rioux for his work on the mechanical design of the treadmill, Alessandro Crespi for his advices on electronics and Jérôme Savary who helped me with Altium designer.

6 User manual for mouse treadmill software

The software is well documented (just run doxygen using the Doxyfile in the docs folder), nevertheless some important things are pointed out in this report so that the user can more easily install and start using the mouse treadmill. In this manual the following sections are provided: the installation guide for the PC software 6.1 , a user manual for the GUI 6.2 as well as a guide on how to expand the system with new messages 6.4. Note that all the provided commands and instructions are tested for MAC. MAVLink is available also for LINUX and WINDOWS, the user therefore adapt these commands to be able to install and successfully use the software on his own machine.

On <https://github.com/DidierNegretto/3DMouseTreadmill> it is possible to find example code for writing a routine and reading the log files, do not hesitate to take inspiration³ from this code.

6.1 Installation of the PC software

First python 3 needs to be installed, for that see [5]. GIT needs to be install as well. Some other python packages needs to be installed, they can be obtained using PiP. The required ones are:

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

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

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

1. Clone the git repository of the project using

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

2. Move inside the repository

```
$ cd 3DMouseTreadmill/
```

3. Make sure no previous version of pymavlink is installed

```
$ pip uninstall pymavlink
```

4. Remove the mavlink directory

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

5. Clone the mavlink repository

³ "inspiration" includes, but it is not limited to copy-pasting. Remember to cite the sources of your inspiration.

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

6. Update the submodule

```
$ git submodule update --init --recursive
```

7. Copy mouse.xml file and the mouse.py files into mavlink/pymavlink/dialects/v20

8. Change directory to mavlink/

```
$ cd mavlink
```

9. Export the path to the repository so that python will find all the code it needs to run

```
$ export PYTHONPATH='path_to_repository/3DMouseTreadmill/'
```

10. Change directory to pymavlink

```
$ cd pymavlink
```

11. Setup everything using the setup.py provided

```
$ python3 setup.py install --user
```

6.2 How to use the GUI

In this section the use of the GUI and its functionalities are described.

You can use the GUI only after installing the PC software as shown in 6.1. To run it you just need to run the mouseController.py using python3. Note that you will need to change the port according to the port on which the stm32 is connected as well as the import routine as mouseRoutine if you change the name of the file in which the routine is.

First of all the GUI provided can be expanded using the functions in the mouse.py generated using mavlink, and thus can be improved for future versions of the project. One screenshot of the GUI is shown in figure 6.10. Figure 6.10 is taken on a MAC, the GUI have the same functionalities on other platforms, but it might look different. The library used to design the GUI is Appjar, which is compatible with MAC, LINUX and Windows.

- **A** In this region the content of the HEARTBEAT message are presented. Time is the time from boot of the system in milliseconds. Modes is the mode in which the stm32 is. The mode can be STOP, SPEED AUTO or RUNNING.
- **B** In this region the real-time data are plotted. The top plot shows the X and Y motor signals, the middle one shows the X and Y speed setpoints and the bottom one shows the motor signal. By using the top left buttons it is possible to save the plots and navigate them, it is advisable to store the data and plot them afterwards using another script for better analysis due to the fast update of the plots.

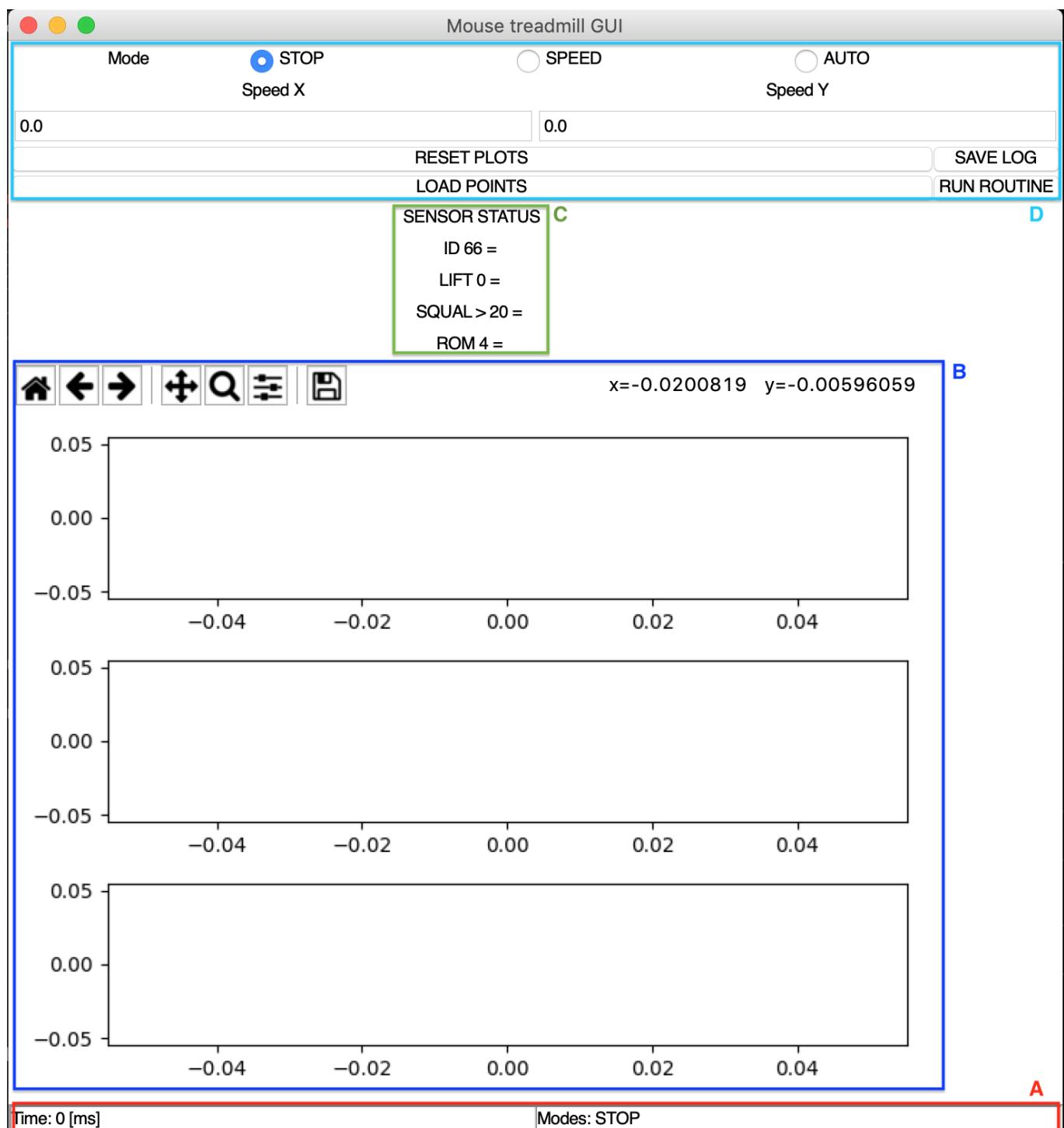


Figure 6.10 – GUI screenshot on a MAC.

- **C** In this region data from the sensors are displayed. ID is the product ID of the sensor and is used to verify that the communication between the sensor and the board is working correctly. LIFT is 0 if the sensor detects correctly the surface and 1 if it does not. SQUAL is the surface quality information. This value should be greater than 20 for the measure to be good. ROM is the SROM ID of the sensor. This value is used to verify that the SROM is flashed correctly during initialization. If everything is working correctly you should see something like table 9

SENSOR STATUS	
ID	66 = 66 66
LIFT	0 = 0 0
SQUAL	> 20 = 34 43
ROM	4 = 4 4

Table 9 – Example of GUI output when the sensors are initialized and connected correctly and detecting a good quality surface. Before = the name of the information and its correct value are shown, after the sensor x | sensor y readings are displayed.

- **D** In this region the input from the user are taken. In the first line the user can select the mode to be used:

- **STOP:** When this mode is selected the motors are stopped.
- **SPEED:** When this mode is selected the speed setpoints can be typed in the two entries under the Speed X and Speed Y labels.
- **AUTO:** When this mode is selected the user can load the points of the routine on the board (Modes: LOAD) and then run the routine (Modes: RUNNING).

Finally the RESET PLOTS button is used to reset the plot in case of reset on the board, the SAVE LOG button stores all the data received in a file in /log/log_TIME.txt, where TIME is the time expressed in [ns]. This is done to avoid overwriting logs that were previously acquired. The LOAD POINTS sends the points defined in routine.py to the board. This will work only if the mode is set to AUTO (should see LOAD in Modes in **A** and the time should not be updated). Finally the RUN ROUTINE button starts the routine on the board (the board goes in mode RUNNING).

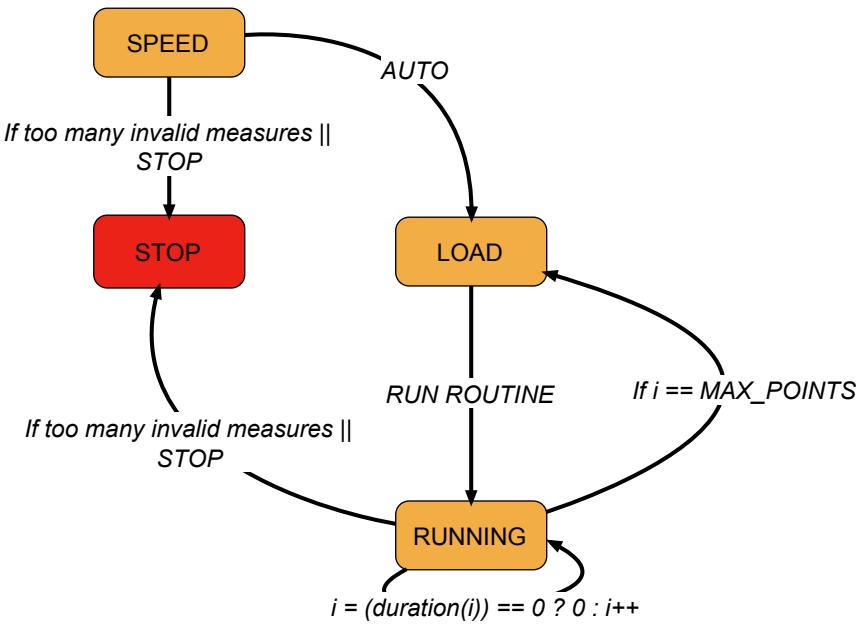


Figure 6.11 – Finite state machine of the mouse treadmill.

The finite state machine of the machine is shown in figure 6.11. All the capital letters conditions (except for MAX_POINTS) are widgets on the GUI that can be pressed by the user while using the machine.

6.3 How to write a routine

In this section the way to properly define a routine is described. An example routine is provided in MouseTreadmillPC/python/routine.py. The routine is a python dictionary containing a list of durations, setpoint_x and setpoint_y. The two setpoints define the desired speed along x and y, while the duration is the time span during which the two setpoints are applied. One should notice that the system time is discrete and increased every millisecond, moreover one should take into account the settling time for the control and the maximum acceleration provided by the motors to do a proper discretization of the desired speed profile.

A duration of 0 means that the end of the routine is reached and the routine is started again at the first point defined. A maximum of 255 points can be defined, if more points are needed the id of the point have to be changed from type uint8_t to uint16_t to allow for IDs above 255. A memory limitation is still present, but for a number of points above 1'000. An example script to generate a routine is given (gen_routine.py).

6.4 How to extend the system

To extend the system with new messages and features the main operation consist in modifying A. This files describes all the messages and constants used in the communication protocol, thus it possible to add/modify them. If you need to create a new message or constant, please have a look at the already defined ones and use them as a template. To extend the system please follow the following steps:

1. Get the basic system installed correctly, for that see 6.1.
2. Modify A (mouse.xml) as needed.
3. Generate the C libraries for the STM32, for that you need:

```
$ cd 3DMouseTreadmill/mavlink
$ python 3 mavgenerate.py
```

Now a GUI asking you information appear, this must be filled as follow:

- **XML** there you indicate the mouse.xml file that was previously modified
- **Out** there you indicate the 3DMouseTreadmill/MAVLink Library/
- **Language** Choose C
- **Protocol** Choose 2.0
- **Validate** Choose Yes
- **Validate Units** Choose Yes

Now you can press on generate. The GUI should be similar to figure 6.12a. If some errors are shown, correct them and try again.

4. Adapt the code in the STM32 project if needed.
5. Generate the python libraries for the PC, for that you need:
 - (a) Run mavgenerate.py (if not still running)

```
$ python 3 mavgenerate.py
```

Now a GUI asking you information appear, this must be filled as follow:

- **XML** there you indicate the mouse.xml file that was previously modified
- **Out** there you indicate the 3DMouseTreadmill/mouse.py
- **Language** Choose Python
- **Protocol** Choose 2.0
- **Validate** Choose Yes
- **Validate Units** Choose Yes

Now you can press on generate. The GUI should be similar to figure 6.12b. If some errors are shown, correct them and try again.

- (b) Change directory to the parent one

```
$ cd ../
```

- (c) repeat the installation guide (see 6.1) from point 3.
6. Adapt the python code if necessary.

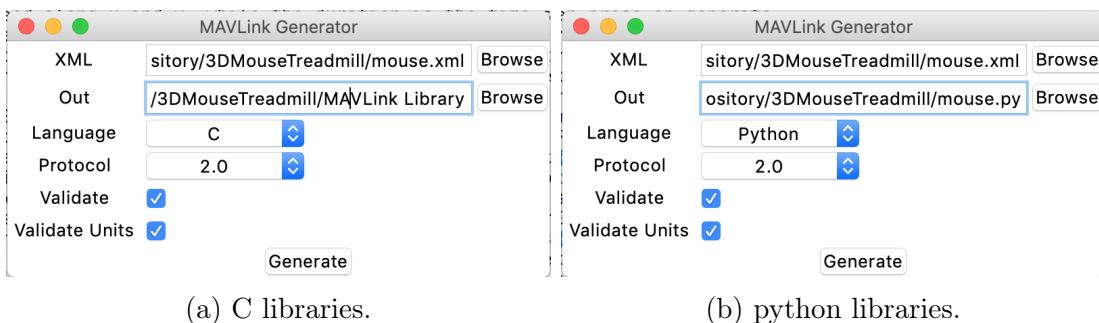


Figure 6.12 – Mavgenerate screenshots properly setup for generating python and C libraries.

7 What to do if you do not know what to do

If you find yourself in the situation depicted in figure 7.13

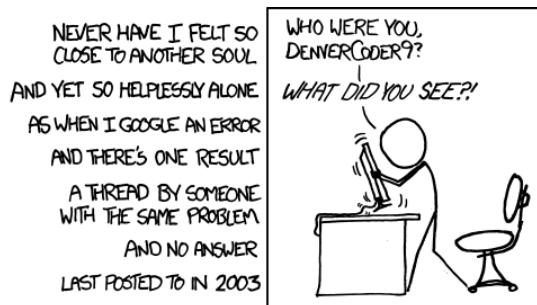


Figure 7.13 – Situation in which you might be if nothing works as expected [6]

And you have tried everything, you might be able to reach *DenverCoder9* by emailing:

`didier.negretto@epfl.ch`

References

- [1] Jared M. Clegg, Roberto Leiras, Alexia Montalant, Ian R. Wickersham, and Ole Kiehn, *Brainstem Neurons that Command Left/Right Locomotor Asymmetries*
- [2] Jakob Voigts, Mark T. Harnett, *Somatic and Dendritic Encoding of Spatial Variables in Retrosplenial Cortex Differs during 2D Navigation*
- [3] Edward R. Tufte, *The visual display of quantitative information.*
- [4] MAVLink Developer Guide, <https://mavlink.io/en/>
- [5] Python website, <https://www.python.org/downloads/>
- [6] Randall Munroe, <https://xkcd.com/979/>

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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</description>
8       <entry value="0" name="MOUSE_MODE_STOP">
9         <description>All motion of mouse treadmill is stopped</description>
10        </entry>
11       <entry value="1" name="MOUSE_MODE_SPEED">
12         <description>Constanst speed is applied. Speed selected by PC
13           message SPEED_SETPOINT.</description>
14       </entry>
15       <entry value="2" name="MOUSE_MODE_AUTO_LOAD">
16         <description>Predefined speed profile is loaded</description>
17       </entry>
18       <entry value="3" name="MOUSE_MODE_AUTO_RUN">
19         <description>Predefined speed profile is applied</description>
20       </entry>
21     </enum>
22     <enum name="MOUSE_ERROR">
23       <description>This enum defines the possible errors</description>
24       <entry value="0" name="MOTOR_ERROR">
25         <description>The motor driver flaged an error, this might be due to
26           many sources, see datasheet of motor driver.</description>
27       </entry>
28       <entry value="1" name="MOTOR_LOW_SPEED">
29         <description>The speed setpoint chosen is too low to be achieved.</
30           description>
31       </entry>
32       <entry value="2" name="MOTOR_HIGH_SPEED">
33         <description>The speed setpoint chosen is too high to be achieved.</
34           description>
35       </entry>
36       <entry value="3" name="MOUSE_ROUTINE_TOO_LONG">
37         <description>More than 255 points have been defined in the mouse
38           routine.</description>
39       </entry>
40       <entry value="4" name="SENSOR_NOT RESPONDING">
41         <description>One sensor is not responding correctly.</description>
42       </entry>
43     </enum>
44     <enum name="SENSOR_ID">
45       <description>This enum defines the sensors directions</description>
46       <entry value="0" name="SENSOR_X">
47         <description>Sensor ID for X direction.</description>
48       </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
52             present and responding. Sender = STM32 Receiver = PC
53     </description>
54     <field type="uint8_t" name="mode" enum="MOUSE_MODE">Actual operating
55         mode</field>
56     <field type="uint32_t" name="time">Time from boot of system</field>
57 </message>
58     <message id="1" name="SPEED_INFO">
59         <description>The message giving the actual speed of the motor. Sender =
60             STM32 Receiver = PC
61     </description>
62     <field type="uint32_t" name="time_x">Time from boot of system for
63         speed_x measure</field>
64     <field type="uint32_t" name="time_y">Time from boot of system for
65         speed_y measure</field>
66     <field type="float" name="speed_x">Speed in x direction</field>
67     <field type="float" name="speed_y">Speed in y direction</field>
68     <field type="uint8_t" name="valid">0 if data are not valid, 1 if data
69         are valid </field>
70 </message>
71     <message id="2" name="SPEED_SETPOINT">
72         <description>The message is sent to send and validate the setpoint sent
73             from computer. Sender = PC/STM32 Receiver = STM32/PC
74     </description>
75     <field type="float" name="setpoint_x">Speed setpoint in x direction</
76         field>
77     <field type="float" name="setpoint_y">Speed setpoint in y direction</
78         field>
79 </message>
80     <message id="3" name="MODE_SELECTION">
81         <description>This message is used to select the mode of the STM32 Sender
82             = PC Receiver = STM32
83     </description>
84     <field type="uint8_t" name="mode" enum="MOUSE_MODE">Actual operating
85         mode</field>
86 </message>
87     <message id="4" name="MOTOR_SETPOINT">
88         <description>This message defines the raw motor input values. This
89             values defines the Duty_Cycle up time for PWM signals. Sender =
90             STM32 Receiver = PC
91     </description>
92     <field type="uint32_t" name="time">Time from boot of system</field>
93     <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
85             point for auto mode Sender = STM32 Receiver = PC
86         </description>
87         <field type="uint16_t" name="point_id">Last ID of point loaded</field>
88     </message>
89     <message id="6" name="POINT">
90         <description>This message is used to send one point for auto mode.
91             Sender = PC Receiver = STM32
92         </description>
93         <field type="uint32_t" name="duration">Time during which the setpoint
94             need to be kept</field>
95         <field type="uint16_t" name="point_id">point ID</field>
96         <field type="float" name="setpoint_x">Speed setpoint in x direction</
97             field>
98         <field type="float" name="setpoint_y">Speed setpoint in y direction</
99             field>
100     </message>
101     <message id="7" name="ERROR">
102         <description>This message is used to send errors Sender = STM32 Receiver
103             = PC
104         </description>
105         <field type="uint32_t" name="time">Time from boot of system</field>
106         <field type="uint8_t" name="error" enum="MOUSE_ERROR">error ID</field>
107     </message>
108     <message id="8" name="RAW_SENSOR">
109         <description>This message contains raw sensor values Sender = STM32
110             Receiver = PC
111         </description>
112         <field type="uint32_t" name="time">Time from boot of system</field>
113         <field type="uint8_t" name="sensor_id">0 for X, 1 for Y.</field>
114         <field type="int16_t" name="delta_x">Displacement along sensor's x
115             in counts per inch.</field>
116         <field type="int16_t" name="delta_y">Displacement along
117             sensor's y in counts per inch.</field>
118         <field type="uint8_t" name="squal">Quality of the surface.
119             For white paper is around 30.</field>
120         <field type="uint8_t" name="lift">1 if the sensor is lifted (
121             not measuring). 0 otherwise</field>
122         <field type="uint8_t" name="product_id">0x42 if the serial
123             communication with the sensor works correctly.</field>
124         <field type="uint8_t" name="srom_id">0x00 if initialisation is not done.
125             Other value if done correctly.</field>
126     </message>
127   </messages>
128 </mavlink>

```

B Motor proposition

Configured drive

Motor - ECXSP16M BL KL A STD 24V

Gearhead - GPX16 SP STE 44:1

Part number: B7A31C479448 Revision number 2

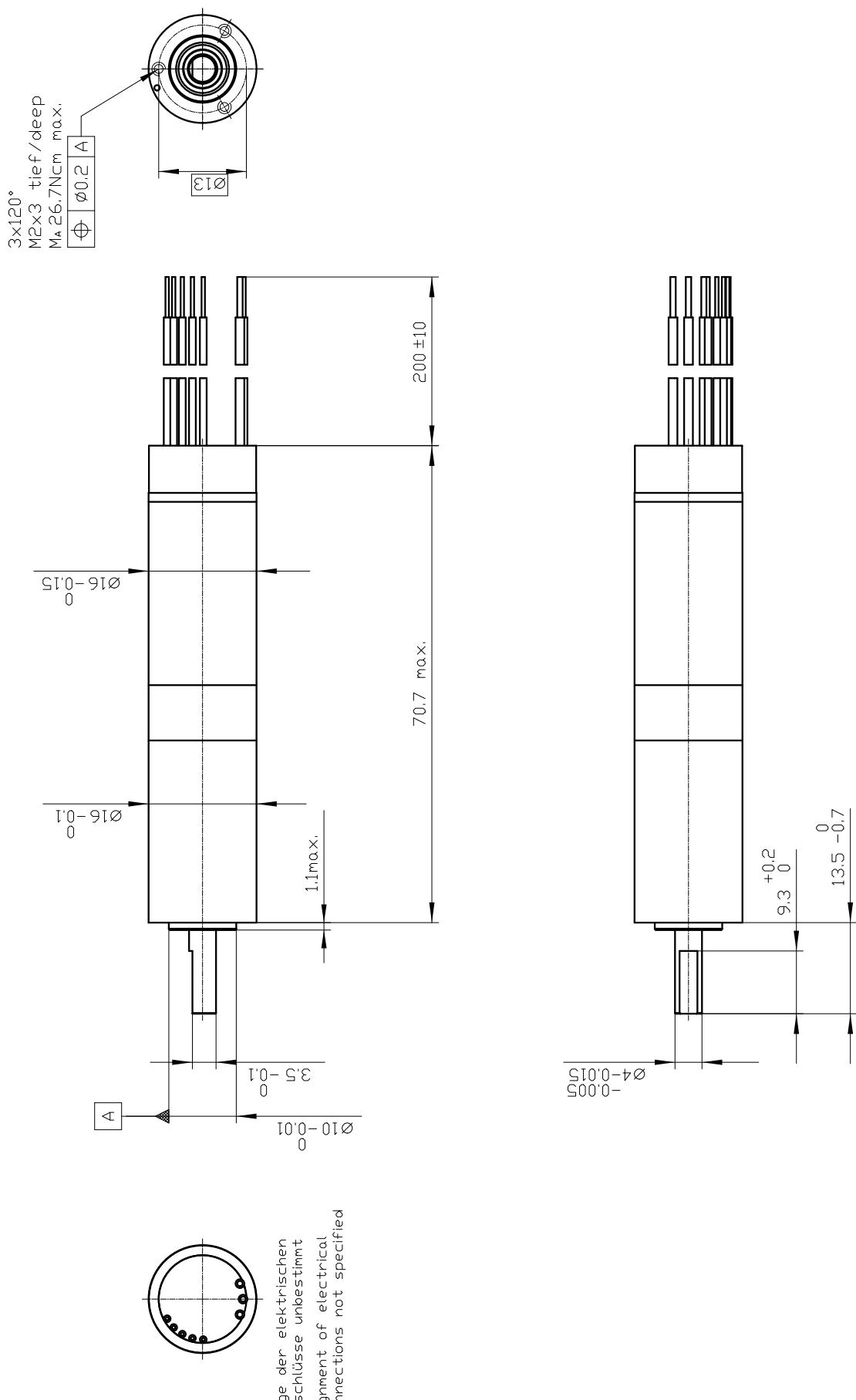
Orders are processed and shipped from Switzerland within 11 working days.

General Terms and Conditions: https://www.maxongroup.ch/maxon/view/content/terms_and_conditions_page

To open the integrated CAD file, please save this document and open it in Acrobat Reader. The STEP file is available after a double-click on the pin icon.

B7A31C479448.stp (STP AP 214)

Open configuration: <https://www.maxongroup.com/maxon/view/configurator/?ConfigID=B7A31C479448>



Unit of measure: mm



ISO 1101

ISO 965-1

ISO 2768-m

ISO 8015

Motor (Cable type: AWG22)

Red	Motor 1
Black	Motor 2
White	Motor 3

Hall-Sensor (Cable type: AWG26)

Orange	V _{hall} 3...24V
Blue	GND
Yellow	Hall-Sensor 1
Brown	Hall-Sensor 2
Gray	Hall-Sensor 3

Summary of your selected configuration

Total weight of the drive: 105.6 g

ECXSP16M BL KL A STD 24V

Product detail

Commutation	With Hall sensors
Nominal voltage	24 V
Motor bearings	Preloaded ball bearing
Version	Standard

GPX16 SP STE 44:1

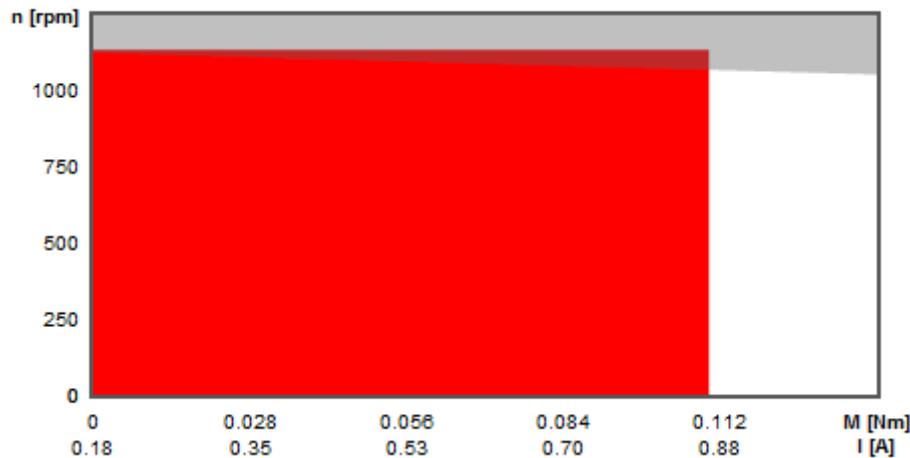
Product detail

Reduction	44
Number of stages	2

Legend for part designation

EB	Precious metal brushes	GB	Graphite brushes	CLL	Spark suppression	BL	Brushless
A	Hall sensors	B	Sensorless	KL	Ball bearings	SL	Sintered bearings
GPX	Planetary gearhead	ENX	Encoder	ENC	Encoder	IMP	Pulses
ST	Number of stages	HP	High Power	S/M/L	Short/medium/long	HS	High Speed
STE	Sterilizable	INT	Integ.	STD	Standard	SP	Speed
ABS	Absolute	LN	Reduced noise level	A	Standard	LZ	Reduced backlash
C	Ceramic bearing			STEC	Sterilizable, Ceramic bearing		

Selected operating point



- | | | | |
|--|----------------------------|--|---|
| | Continuous operation range | | Out of voltage range |
| | Continuous operation range | | Not recommended range |
| | Selected operating point | | Continuous operation range at reduced thermal resistance Rth2 50% |

ECXSP16M BL KL A STD 24V



Product specification

Values at nominal voltage

Nominal voltage	24 V
No load speed	49600 min ⁻¹
No load current	177 mA
Nominal speed	45300 min ⁻¹
Nominal torque (max. continuous torque)	4.93 mNm
Nominal current (max. continuous current)	1.24 A
Stall torque	63.2 mNm
Stall current	13.9 A
Max. efficiency	79.1 %

Characteristics

Max. output power continuous	23.5 W
Terminal resistance phase-to-phase	1.73 Ω
Terminal inductance phase-to-phase	0.0893 mH
Torque constant	4.55 mNm A ⁻¹
Speed constant	2100 min ⁻¹ V ⁻¹
Speed/torque gradient	797 min ⁻¹ mNm ⁻¹
Mechanical time constant	6.73 ms
Rotor inertia	0.806 gcm ²

Thermal data

Thermal resistance housing-ambient	20.3 KW ⁻¹
Thermal resistance winding-housing	1.52 KW ⁻¹
Thermal time constant of the winding	1.83 s
Thermal time constant of the motor	508 s
Ambient temperature	-20...100 °C
Max. winding temperature	125 °C

Mechanical data

Max. permissible speed	55000 min ⁻¹
Axial play	0...0.29 mm
Preload	1.5 N
Direction of force	Zug
Radial backlash	0 mm
Max. axial load (dynamic)	1.5 N

Max. force for press fits (static)	60 N
Static, supported shaft	2500 N
Max. radial load 5 mm from flange	10 N
Measurement from the flange	5 mm

Further specifications

Number of pole pairs	1
Number of phases	3
Typical noise level	50 dBA (50000 min ⁻¹)
Typical noise level at reference speed	50000 min ⁻¹
Number of autoclave cycles	0

Information about motor data. https://www.maxongroup.com/medias/CMS_Downloads/DIVERSES/12_137_EN.pdf

GPX16 SP STE 44:1



Product specification

Gearhead data

Reduction	44:1
Absolute reduction	4356/100
Number of stages	2
Max. continuous torque	0.11 Nm
Max. intermittent torque	0.14 Nm
Direction of rotation, drive to output	=
Max. efficiency	80 %
Average backlash no-load	1.6 °
Mass inertia	0.014 gmc ²
Max. transmittable power (continuous)	21 W
Max. short-time transferable output	25 W

Technical data

Output shaft bearing	Wälzlager
Max. radial play, 5 mm from flange	max. 0.1 mm
Axial play	0...0.1 mm
Max. permissible radial load, 5 mm from flange	35 N
Max. permissible axial load	30 N
Max. permissible force for press fits	100 N
Max. continuous input speed	50000 min ⁻¹
Max. intermittent input speed	70000 min ⁻¹
Recommended temperature range	-10..135 °C

Information about gearhead data: https://www.maxongroup.com/medias/CMS_Downloads/DIVERSES/12_203_EN.pdf

ESCON Module 24/2



Product specification

Motor

DC motors up to	48 W
EC motors up to	48 W

Sensor

Without sensor (DC motors)	Yes
Sensorless (EC motors)	
Digital incremental encoder (2-channel, single-ended)	Yes
Digital incremental encoder (2-channel, differential)	Yes
Digital incremental encoder (3-channel, differential)	Yes
Digital Hall sensors (EC motors)	Yes
SSI absolute encoder	
Analog incremental encoder (2-channel, differential)	

Operating modes

Current controller	Yes
Speed controller (open loop)	Yes
Speed controller (closed loop)	Yes
Positioning controller	

Electrical data

Operating voltage VCC	10.24 VDC
Logic supply voltage VC optional	.. VDC
Max. output voltage (factor * VCC)	0.98 *
Max. output current I _{max}	6 A
Max. duration of peak output current I _{max}	4 s
Continuous output current I _{cont}	2 A
Switching frequency of the power stage	53.6 kHz
Sampling rate, PI current controller	53.6 kHz
Sampling rate, PI speed controller (closed loop)	5.36 kHz
Sampling rate, PID positioning controller	kHz
Max. efficiency	92 %
Max. speed (DC motors)	150000 min-1
Max. speed (1 pole pair), block commutation	150000 min-1
Max. speed (1 pole pair), sinusoidal commutation	min-1
Built-in motor choke per phase	uH

Inputs

Hall sensor signals	H1, H2, H3
Encoder signals	A, A\, B, B\
Max. encoder input frequency	1 MHz
Digitale Eingänge	2

Functionality of digital inputs	Enable, enable CW, enable CCW, enable CW+CCW, enable + direction of rotation, stop, PWM set value, RC Servo set value, fixed set value
Analog inputs	2
Resolution, range, circuit	12-bit, -10...+10V, differential
Functionality of inputs	Set value, current limit, offset, speed ramp
Potentiometers	
Functionality of the potentiometers	
DIP switch	
Functionality of the DIP switch	

Outputs

Digital outputs	2
Functionality of digital outputs	ready, speed comparator, current comparator, commutation frequency
Analog outputs	2
Resolution, range	12-bit, -4...+4V
Functionality of analog outputs	current monitor, speed monitor, temperature, fixed value

Voltage outputs

Hall sensor supply voltage	+5 VDC, max. 30 mA
Encoder supply voltage	+5 VDC, max. 70 mA
Auxiliary output voltage	+5 VDC, max. 10 mA
Output voltage (reference)	

Ambient conditions

Temperature – operation	-30.. 60 °C
Temperature – storage	-40 .. 85 °C
Temperature – extended range	+60...+80 °C, Derating: -0.1 A/°C
Humidity (non-condensing)	5 .. %

Mechanical data

Weight	7 g
Dimensions (L x W x H)	35.6 x 26.7 x 12.7 mm
Mounting	mountable on socket terminal strips pitch 2.54 mm

C Code for STM32 NUCLEO 64 board

C.1 Main

```

1 /* USER CODE BEGIN Header */
2 /**
3 ****
4 * @file      : main.h
5 * @brief     : Header for main.c file.
6 *             This file contains the common defines of the application.
7 ****
8 * @attention
9 *
10 * <h2><center>&copy; Copyright (c) 2019 STMicroelectronics.
11 * All rights reserved.</center></h2>
12 *
13 * This software component is licensed by ST under BSD 3-Clause license,
14 * the "License"; You may not use this file except in compliance with the
15 * License. You may obtain a copy of the License at:
16 *          opensource.org/licenses/BSD-3-Clause
17 *
18 ****
19 */
20 /* USER CODE END Header */
21
22 /* Define to prevent recursive inclusion -----*/
23 #ifndef __MAIN_H
24 #define __MAIN_H
25
26 #ifdef __cplusplus
27 extern "C" {
28 #endif
29
30 /* Includes
-----*/
31 #include "stm32l4xx_hal.h"
32
33 /* Private includes
-----*/
34 /* USER CODE BEGIN Includes */
35 #include "mouseDriver.h"
36 #include "mavlink.h"
37 /* USER CODE END Includes */
38
39 /* Exported types
-----*/
40 /* USER CODE BEGIN ET */
41 /**
42 * A structure to represent one sensor
43 */
44 typedef struct SENSOR{
45     /*@{*/
46     GPIO_TypeDef * cs_port; /*< the chip select port for the sensor */
47     uint8_t cs_pin; /*< the chip select pin for the sensor */
48     GPIO_TypeDef * pw_port; /*< the power port for the sensor */
49     uint8_t pw_pin; /*< the power pin for the sensor */
50     uint8_t status; /*< the sensor status. This is the SROM_ID after the upload of the
51     firmware. This value should not be 0 otherwise the upload of the SROM is failed. */
52     /*@}*/

```

```

53 } sensor_t;
54 /* USER CODE END ET */
55
56 /* Exported constants
-----*/
57 /* USER CODE BEGIN EC */
58
59 /* USER CODE END EC */
60
61 /* Exported macro
-----*/
62 /* USER CODE BEGIN EM */
63
64 /* USER CODE END EM */
65
66 void HAL_TIM_MspPostInit(TIM_HandleTypeDef *htim);
67
68 /* Exported functions prototypes -----*/
69 void Error_Handler(void);
70
71 /* USER CODE BEGIN EFP */
72 */
73 \fn main_transmit_buffer(uint8_t *outBuffer, uint16_t msg_size)
74 \param outBuffer buffer to be transmitted over UART
75 \param msg_size size of the buffer
76 \brief This function sends the buffer using UART.
77
78 \attention The transmission is done using a DMA. Before sending a message
79 it is important to check that the previous one has been sent. This can be done
80 using \ref main_get_huart_tx_state .
81 */
82 void main_transmit_buffer(uint8_t *outBuffer, uint16_t msg_size);
83 */
84 \fn main_stop_motors()
85 \brief This function stops the motors
86
87 The PWM duty cycle is set to 0% for the two motors
88 \note The PWM duty cycle is represented by a uint type.
89 The min/max of that value are defined by how the timer is
90 setup in the microcontroller. The max value can be limited
91 by limitations in the motors or in the mechanical build of the
92 machine
93 */
94 void main_stop_motors(void);
95 */
96 \fn main_set_motors_speed(mavlink_motor_setpoint_t motor )
97 \param motor PWM duty cycle for the two motors
98 \brief This sets the motor duty cycle to one specified in the
99 motor parameter
100
101 The PWM duty cycle is set to 0% for the two motors
102 \note The PWM duty cycle is represented by a uint type.
103 The min/max of that value are defined by how the timer is
104 setup in the microcontroller. The max value can be limited
105 by limitations in the motors or in the mechanical build of the
106 machine
107 */
108 void main_set_motors_speed(mavlink_motor_setpoint_t motor );
109 */
110 \fn main_get_huart_tx_state()

```

```

111 \return the HAL_state of UART transmit
112 \brief Function used to verify if the channel for writing the buffer is available or busy.
113 */
114 int main_get_huart_tx_state(void);
115 */
116 \fn main_write_sensor(sensor_t sensor, uint8_t adress, uint8_t data)
117 \param sensor sensor to which we want to write
118 \param adress adress of the register to be modified
119 \param data data to written in the given sensor and register
120 \brief This function writes a byte in a given register of a given sensor.
121
122 \note The writing is done by generating proper signals in the pins. For more details
123 on the sensor register and timing diagrams see resources/sensorDatasheet.pdf
124 */
125 void main_write_sensor (sensor_t sensor, uint8_t adress, uint8_t data);
126 */
127 \fn main_read_sensor(sensor_t sensor, uint8_t adress)
128 \param sensor sensor from which we want to read
129 \param adress adress of the register to be read
130 \return the value in the given register and sensor
131 \brief This function reads a byte in a given register of a given sensor.
132
133 \note The reading is done by generating proper signals in the pins. For more details
134 on the sensor register and timing diagrams see resources/sensorDatasheet.pdf
135 */
136 uint8_t main_read_sensor (sensor_t sensor, uint8_t adress );
137 */
138 \deprecated
139 \fn main_transmit_spi(uint8_t data)
140 \param data data to be transmitted on the spi2
141 \brief This function transmit one byte on the spi2
142 */
143 void main_transmit_spi(uint8_t data);
144 */
145 \fn main_wait_160us()
146 \brief function used to wait around 160 [us].
147 \note the wait is achieved by toggling the green LED.
148 */
149 void main_wait_160us(void);
150 */
151 \fn main_wait_20us()
152 \brief function used to wait around 20 [us].
153 \note the wait is achieved by toggling the green LED.
154 */
155 void main_wait_20us(void);
156 */
157 \fn main_write_sensor_burst(uint8_t data)
158 \param data by to be written during the burst
159 \brief function used during a write burst
160 \attention Use this function only during a burst write.
161 */
162 void main_write_sensor_burst(uint8_t data);
163 */
164 \fn main_read_sensor_motion_burst(uint8_t *data )
165 \param data pointer on a table of uint8_t used to store the
166 data read from a motion read burst
167 \brief function used to do a burst read for the motion read burst
168 as specified in resources/resources/sensorDatasheet.pdf
169
170 \attention Use this function only during a motion read burst.

```

```

171 \note The data received from the motion read burst are raw datas and have
172 to be treated to obtain meaningful values and verify that the sensor is not
173 lifted and the surface quality is good enough to consider the measure as valid.
174 */
175 void main_read_sensor_motion_burst(uint8_t *data );
176 /*
177 * PW_0 is power pin for sensor X (PB_0)
178 * PW_1 is the power pin for sensor Y (PA_4)
179 * CS_0 is the chip select for sensor X (PC_0)
180 * CS_1 is the chip select for sensor Y (PC_1)
181 */
182
183 /* USER CODE END EFP */
184
185 /* Private defines
-----*/
186 #define DT_HEART 200
187 #define PRESCALER_HEART 1000
188 #define CLOCK_FREQ 80000000
189 #define COUNTER_PERIOD_HEART ((CLOCK_FREQ/(PRESCALER_HEART))*0.001*DT_HEART)
190 #define PRESCALER_PWM 1000
191 #define COUNTER_PERIOD_PWM 255
192 #define PULSE_PWM 10
193 #define B1_Pin GPIO_PIN_13
194 #define B1_GPIO_Port GPIOC
195 #define CS_0_Pin GPIO_PIN_0
196 #define CS_0_GPIO_Port GPIOC
197 #define CS_1_Pin GPIO_PIN_1
198 #define CS_1_GPIO_Port GPIOC
199 #define USART_TX_Pin GPIO_PIN_2
200 #define USART_TX_GPIO_Port GPIOA
201 #define USART_RX_Pin GPIO_PIN_3
202 #define USART_RX_GPIO_Port GPIOA
203 #define PW_1_Pin GPIO_PIN_4
204 #define PW_1_GPIO_Port GPIOA
205 #define LD2_Pin GPIO_PIN_5
206 #define LD2_GPIO_Port GPIOA
207 #define PW_0_Pin GPIO_PIN_0
208 #define PW_0_GPIO_Port GPIOB
209 #define TMS_Pin GPIO_PIN_13
210 #define TMS_GPIO_Port GPIOA
211 #define TCK_Pin GPIO_PIN_14
212 #define TCK_GPIO_Port GPIOA
213 #define SWO_Pin GPIO_PIN_3
214 #define SWO_GPIO_Port GPIOB
215 /* USER CODE BEGIN Private defines */
216
217 /* USER CODE END Private defines */
218
219 #ifdef __cplusplus
220 }
221 #endif
222
223 #endif /* __MAIN_H */
224
225 /***** (C) COPYRIGHT STMicroelectronics *****END OF FILE****/

```

```

1 /* USER CODE BEGIN Header */
2 /**
3 ****
4 * @file      : main.c

```

```

5 * @brief      : Main program body
6 ****
7 * @attention
8 *
9 * <h2><center>&copy; Copyright (c) 2019 STMicroelectronics.
10 * All rights reserved.</center></h2>
11 *
12 * This software component is licensed by ST under BSD 3-Clause license,
13 * the "License"; You may not use this file except in compliance with the
14 * License. You may obtain a copy of the License at:
15 *          opensource.org/licenses/BSD-3-Clause
16 *
17 ****
18 */
19 /* USER CODE END Header */
20
21 /* Includes
22 */
22 #include "main.h"
23
24 /* Private includes
25 */
25 /* USER CODE BEGIN Includes */
26
27 /* USER CODE END Includes */
28
29 /* Private typedef
30 */
30 /* USER CODE BEGIN PTD */
31
32 /* USER CODE END PTD */
33
34 /* Private define
35 */
35 /* USER CODE BEGIN PD */
36 */
36 /*!
37 \def TIMEOUT
38 \brief Constant used as timeout in ms.
39 \deprecated Using DMA makes the transfer free from the processor, thus the
40 TIMEOUT never appens.
41 */
41 /*!
42 #define TIMEOUT 2
43 /* USER CODE END PD */
44
45 /* Private macro
46 */
46 /* USER CODE BEGIN PM */
47
48 /* USER CODE END PM */
49
50 /* Private variables
51 */
51 SPI_HandleTypeDef hspi2;
52
53 TIM_HandleTypeDef htim1;
54 TIM_HandleTypeDef htim7;
55
56 UART_HandleTypeDef huart2;
57 DMA_HandleTypeDef hdma_usart2_tx;

```

```

58 /* USER CODE BEGIN PV */
59 /**
60 \var inByte
61 \brief Buffer for one byte.
62
63 This is the buffer used to copy data from UART. When one byte is available it is stored in
64 inByte and then parsed using the mavlink_parse_char function. Everytime one
65 byte arrives the inByte variable is overwritten.
66 */
67 static uint8_t inByte = 0;
68 /* USER CODE END PV */
69
70 /* Private function prototypes -----
71 */
72 void SystemClock_Config(void);
73 static void MX_GPIO_Init(void);
74 static void MX_USART2_UART_Init(void);
75 static void MX_TIM7_Init(void);
76 static void MX_TIM1_Init(void);
77 static void MX_DMA_Init(void);
78 static void MX_SPI2_Init(void);
79 /* USER CODE BEGIN PFP */
80 void main_wait_160us(void){
81     int i = 0;
82     i = 0;
83     while(i<900){
84         HAL_GPIO_TogglePin(GPIOA, GPIO_PIN_5);
85         i++;
86     }
87 }
88 void main_wait_20us(void){
89     int i = 0;
90     i = 0;
91     while(i<185){
92         HAL_GPIO_TogglePin(GPIOA, GPIO_PIN_5);
93         i++;
94     }
95 }
96 /**
97 \fn main_wait_1us(void)
98 \brief Function for waiting approximately one microsecond
99 */
100 void main_wait_1us(void){
101     int i = 0;
102     i = 0;
103     while(i<25){
104         HAL_GPIO_TogglePin(GPIOA, GPIO_PIN_5);
105         i++;
106     }
107 }
108 int main_get_huart_tx_state(void){
109     return (HAL_DMA_GetState(&hdma_usart2_tx));
110 }
111 void main_transmit_buffer(uint8_t *outBuffer, uint16_t msg_size){
112     HAL_UART_Transmit_DMA(&huart2, outBuffer, msg_size);
113 }
114 void main_stop_motors(void)
115 {
116     HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_1);

```

```

117 HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_2);
118 }
119 void main_set_motors_speed(mavlink_motor_setpoint_t motor )
120 {
121
122     htim1.Instance->CCR1 = motor.motor_x;
123     htim1.Instance->CCR2 = motor.motor_y;
124
125     if (motor.motor_x == 0)
126         HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_1);
127     else
128         HAL_TIM_PWM_Start(&htim1, TIM_CHANNEL_1);
129
130     if (motor.motor_y == 0)
131         HAL_TIM_PWM_Stop(&htim1, TIM_CHANNEL_2);
132     else
133         HAL_TIM_PWM_Start(&htim1, TIM_CHANNEL_2);
134
135 }
136 uint8_t main_read_sensor (const sensor_t sensor, uint8_t adress ){
137     uint8_t value = 0;
138     uint8_t adress_read = adress & 0x7F;
139
140     HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_RESET);
141     HAL_SPI_Transmit(&hspi2, &adress_read, 1, 100);
142     main_wait_160us();
143     HAL_SPI_Receive(&hspi2, &value, 1, 100);
144     main_wait_1us();
145     HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_SET);
146     main_wait_20us();
147     return (value);
148 }
149
150 void main_write_sensor (const sensor_t sensor, uint8_t adress, uint8_t data){
151     uint8_t value = data;
152     uint8_t adress_write = adress | 0x80;
153     uint8_t pack[2];
154     pack[0] = adress_write;
155     pack[1] = value;
156
157     HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_RESET);
158     HAL_SPI_Transmit(&hspi2, pack, 2, 10);
159     main_wait_20us();
160     HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_SET);
161     main_wait_160us();
162     main_wait_20us();
163 }
164 void main_write_sensor_burst(uint8_t data){
165     HAL_SPI_Transmit(&hspi2, &data, 1, 10);
166     main_wait_20us();
167 }
168 void main_read_sensor_motion_burst(uint8_t *data ){
169     HAL_SPI_Receive(&hspi2,data,12,100);
170     main_wait_1us();
171 }
172 void main_transmit_spi(uint8_t data){
173     uint8_t data_out = data;
174     HAL_SPI_Transmit(&hspi2, &data_out, 1, 10);
175 }
176 /* USER CODE END PFP */

```

```

177
178 /* Private user code
179 /*-----*/
180 */
181 \fn TM7_IRQHandler(void)
182 \brief Handle for IRQ of Timer 7
183
184 Timer 7 is used to generate a periodic interrupt to send status messages.
185 Those messages give information about the status of the system and are sent periodically.
186 The messages giving more important information such as the speed of the ball are sent
187 as fast as possible, which means faster than the status messages.
188 */
189 void TM7_IRQHandler(void){
190   HAL_TIM_IRQHandler(&htim7);
191 }
192
193 */
194 \fn HAL_UART_RxCpltCallback(UART_HandleTypeDef *huart)
195 \param huart pointer on huart structure (as defined in the HAL library)
196 \brief Function called everytime a new byte is available from UART communication
197
198 This function is used to receive data from UART communication. Everytime one byte is
199 received by the STM32 it is copied in the \ref inByte and then passed to the mavlink_parse_char
200 function. Once enough byte are taken and one message is received the function
201 \ref mouseDriver_readMsg is called and a subsequent action is taken.
202 */
203 void HAL_UART_RxCpltCallback(UART_HandleTypeDef *huart){
204   HAL_NVIC_DisableIRQ(USART2_IRQn);
205   mavlink_message_t inmsg;
206   mavlink_status_t msgStatus;
207   if (huart->Instance == USART2){
208     /* Receive one byte in interrupt mode */
209     HAL_UART_Receive_IT(&huart2, &inByte, 1);
210     if(mavlink_parse_char(0, inByte, &inmsg, &msgStatus)){
211       mouseDriver_readMsg(inmsg);
212     }
213   }
214   HAL_NVIC_EnableIRQ(USART2_IRQn);
215 }
216
217 */
218 \fn HAL_TIM_PeriodElapsedCallback(TIM_HandleTypeDef *htim)
219 \param htim pointer on timer structure (as defined in the HAL library)
220 \brief Function called everytime a certain time is enlapsed
221
222 This function is used to send periodically some status information to the PC.
223 */
224
225 void HAL_TIM_PeriodElapsedCallback(TIM_HandleTypeDef *htim){
226   if (htim->Instance==TIM7){
227     mouseDriver_send_status_msg();
228   }
229 }
230 /* USER CODE END 0 */
231
232 /**
233 * @brief The application entry point.
234 * @retval int
235 */

```

```

236 int main(void)
237 {
238     /* USER CODE BEGIN 1 */
239
240     /* USER CODE END 1 */
241
242
243     /* MCU Configuration
244     -----*/
245
246     /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
247     HAL_Init();
248
249     /* USER CODE BEGIN Init */
250
251     /* USER CODE END Init */
252
253     /* Configure the system clock */
254     SystemClock_Config();
255
256     /* USER CODE BEGIN SysInit */
257
258     /* Initialize all configured peripherals */
259     MX_GPIO_Init();
260     MX_USART2_UART_Init();
261     MX_TIM7_Init();
262     MX_TIM1_Init();
263     MX_DMA_Init();
264     MX_SPI2_Init();
265
266     /* USER CODE BEGIN 2 */
267     HAL_InitTick(0);
268     HAL_NVIC_SetPriority USART2_IRQn, 1, 0;
269     HAL_NVIC_EnableIRQ USART2_IRQn;
270     HAL_NVIC_SetPriority TIM7_IRQn, 2, 0;
271     HAL_NVIC_EnableIRQ TIM7_IRQn;
272     HAL_GPIO_WritePin(GPIOC, CS_0_Pin|CS_1_Pin, GPIO_PIN_SET);
273
274     HAL_UART_Receive_IT(&huart2, &inByte, 1);
275     HAL_TIM_Base_Start_IT(&htim7);
276     HAL_GPIO_WritePin(GPIOC, GPIO_PIN_0, GPIO_PIN_SET);
277
278     mouseDriver_init();
279
280     /* USER CODE END 2 */
281
282     /* Infinite loop */
283     /* USER CODE BEGIN WHILE */
284
285     while (1)
286     {
287         mouseDriver_idle();
288         /* USER CODE END WHILE */
289
290         /* USER CODE BEGIN 3 */
291     }
292     /* USER CODE END 3 */
293 }
```

```

295 /**
296 * @brief System Clock Configuration
297 * @retval None
298 */
299 void SystemClock_Config(void)
300 {
301     RCC_OscInitTypeDef RCC_OscInitStruct = {0};
302     RCC_ClkInitTypeDef RCC_ClkInitStruct = {0};
303     RCC_PeriphCLKInitTypeDef PeriphClkInit = {0};
304
305     /** Initializes the CPU, AHB and APB busses clocks
306 */
307     RCC_OscInitStruct.OscillatorType = RCC_OSCILLATORTYPE_HSI;
308     RCC_OscInitStruct.HSISState = RCC_HSI_ON;
309     RCC_OscInitStruct.HSICalibrationValue = RCC_HSICALIBRATION_DEFAULT;
310     RCC_OscInitStruct.PLL.PLLState = RCC_PLL_ON;
311     RCC_OscInitStruct.PLL.PLLSource = RCC_PLLSOURCE_HSI;
312     RCC_OscInitStruct.PLL.PLLM = 1;
313     RCC_OscInitStruct.PLL.PLLN = 10;
314     RCC_OscInitStruct.PLL.PLLP = RCC_PLLP_DIV7;
315     RCC_OscInitStruct.PLL.PLLQ = RCC_PLLQ_DIV2;
316     RCC_OscInitStruct.PLL.PLLR = RCC_PLLR_DIV2;
317     if (HAL_RCC_OscConfig(&RCC_OscInitStruct) != HAL_OK)
318     {
319         Error_Handler();
320     }
321     /** Initializes the CPU, AHB and APB busses clocks
322 */
323     RCC_ClkInitStruct.ClockType = RCC_CLOCKTYPE_HCLK|RCC_CLOCKTYPE_SYSCLK
324                     |RCC_CLOCKTYPE_PCLK1|RCC_CLOCKTYPE_PCLK2;
325     RCC_ClkInitStruct.SYSCLKSource = RCC_SYSCLKSOURCE_PLLCLK;
326     RCC_ClkInitStruct.AHBCLKDivider = RCC_SYSCLK_DIV1;
327     RCC_ClkInitStruct.APB1CLKDivider = RCC_HCLK_DIV1;
328     RCC_ClkInitStruct.APB2CLKDivider = RCC_HCLK_DIV1;
329
330     if (HAL_RCC_ClockConfig(&RCC_ClkInitStruct, FLASH_LATENCY_4) != HAL_OK)
331     {
332         Error_Handler();
333     }
334     PeriphClkInit.PeriphClockSelection = RCC_PERIPHCLK_USART2;
335     PeriphClkInit.Usart2ClockSelection = RCC_USART2CLKSOURCE_PCLK1;
336     if (HAL_RCCEx_PeriphCLKConfig(&PeriphClkInit) != HAL_OK)
337     {
338         Error_Handler();
339     }
340     /** Configure the main internal regulator output voltage
341 */
342     if (HAL_PWREx_ControlVoltageScaling(PWR_REGULATOR_VOLTAGE_SCALE1) != HAL_OK)
343     {
344         Error_Handler();
345     }
346 }
347
348 /**
349 * @brief SPI2 Initialization Function
350 * @param None
351 * @retval None
352 */
353 static void MX_SPI2_Init(void)
354 {

```

```

355
356 /* USER CODE BEGIN SPI2_Init 0 */
357 HAL_GPIO_DeInit(GPIOC, GPIO_PIN_3);
358
359 /*GPIO_InitTypeDef pin;
360 pin.Pin = GPIO_PIN_3;
361 pin.Mode = GPIO_MODE_OUTPUT_PP;
362 pin.Pull = GPIO_PULLDOWN;
363 pin.Speed = GPIO_SPEED_MEDIUM;
364 HAL_GPIO_Init(GPIOC, &pin);
365 HAL_GPIO_WritePin(GPIOC,GPIO_PIN_3, GPIO_PIN_RESET);*/
366
367 __HAL_RCC_SPI2_CLK_ENABLE();
368 __HAL_SPI2_CLK_ENABLE();
369 /* USER CODE END SPI2_Init 0 */
370
371 /* USER CODE BEGIN SPI2_Init 1 */
372
373 /* USER CODE END SPI2_Init 1 */
374 /* SPI2 parameter configuration*/
375 hspi2.Instance = SPI2;
376 hspi2.Init.Mode = SPI_MODE_MASTER;
377 hspi2.Init.Direction = SPI_DIRECTION_2LINES;
378 hspi2.Init.DataSize = SPI_DATASIZE_8BIT;
379 hspi2.Init.CLKPolarity = SPI_POLARITY_HIGH;
380 hspi2.Init.CLKPhase = SPI_PHASE_2EDGE;
381 hspi2.Init.NSS = SPI_NSS_SOFT;
382 hspi2.Init.BaudRatePrescaler = SPI_BAUDRATEPRESCALER_256;
383 hspi2.Init.FirstBit = SPI_FIRSTBIT_MSB;
384 hspi2.Init.TIMode = SPI_TIMODE_DISABLE;
385 hspi2.Init.CRCCalculation = SPI_CRCALCULATION_DISABLE;
386 hspi2.Init.CRCPolynomial = 7;
387 hspi2.Init.CRCLength = SPI_CRC_LENGTH_DATASIZE;
388 hspi2.Init.NSSPMode = SPI NSS PULSE_DISABLE;
389 if (HAL_SPI_Init(&hspi2) != HAL_OK)
390 {
391     Error_Handler();
392 }
393 /* USER CODE BEGIN SPI2_Init 2 */
394
395
396 /* USER CODE END SPI2_Init 2 */
397
398 }
399
400 /**
401 * @brief TIM1 Initialization Function
402 * @param None
403 * @retval None
404 */
405 static void MX_TIM1_Init(void)
406 {
407
408 /* USER CODE BEGIN TIM1_Init 0 */
409
410 /* USER CODE END TIM1_Init 0 */
411
412 TIM_ClockConfigTypeDef sClockSourceConfig = {0};
413 TIM_MasterConfigTypeDef sMasterConfig = {0};
414 TIM_OC_InitTypeDef sConfigOC = {0};

```

```

415 TIM_BreakDeadTimeConfigTypeDef sBreakDeadTimeConfig = {0};
416
417 /* USER CODE BEGIN TIM1_Init 1 */
418
419 /* USER CODE END TIM1_Init 1 */
420 htim1.Instance = TIM1;
421 htim1.Init.Prescaler = PRESCALER_PWM;
422 htim1.Init.CounterMode = TIM_COUNTERMODE_UP;
423 htim1.Init.Period = COUNTER_PERIOD_PWM;
424 htim1.Init.ClockDivision = TIM_CLOCKDIVISION_DIV1;
425 htim1.Init.RepetitionCounter = 0;
426 htim1.Init.AutoReloadPreload = TIM_AUTORELOAD_PRELOAD_DISABLE;
427 if (HAL_TIM_Base_Init(&htim1) != HAL_OK)
428 {
429     Error_Handler();
430 }
431 sClockSourceConfig.ClockSource = TIM_CLOCKSOURCE_INTERNAL;
432 if (HAL_TIM_ConfigClockSource(&htim1, &sClockSourceConfig) != HAL_OK)
433 {
434     Error_Handler();
435 }
436 if (HAL_TIM_PWM_Init(&htim1) != HAL_OK)
437 {
438     Error_Handler();
439 }
440 sMasterConfig.MasterOutputTrigger = TIM_TRGO_RESET;
441 sMasterConfig.MasterOutputTrigger2 = TIM_TRGO2_RESET;
442 sMasterConfig.MasterSlaveMode = TIM_MASTERSLAVEMODE_DISABLE;
443 if (HAL_TIMEx_MasterConfigSynchronization(&htim1, &sMasterConfig) != HAL_OK)
444 {
445     Error_Handler();
446 }
447 sConfigOC.OCMode = TIM_OCMODE_PWM1;
448 sConfigOC.Pulse = PULSE_PWM;
449 sConfigOC.OCPolarity = TIM_OCPOLARITY_HIGH;
450 sConfigOC.OCNPolarity = TIM_OCNPOLARITY_HIGH;
451 sConfigOC.OCFastMode = TIM_OCFAST_DISABLE;
452 sConfigOC.OCIdleState = TIM_OCIDLESTATE_RESET;
453 sConfigOC.OCNIdleState = TIM_OCNIDLESTATE_RESET;
454 if (HAL_TIM_PWM_ConfigChannel(&htim1, &sConfigOC, TIM_CHANNEL_1) != HAL_OK)
455 {
456     Error_Handler();
457 }
458 if (HAL_TIM_PWM_ConfigChannel(&htim1, &sConfigOC, TIM_CHANNEL_2) != HAL_OK)
459 {
460     Error_Handler();
461 }
462 sBreakDeadTimeConfig.OffStateRunMode = TIM_OSSR_DISABLE;
463 sBreakDeadTimeConfig.OffStateIDLEMode = TIM_OSSI_DISABLE;
464 sBreakDeadTimeConfig.LockLevel = TIM_LOCKLEVEL_OFF;
465 sBreakDeadTimeConfig.DeadTime = 0;
466 sBreakDeadTimeConfig.BreakState = TIM_BREAK_DISABLE;
467 sBreakDeadTimeConfig.BreakPolarity = TIM_BREAKPOLARITY_HIGH;
468 sBreakDeadTimeConfig.BreakFilter = 0;
469 sBreakDeadTimeConfig.Break2State = TIM_BREAK2_DISABLE;
470 sBreakDeadTimeConfig.Break2Polarity = TIM_BREAK2POLARITY_HIGH;
471 sBreakDeadTimeConfig.Break2Filter = 0;
472 sBreakDeadTimeConfig.AutomaticOutput = TIM_AUTOMATICOUTPUT_DISABLE;
473 if (HAL_TIMEx_ConfigBreakDeadTime(&htim1, &sBreakDeadTimeConfig) != HAL_OK)
474 {

```

```

475     Error_Handler();
476 }
477 /* USER CODE BEGIN TIM1_Init 2 */
478
479 /* USER CODE END TIM1_Init 2 */
480 HAL_TIM_MspPostInit(&htim1);
481 }
482 }
483
484 /**
485 * @brief TIM7 Initialization Function
486 * @param None
487 * @retval None
488 */
489 static void MX_TIM7_Init(void)
490 {
491
492 /* USER CODE BEGIN TIM7_Init 0 */
493
494 /* USER CODE END TIM7_Init 0 */
495
496 TIM_MasterConfigTypeDef sMasterConfig = {0};
497
498 /* USER CODE BEGIN TIM7_Init 1 */
499
500 /* USER CODE END TIM7_Init 1 */
501 htim7.Instance = TIM7;
502 htim7.Init.Prescaler = PRESCALER_HEART;
503 htim7.Init.CounterMode = TIM_COUNTERMODE_UP;
504 htim7.Init.Period = COUNTER_PERIOD_HEART;
505 htim7.Init.AutoReloadPreload = TIM_AUTORELOAD_PRELOAD_DISABLE;
506 if (HAL_TIM_Base_Init(&htim7) != HAL_OK)
507 {
508     Error_Handler();
509 }
510 sMasterConfig.MasterOutputTrigger = TIM_TRGO_RESET;
511 sMasterConfig.MasterSlaveMode = TIM_MASTERSLAVEMODE_DISABLE;
512 if (HAL_TIMEx_MasterConfigSynchronization(&htim7, &sMasterConfig) != HAL_OK)
513 {
514     Error_Handler();
515 }
516 /* USER CODE BEGIN TIM7_Init 2 */
517
518 /* USER CODE END TIM7_Init 2 */
519
520 }
521
522 /**
523 * @brief USART2 Initialization Function
524 * @param None
525 * @retval None
526 */
527 static void MX_USART2_UART_Init(void)
528 {
529
530 /* USER CODE BEGIN USART2_Init 0 */
531 /* DMA controller clock enable */
532 __DMA1_CLK_ENABLE();
533
534 /* Peripheral DMA init*/

```

```

535 hdma_usart2_tx.Init.Direction = DMA_MEMORY_TO_PERIPH;
536 hdma_usart2_tx.InitPeriphInc = DMA_PINC_DISABLE;
537 hdma_usart2_tx.InitMemInc = DMA_MINC_ENABLE;
538 hdma_usart2_tx.InitPeriphDataAlignment = DMA_MDATAALIGN_BYTE;
539 hdma_usart2_tx.InitMemDataAlignment = DMA_MDATAALIGN_BYTE;
540 hdma_usart2_tx.InitMode = DMA_NORMAL;
541 hdma_usart2_tx.InitPriority = DMA_PRIORITY_LOW;
542 HAL_DMA_Init(&hdma_usart2_tx);
543
544 __HAL_LINKDMA(&huart2,hdmatx,hdma_usart2_tx);
545 /* USER CODE END USART2_Init 0 */
546
547 /* USER CODE BEGIN USART2_Init 1 */
548
549 /* USER CODE END USART2_Init 1 */
550 huart2.Instance = USART2;
551 huart2.Init.BaudRate = 230400;
552 huart2.Init.WordLength = UART_WORDLENGTH_8B;
553 huart2.Init.StopBits = UART_STOPBITS_1;
554 huart2.Init.Parity = UART_PARITY_NONE;
555 huart2.Init.Mode = UART_MODE_TX_RX;
556 huart2.Init.HwFlowCtl = UART_HWCONTROL_NONE;
557 huart2.Init.OverSampling = UART_OVERSAMPLING_16;
558 huart2.Init.OneBitSampling = UART_ONE_BIT_SAMPLE_DISABLE;
559 huart2.AdvancedInit.AdvFeatureInit = UART_ADVFEATURE_NO_INIT;
560 if (HAL_UART_Init(&huart2) != HAL_OK)
561 {
562     Error_Handler();
563 }
564 /* USER CODE BEGIN USART2_Init 2 */
565
566 /* USER CODE END USART2_Init 2 */
567
568 }
569
570 /**
571 * Enable DMA controller clock
572 */
573 static void MX_DMA_Init(void)
574 {
575
576     /* DMA controller clock enable */
577     __HAL_RCC_DMA1_CLK_ENABLE();
578
579     /* DMA interrupt init */
580     /* DMA1_Channel7_IRQHandler interrupt configuration */
581     HAL_NVIC_SetPriority(DMA1_Channel7_IRQn, 0, 0);
582     HAL_NVIC_EnableIRQ(DMA1_Channel7_IRQn);
583
584 }
585
586 /**
587 * @brief GPIO Initialization Function
588 * @param None
589 * @retval None
590 */
591 static void MX_GPIO_Init(void)
592 {
593     GPIO_InitTypeDef GPIO_InitStruct = {0};
594

```

```

595 /* GPIO Ports Clock Enable */
596 __HAL_RCC_GPIOC_CLK_ENABLE();
597 __HAL_RCC_GPIOH_CLK_ENABLE();
598 __HAL_RCC_GPIOA_CLK_ENABLE();
599 __HAL_RCC_GPIOB_CLK_ENABLE();
600
601 /*Configure GPIO pin Output Level */
602 HAL_GPIO_WritePin(GPIOC, CS_0_Pin|CS_1_Pin, GPIO_PIN_RESET);
603
604 /*Configure GPIO pin Output Level */
605 HAL_GPIO_WritePin(GPIOA, PW_1_Pin|LD2_Pin, GPIO_PIN_RESET);
606
607 /*Configure GPIO pin Output Level */
608 HAL_GPIO_WritePin(PW_0_GPIO_Port, PW_0_Pin, GPIO_PIN_RESET);
609
610 /*Configure GPIO pin : B1_Pin */
611 GPIO_InitStruct.Pin = B1_Pin;
612 GPIO_InitStruct.Mode = GPIO_MODE_IT_FALLING;
613 GPIO_InitStruct.Pull = GPIO_NOPULL;
614 HAL_GPIO_Init(B1_GPIO_Port, &GPIO_InitStruct);
615
616 /*Configure GPIO pins : CS_0_Pin CS_1_Pin */
617 GPIO_InitStruct.Pin = CS_0_Pin|CS_1_Pin;
618 GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;
619 GPIO_InitStruct.Pull = GPIO_NOPULL;
620 GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_LOW;
621 HAL_GPIO_Init(GPIOC, &GPIO_InitStruct);
622
623 /*Configure GPIO pins : PW_1_Pin LD2_Pin */
624 GPIO_InitStruct.Pin = PW_1_Pin|LD2_Pin;
625 GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;
626 GPIO_InitStruct.Pull = GPIO_NOPULL;
627 GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_LOW;
628 HAL_GPIO_Init(GPIOA, &GPIO_InitStruct);
629
630 /*Configure GPIO pin : PW_0_Pin */
631 GPIO_InitStruct.Pin = PW_0_Pin;
632 GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;
633 GPIO_InitStruct.Pull = GPIO_NOPULL;
634 GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_LOW;
635 HAL_GPIO_Init(PW_0_GPIO_Port, &GPIO_InitStruct);
636
637 }
638
639 /* USER CODE BEGIN 4 */
640
641 /* USER CODE END 4 */
642
643 /**
644 * @brief This function is executed in case of error occurrence.
645 * @retval None
646 */
647 void Error_Handler(void)
648 {
649 /* USER CODE BEGIN Error_Handler_Debug */
650 /* User can add his own implementation to report the HAL error return state */
651
652 /* USER CODE END Error_Handler_Debug */
653 }
654

```

```

655 #ifdef USE_FULL_ASSERT
656 /**
657 * @brief Reports the name of the source file and the source line number
658 * where the assert_param error has occurred.
659 * @param file: pointer to the source file name
660 * @param line: assert_param error line source number
661 * @retval None
662 */
663 void assert_failed(char *file, uint32_t line)
664 {
665 /* USER CODE BEGIN 6 */
666 /* User can add his own implementation to report the file name and line number,
667 tex: printf("Wrong parameters value: file %s on line %d\r\n", file, line) */
668 /* USER CODE END 6 */
669 }
670 #endif /* USE_FULL_ASSERT */
671
672 /***** (C) COPYRIGHT STMicroelectronics *****END OF FILE*****/

```

C.2 Treadmill driver

```

1 /*! \file mouseDriver.c
2 \brief Implementation of the driver for the mouse treadmil project.
3
4 \author Didier Negretto
5 */
6 #ifndef MOUSEDRIVER_C_
7 #define MOUSEDRIVER_C_
8
9 #ifndef TEST
10 #include "mouseDriver.h"
11 #else
12 #include "../test/test_mouseDriver.h"
13 #endif
14 */
15 \def K
16 \brief Proportional coefficient for motor control.
17 */
18 #define K 10
19 */
20 \def K
21 \brief Proportional coefficient for motor control.
22 */
23 #define I 10
24 */
25 \def I
26 \brief Integral coefficient for motor control.
27 */
28 #define MAX_MOTOR_SIGNAL 255
29 */
30 \def MAX_MOTOR_SIGNAL
31 \brief Max value for the motor signal
32 \attention This value is used to limit the motor speed. If this is changed the motors might break !!
33
34 This value limits the motor speed and thus is used to vaoid spinning the motor too fast and break it.
35 If this value is changed the motor might spin too fast and destroy itself or the gear box. Extreme caution
36 needs to be taken if this value is modified.
37 */
38 #define MIN_MOTOR_SIGNAL 10
39 */
40 \def MIN_MOTOR_SIGNAL

```

```

41 \brief Min value for the motor signal. Any value lower than that will cause the motor to stop
42 */
43 #define MAX_MISSING_MEASURES 15
44 */
45 \def MAX_MISSING_MEASURES
46 \brief After MAX_MISSING_MEASURES non valid measures from sensors the motors are stopped and mode goes
47 to stop.
48 */
49 #ifndef TEST
50 */
51 \var actual_mode
52 \brief Global variable defining the mode of the machine
53
54 This value is updated based on the received messages. When a routine is running it is
55 only possible to stop the machine.
56 */
57 static uint8_t actual_mode = MOUSE_MODE_STOP;
58 */
59 \var actual_speed_measure
60 \brief Global variable for the measured speed
61
62 This value is updated based on sensor.
63 */
64 static mavlink_speed_info_t actual_speed_measure;
65 */
66 \var actual_speed_setpoint
67 \brief Global variable for the speed setpoint
68
69 This value is updated based on messages when the mode is set to SPEED.
70 */
71 static mavlink_speed_setpoint_t actual_speed_setpoint;
72 */
73 \var actual_motor_signal
74 \brief Global variable for the speed motor signal
75
76 This value is updated based on closed-loop control and the value provided in
77 \ref actual_speed_setpoint and \ref actual_speed_measure.
78 It is also possible to overwrite it by sending a mavlink_motor_setpoint_t message if the
79 mode is set to SPEED.
80 */
81 static mavlink_motor_setpoint_t actual_motor_signal;
82 */
83 \var points
84 \brief Global variable for storing the points to be followed in AUTO mode
85
86 The maximum 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 raw 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 whith a priority lower than 0 (1,2,3,...),
128 otherwise the HAL_Delay() function stall and the STM32 crashes.
129
130 This function access global variables to send information to the computer.
131 Given one message ID the functions reads the information from a global variable and
132 sends it using the DMA as soon as the previous messages are sent.
133 */
134 void mouseDriver_sendMsg(uint32_t msgid);
135 /*!
136 \fn mouseDriver_initSetpoint
137 \brief Function that initializes the motor setpoint to 0.
138
139 This function initializes \ref actual_speed_setpoint.
140 */
141 void mouseDriver_initSetpoint(void);
142 /*!
143 \fn mouseDriver_initMode
144 \brief Function that initializes the mode to MOUSE_MODE_STOP
145
146 This function modifies \ref actual_mode by setting it to MOUSE_MODE_STOP.
147 */
148 void mouseDriver_initMode(void);
149 /*!
150 \fn mouseDriver_initPoints
151 \brief Function that initializes the routine points for AUTO mode to 0.
152
153 This function modifies \ref points by setting all their fields to 0.
154 */
155 void mouseDriver_initPoints(void);/*
156 \fn mouseDriver_setMode(uint8_t mode)
157 \param mode is the mode in which the driver should be set.
158 \brief Function that sets the mode of the machine.
159
160 This functions modifies the mode of the machine. Not all transitions are possible,

```

```

161 this functions verifies that the transitions are lawful.
162 */
163 void mouseDriver_setMode(uint8_t mode);
164
165 */
166 \fn mouseDriver_initMotorSignal
167 \brief Function that initializes the motor signals to 0.
168
169 This function modifies \ref actual_motor_signal by setting all their fields to 0.
170 */
171 void mouseDriver_initMotorSignal(void);
172
173 void mouseDriver_initSetpoint(void){
174     actual_speed_setpoint.setpoint_x = 0;
175     actual_speed_setpoint.setpoint_y = 0;
176 }
177 void mouseDriver_initMode(void){
178     actual_mode = MOUSE_MODE_STOP;
179 }
180 void mouseDriver_initPoints(void){
181     for(int i=0; i<MAX_POINTS; i++){
182         points[i].duration = 0;
183         points[i].setpoint_x = 0;
184         points[i].setpoint_y = 0;
185         points[i].point_id = 0;
186     }
187     actual_point = 0;
188     actual_point_start_time = 0;
189 }
190 void mouseDriver_initMotorSignal(void){
191     actual_motor_signal.motor_x = 0;
192     actual_motor_signal.motor_y = 0;
193 }
194 void mouseDriver_init(void){
195     mouseDriver_initMode();
196     mouseDriver_initSetpoint();
197     mouseDriver_initPoints();
198     mouseDriver_initMotorSignal();
199
200     /* Init sensor as well */
201     sensorDriver_init();
202     main_stop_motors();
203 }
204 uint32_t mouseDriver_getTime (void){
205     return (HAL_GetTick());
206 }
207 void mouseDriver_send_status_msg(void){
208     send_msg = 1;
209 }
210 void mouseDriver_control_idle(void){
211     static int count = 0;
212     static float integral_x = 0;
213     static float integral_y = 0;
214     float error_x = 0;
215     float error_y = 0;
216     if (actual_speed_measure.valid == 0){
217         count++;
218         if(count >= MAX_MISSING_MEASURES){
219             main_stop_motors();
220             mouseDriver_setMode(MOUSE_MODE_STOP);

```

```

221     integral_x = 0;
222     integral_y = 0;
223 }
224 return;
225 }
226 if (actual_mode == MOUSE_MODE_SPEED || actual_mode == MOUSE_MODE_AUTO_RUN){
227     actual_motor_signal.time = mouseDriver_getTime();
228     error_x = actual_speed_setpoint.setpoint_x - actual_speed_measure.speed_x;
229     error_y = actual_speed_setpoint.setpoint_y - actual_speed_measure.speed_y;
230     actual_motor_signal.motor_x = (float)K*(error_x)+(float)I*integral_x;
231     actual_motor_signal.motor_y = (float)K*(error_y)+(float)I*integral_y;
232
233     if (actual_motor_signal.motor_x > MAX_MOTOR_SIGNAL){
234         actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL;
235     }
236     if (actual_motor_signal.motor_y > MAX_MOTOR_SIGNAL){
237         actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL;
238     }
239
240     main_set_motors_speed(actual_motor_signal);
241     integral_x += (actual_motor_signal.motor_x < MAX_MOTOR_SIGNAL)? error_x : 0;
242     integral_y += (actual_motor_signal.motor_y < MAX_MOTOR_SIGNAL)? error_y : 0;
243     count = 0;
244 }
245 else{
246     actual_motor_signal.motor_x = 0;
247     actual_motor_signal.motor_y = 0;
248     main_stop_motors();
249     integral_x = 0;
250     integral_y = 0;
251 }
252 }

253
254 void mouseDriver_setMode(uint8_t mode){
255     if (mode == MOUSE_MODE_STOP){
256         main_stop_motors();
257         actual_point = 0;
258         actual_mode = MOUSE_MODE_STOP;
259         mouseDriver_initMotorSignal();
260     }
261     if (mode == MOUSE_MODE_AUTO_LOAD){
262         actual_mode = mode;
263         mouseDriver_sendMsg(MAVLINK_MSG_ID_HEARTBEAT);
264     }
265     if (actual_mode == MOUSE_MODE_AUTO_LOAD && mode == MOUSE_MODE_AUTO_RUN ){
266         actual_point = 0;
267         actual_point_start_time = mouseDriver_getTime();
268         actual_speed_setpoint.setpoint_x = points[0].setpoint_x;
269         actual_speed_setpoint.setpoint_y = points[0].setpoint_y;
270         actual_mode = mode;
271     }
272
273     if (actual_mode != MOUSE_MODE_AUTO_RUN)
274         actual_mode = mode;
275 }
276 void mouseDriver_sendMsg(uint32_t msgid){
277     mavlink_message_t msg;
278     static uint8_t outBuffer[MAX_BYTE_BUFFER_SIZE];
279     static uint16_t msg_size = 0;
280

```

```

281 while (main_get_huart_tx_state() == HAL_BUSY){
282     /*Wait for other messages to be sent*/
283     HAL_Delay(1);
284 }
285
286 switch(msgid){
287     case MAVLINK_MSG_ID_HEARTBEAT:
288         mavlink_msg_heartbeat_pack(SYS_ID,COMP_ID, &msg, actual_mode, mouseDriver_getTime());
289         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
290         main_transmit_buffer(outBuffer, msg_size);
291         break;
292     case MAVLINK_MSG_ID_SPEED_SETPOINT:
293         mavlink_msg_speed_setpoint_encode(SYS_ID,COMP_ID, &msg, &actual_speed_setpoint);
294         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
295         main_transmit_buffer(outBuffer, msg_size);
296         break;
297     case MAVLINK_MSG_ID_MOTOR_SETPOINT:
298         mavlink_msg_motor_setpoint_encode(SYS_ID,COMP_ID, &msg, &actual_motor_signal);
299         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
300         main_transmit_buffer(outBuffer, msg_size);
301         break;
302     case MAVLINK_MSG_ID_SPEED_INFO:
303         mavlink_msg_speed_info_encode(SYS_ID,COMP_ID, &msg, &actual_speed_measure);
304         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
305         main_transmit_buffer(outBuffer, msg_size);
306         break;
307     case MAVLINK_MSG_ID_ERROR:
308         mavlink_msg_error_encode(SYS_ID,COMP_ID,&msg,&actual_error);
309         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
310         main_transmit_buffer(outBuffer, msg_size);
311         break;
312     case MAVLINK_MSG_ID_POINT_LOADED:
313         mavlink_msg_point_loaded_pack(SYS_ID,COMP_ID,&msg,actual_point);
314         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
315         main_transmit_buffer(outBuffer, msg_size);
316         break;
317     case MAVLINK_MSG_ID_POINT:
318         mavlink_msg_point_encode(SYS_ID,COMP_ID,&msg,&points[actual_point]);
319         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
320         main_transmit_buffer(outBuffer, msg_size);
321         break;
322     case MAVLINK_MSG_ID_RAW_SENSOR:
323         mavlink_msg_raw_sensor_encode(SYS_ID,COMP_ID,&msg,&actual_raw_sensor[0]);
324         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
325         main_transmit_buffer(outBuffer, msg_size);
326         while (main_get_huart_tx_state() == HAL_BUSY){
327             /*Wait for other messages to be sent*/
328             HAL_Delay(1);
329         }
330         mavlink_msg_raw_sensor_encode(SYS_ID,COMP_ID,&msg,&actual_raw_sensor[1]);
331         msg_size = mavlink_msg_to_send_buffer(outBuffer, &msg);
332         main_transmit_buffer(outBuffer, msg_size);
333         break;
334     default:
335         break;
336     }
337 }
338 void mouseDriver_idle (void){
339     uint64_t difference = 0;
340     sensorDriver_motion_read_speed(actual_raw_sensor, &actual_speed_measure);

```

```

341 switch(actual_mode){
342 case MOUSE_MODE_STOP:
343     mouseDriver_initSetpoint();
344     mouseDriver_initMotorSignal();
345     actual_motor_signal.time = mouseDriver_getTime();
346     main_stop_motors();
347     mouseDriver_control_idle();
348     mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_INFO);
349
350     break;
351 case MOUSE_MODE_SPEED:
352     mouseDriver_control_idle();
353     mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_INFO);
354     mouseDriver_sendMsg(MAVLINK_MSG_ID_MOTOR_SETPOINT);
355
356     break;
357 case MOUSE_MODE_AUTO_LOAD:
358     if (actual_point == 255){
359         actual_error.error = MOUSE_ROUTINE_TOO_LONG;
360         actual_error.time = mouseDriver_getTime();
361         mouseDriver_control_idle();
362         mouseDriver_sendMsg(MAVLINK_MSG_ID_ERROR);
363     }
364     break;
365 case MOUSE_MODE_AUTO_RUN:
366     difference = mouseDriver_getTime() - actual_point_start_time;
367     if (difference >= points[actual_point].duration){
368         if (actual_point < MAX_POINTS-1){
369             actual_point++;
370
371             if(points[actual_point].duration == 0){
372                 actual_point = 0;
373             }
374             actual_speed_setpoint.setpoint_x = points[actual_point].setpoint_x;
375             actual_speed_setpoint.setpoint_y = points[actual_point].setpoint_y;
376             actual_point_start_time = mouseDriver_getTime();
377         }
378     }
379     if (actual_point == MAX_POINTS){
380         mouseDriver_setMode(MOUSE_MODE_AUTO_LOAD);
381     }
382     mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_INFO);
383     mouseDriver_sendMsg(MAVLINK_MSG_ID_MOTOR_SETPOINT);
384     mouseDriver_control_idle();
385     break;
386 default:
387     break;
388 }
389 if (send_msg == 1){
390     send_msg = 0;
391     if(actual_mode != MOUSE_MODE_AUTO_LOAD){
392         mouseDriver_sendMsg(MAVLINK_MSG_ID_HEARTBEAT);
393         mouseDriver_sendMsg(MAVLINK_MSG_ID_SPEED_SETPOINT);
394         mouseDriver_sendMsg(MAVLINK_MSG_ID_RAW_SENSOR);
395         mouseDriver_sendMsg(MAVLINK_MSG_ID_MOTOR_SETPOINT);
396     }
397 }
398
399 }
400 void mouseDriver_readMsg(const mavlink_message_t msg){

```

```

401
402     switch(msg.msgid){
403
404         case MAVLINK_MSG_ID_MODE_SELECTION:
405             mouseDriver_setMode( mavlink_msg_mode_selection_get_mode(&msg));
406             break;
407
408         case MAVLINK_MSG_ID_SPEED_SETPOINT:
409             if (actual_mode == MOUSE_MODE_SPEED)
410                 mavlink_msg_speed_setpoint_decode(&msg, &actual_speed_setpoint);
411             break;
412
413         case MAVLINK_MSG_ID_MOTOR_SETPOINT:
414             if (actual_mode == MOUSE_MODE_SPEED)
415                 mavlink_msg_speed_setpoint_decode(&msg, &actual_speed_setpoint);
416             break;
417
418         case MAVLINK_MSG_ID_POINT:
419             if(actual_mode == MOUSE_MODE_AUTO_LOAD){
420                 mavlink_msg_point_decode(&msg, &points[actual_point]);
421                 if (actual_point == 255){
422                     actual_error.error = MOUSE_ROUTINE_TOO_LONG;
423                     actual_error.time = mouseDriver_getTime();
424                     mouseDriver_sendMsg(MAVLINK_MSG_ID_ERROR);
425                 }
426                 mouseDriver_sendMsg(MAVLINK_MSG_ID_POINT_LOADED);
427                 actual_point++;
428             }
429             break;
430         default:
431             break;
432     };
433 }
434 #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 */
37 \def COMP_ID
38 \brief Component ID for MAVLink
39 */
40 #define COMP_ID 0
41
42 /* maximum size of the trasmit buffer */
43 */
44 \def MAX_BYTE_BUFFER_SIZE
45 \brief MAX size of transmit buffer in bytes
46 */
47 #define MAX_BYTE_BUFFER_SIZE 500
48
49 */
50 \def MAX_POINTS
51 \brief MAX amount of points that can be defined in AUTO mode
52 */
53 #define MAX_POINTS 255
54
55 */
56 \fn mouseDriver_init
57 \brief Function that initializes the driver of the mouse treadmill.
58
59 This functions initialites the mouse treadmill driver. It initializes the sensors as well.
60 */
61 void mouseDriver_init(void);
62
63 */
64 \fn mouseDriver_control_idle
65 \brief Function doing the control on the motors.
66 \attention This function is in charge of generating the control signals for the
67 motors. If it is modified, make sure to respect the specifications of the motor
68 to avoid damaging or destroing them !!
69
70 This function is called periodially to update the control signal for the motors.
71 */
72 void mouseDriver_control_idle(void);
73
74 */
75 \fn mouseDriver_send_status_msg
76 \brief Function generating the signal for sending messages.
77
78 This function is called periodially to set the flag for sending status messages.
79 */
80 void mouseDriver_send_status_msg(void);
81
82 */
83 \fn mouseDriver_readMsg(const mavlink_message_t msg)
84 \param msg MAVLink message to be decoded
85 \brief Function that reads one message.
86

```

```

87 This function is called in main.c. Depending on the received message different actions are taken.
88 */
89 void mouseDriver_readMsg(const mavlink_message_t msg);
90
91 /**
92 \fn mouseDriver_getTime
93 \return The actual time in ms from boot of the system.
94 \brief Function that gets the time of the system from boot.
95 */
96 uint32_t mouseDriver_getTime (void);
97
98 /**
99 \fn mouseDriver_idle
100 \brief Idle function for the mouse treadmill driver.
101 \note This function needs to be called periodically to ensure a correct behaviour.
102
103 This is the idle function of the mouse treadmill. It reads values from the sensors,
104 calls \ref mouseDriver_control_idle, and sends high frequency messages (not the status ones).
105 */
106 void mouseDriver_idle (void);
107
108
109 #endif

```

C.3 Sensor driver

```

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

```

```

36 */
37 void sensorDriver_motion_read_raw(uint8_t sensor_id, mavlink_raw_sensor_t *sensor_data);
38
39 void sensorDriver_powerup(sensor_t *sensor){
40 /* Disable the sensor */
41 HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_SET);
42
43 /* Make sure all sensor is switched off */
44 HAL_GPIO_WritePin(sensor->pw_port, sensor->pw_pin, GPIO_PIN_RESET);
45 main_write_sensor(*sensor, 0x00, 0x00);
46 HAL_Delay(100);
47
48 /* Gives voltage to sensors */
49 HAL_GPIO_WritePin(sensor->pw_port, sensor->pw_pin , GPIO_PIN_SET);
50 HAL_Delay(300);
51
52 /* Reset SPI port */
53 HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_SET);
54 HAL_Delay(5);
55 HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_RESET);
56 HAL_Delay(5);
57 HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_SET);
58 HAL_Delay(5);
59
60 /* Write to Power_up_Reset register */
61 main_write_sensor(*sensor, Power_Up_Reset, 0x5A);
62
63 /* Wait at least 50 ms */
64 HAL_Delay(50);
65
66 /* Read from data registers */
67 main_read_sensor(*sensor, 0x02);
68 main_read_sensor(*sensor, 0x03);
69 main_read_sensor(*sensor, 0x04);
70 main_read_sensor(*sensor, 0x05);
71 main_read_sensor(*sensor, 0x06);
72
73 /* Start ROM Download */
74 main_write_sensor(*sensor, Config2, 0x20);
75 main_write_sensor(*sensor, SROM_Enable, 0x1d);
76 HAL_Delay(10);
77 main_write_sensor(*sensor,SROM_Enable, 0x18);
78 main_wait_160us();
79 main_wait_20us();
80
81 /* Burst start with adress */
82 HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_RESET);
83 main_write_sensor_burst(SROM_Load_Burst|0x80);
84 for (int i = 0; i < firmware_length; i++){
85 main_write_sensor_burst(firmware_data[i]);
86 }
87 HAL_GPIO_WritePin(sensor->cs_port, sensor->cs_pin, GPIO_PIN_SET);
88 main_wait_160us();
89 main_wait_20us();
90 main_wait_20us();
91
92 /* Read SROM_ID for verification */
93 sensor->status = main_read_sensor(*sensor, SROM_ID);
94
95 /* Write to Config2 for wired mouse */

```

```

96 main_write_sensor(*sensor, Config2, 0x00);
97 }
98 void sensorDriver_init(void){
99 sensorDriver_powerup(&sensor_x);
100 sensorDriver_powerup(&sensor_y);
101 }
102 void sensorDriver_motion_read_raw(uint8_t sensor_id, mavlink_raw_sensor_t * sensor_data){
103 uint8_t data[12];
104 int16_t temp = 0;
105 sensor_t sensor;
106
107 if (sensor_id == SENSOR_X) sensor = sensor_x;
108 else if (sensor_id == SENSOR_Y) sensor = sensor_y;
109 else return;
110 sensor_data->sensor_id = sensor_id;
111
112 /* write to motion burst adress */
113 main_write_sensor(sensor, Motion_Burst, 0xbb);
114
115 /* Prepare for burst */
116 HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_RESET);
117 sensor_data->time = mouseDriver_getTime();
118 main_write_sensor_burst(Motion_Burst);
119 /* Start burst */
120 main_read_sensor_motion_burst(data);
121 HAL_GPIO_WritePin(sensor.cs_port, sensor.cs_pin, GPIO_PIN_SET);
122 /* END of burst */
123 main_wait_20us();
124
125 /* Read other register for stopping burst mode */
126 sensor_data->product_id = main_read_sensor(sensor, Product_ID);
127
128 /* TWO's Complement */
129 temp = (data[DELTA_X_H]<<8) | (data[DELTA_X_L]);
130 temp = ~temp + 1;
131 sensor_data->delta_x = temp;
132 temp = (data[DELTA_Y_H]<<8) | (data[DELTA_Y_L]);
133 temp = ~temp + 1;
134 sensor_data->delta_y = temp;
135
136 sensor_data->squal = data[SQUAL_READ];
137 sensor_data->lift = (data[MOTION] & 0x08) >> 3;
138 sensor_data->srom_id = sensor.status;
139 }
140 void sensorDriver_motion_read_speed(mavlink_raw_sensor_t sensor_data[2], mavlink_speed_info_t * speed_info){
141 mavlink_raw_sensor_t raw_values[2];
142 uint32_t old_time[2];
143
144 speed_info->valid = 0;
145 old_time[0] = speed_info->time_x;
146 old_time[1] = speed_info->time_y;
147
148 sensorDriver_motion_read_raw(SENSOR_X, &raw_values[0]);
149 sensorDriver_motion_read_raw(SENSOR_Y, &raw_values[1]);
150
151 speed_info->speed_x = -(float)raw_values[0].delta_y*(float)INCH2METER/(float)RESOLUTION;
152 speed_info->speed_x /= (float)(raw_values[0].time-old_time[0])/(float)1000;
153 speed_info->time_x = raw_values[0].time;
154 speed_info->speed_y = -(float)raw_values[1].delta_y*(float)INCH2METER/(float)RESOLUTION;

```

```

155 speed_info->speed_y /= (float)(raw_values[1].time-old_time[1])/(float)1000;
156 speed_info->time_y = raw_values[1].time;
157 sensor_data[0] = raw_values[0];
158 sensor_data[1] = raw_values[1];
159
160 if((raw_values[0].lift == 0) && (raw_values[1].lift == 0) &&
161     (raw_values[0].squal >= SQUAL_THRESH) && (raw_values[0].squal >= SQUAL_THRESH) &&
162     (raw_values[0].product_id == 66) && (raw_values[1].product_id == 66)){
163     speed_info->valid = 1;
164 }
165 else{
166     speed_info->valid = 0;
167 }
168 }
```

```

1 /*! \file sensorDriver.h
2 \brief Header of the sensor driver for the mouse treadmil project.
3
4 \author Didier Negretto
5 */
6 #pragma once
7
8 #ifndef SENSORDRIVER_H_
9 #define SENSORDRIVER_H_
10
11 #ifndef TEST
12 #include "main.h"
13 #include "mavlink.h"
14 #include "sensorSROM.h"
15 #endif
16
17 /* BEGIN DEFINES FOR SENSOR INTERNAL REGISTERS */
18 #define Product_ID 0x00
19 #define Revision_ID 0x01
20 #define Motion 0x02
21 #define Delta_X_L 0x03
22 #define Delta_X_H 0x04
23 #define Delta_Y_L 0x05
24 #define Delta_Y_H 0x06
25 #define SQUAL 0x07
26 #define Raw_Data_Sum 0x08
27 #define Maximum_Raw_data 0x09
28 #define Minimum_Raw_data 0x0A
29 #define Shutter_Lower 0x0B
30 #define Shutter_Upper 0x0C
31 #define Control 0x0D
32 #define Config1 0x0F
33 #define Config2 0x10
34 #define Angle_Tune 0x11
35 #define Frame_Capture 0x12
36 #define SROM_Enable 0x13
37 #define Run_Downshift 0x14
38 #define Rest1_Rate_Lower 0x15
39 #define Rest1_Rate_Upper 0x16
40 #define Rest1_Downshift 0x17
41 #define Rest2_Rate_Lower 0x18
42 #define Rest2_Rate_Upper 0x19
43 #define Rest2_Downshift 0x1A
44 #define Rest3_Rate_Lower 0x1B
45 #define Rest3_Rate_Upper 0x1C
46 #define Observation 0x24
```

```

47 #define Data_Out_Lower 0x25
48 #define Data_Out_Upper 0x26
49 #define Raw_Data_Dump 0x29
50 #define SROM_ID 0x2A
51 #define Min_SQ_Run 0x2B
52 #define Raw_Data_Threshold 0x2C
53 #define Config5 0x2F
54 #define Power_Up_Reset 0x3A
55 #define Shutdown 0x3B
56 #define Inverse_Product_ID 0x3F
57 #define LiftCutoff_Tune3 0x41
58 #define Angle_Snap 0x42
59 #define LiftCutoff_Tune1 0x4A
60 #define Motion_Burst 0x50
61 #define LiftCutoff_Tune_Timeout 0x58
62 #define LiftCutoff_Tune_Min_Length 0x5A
63 #define SROM_Load_Burst 0x62
64 #define Lift_Config 0x63
65 #define Raw_Data_Burst 0x64
66 #define LiftCutoff_Tune2 0x65
67 /* END DEFINES FOR SENSOR INTERNAL REGISTERS */
68
69 #include <mavlink_msg_raw_sensor.h>
70 #include <stdint.h>
71
72 /* DEFINES FOR BURST READ (only usefull data) */
73 #define MOTION 0
74 #define OBSERVATION 1
75 #define DELTA_X_L 2
76 #define DELTA_X_H 3
77 #define DELTA_Y_L 4
78 #define DELTA_Y_H 5
79 #define SQUAL_READ 6
80
81 /**
82 \def SQUAL_THRESH
83 \brief Threshold value on SQUAL to consider the measure valid.
84 */
85 #define SQUAL_THRESH 16
86
87 /**
88 \def RESOLUTION
89 \brief Resolution of the sensor in Count per Inch (CPI)
90 \note This value needs to be updated if the resolution of the sensors is changed,
91
92 This value is used to convert the raw sensor value in counts to meter per second.
93 */
94 #define RESOLUTION 5000
95
96 /**
97 \def INCH2METER
98 \brief Conversion factor to convert inches in meters.
99 */
100 #define INCH2METER 0.0254
101
102 /**
103 \fn sensorDriver_init
104 \brief Initializes all sensors.
105
106 This functions powers down the sensor and does the powering up routine.

```

```

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

```

C.4 Code for unit tests

```

1 /*! \file display.h
2 \brief Header and implementation of display function for unit tests
3
4 \author Didier Negretto
5 */
6
7 #ifndef DISPLAY_H_
8 #define DISPLAY_H_
9
10 /* DEFINES COLORS FOR DISPLAY IN TERMINAL */
11 */
12 \def RED
13 \brief Prints text between RED and \ref END in red color
14 */
15 #define RED "\x1b[31m"
16 */
17 \def GREEN
18 \brief Prints text between GREEN and \ref END in green color
19 */
20 #define GREEN "\x1b[32m"
21 */
22 \def END
23 \brief stops printin using color.
24 */
25 #define END "\x1b[0m"
26
27 #include <stdio.h>
28 #include <stdbool.h>
29 #include <stdlib.h>
30
31 #ifdef COLOR
32 static inline bool display (bool correct, const char *name){
33     if(correct == 1){
34         printf("[\"GREEN \"OK\" END\"] ");
35         printf(name);
36         printf(GREEN " DONE SUCCESSFULLY\n" END);
37         return 1;
38     }

```

```

39 else{
40     printf("[\"RED \"NO\" END\"]    ");
41     printf(name);
42     printf(RED " PERFORMED INCORRECTLY OR NOT AT ALL\n" END);
43     return 0;
44 }
45 return 0;
46 }
47 #else
48 /*!
49 \fn static inline bool display (bool correct, const char *name)
50 \param correct 1 if the test is successfull 0 if it is not
51 \param name pointer to string with the name of the test that is run
52 \return The result of the test (1 if correct == 1, 0 if correct == 0).
53 \brief This function prints on the terminal is the test is passed successfully
54 or not
55 */
56 static inline bool display (bool correct, const char *name){
57     if(correct == 1){
58         printf(" [OK] ");
59         printf("%s", name);
60         printf(" DONE SUCCESSFULLY\n");
61         return 1;
62     }
63     else{
64         printf("[NO]    ");
65         printf("%s", name);
66         printf(" PERFORMED INCORRECTLY OR NOT AT ALL\n");
67         return 0;
68     }
69     return 0;
70 }
71 #endif
72 #endif /* DISPLAY_H_ */

```

```

1 /*! \file main.c
2 \brief Main for unit testss
3 \author Didier Negretto
4
5 This main is compiled and run after the compilation of the stm32 project
6 This main runs the unit tests and prints which tests are passed and which are not
7 \attention The bash script for the automatic unit testing after compilation
8 was written for MAC and may not work on LINUX or Windows. To solve this issue
9 modify CodeSTM32/src/build.sh
10 */
11
12 #include "test_mouseDriver.h"
13 #include "test_sensorDriver.h"
14
15 int main(void){
16
17     bool test = 1;
18
19     printf("=====TESTING CODE FOR MOUSE TREADMILL =====\n");
20     printf("*****TESTING CODE FOR MOUSE TREADMILL *****\n");
21     printf("=====TESTING CODE FOR MOUSE TREADMILL =====\n\n");
22     printf("-----\n");
23     printf("TESTING mouseDriver.c\n");
24     printf("TESTING mouseDriver_init()\n");
25     test &= test_mouseDriver_init();
26     printf("TESTING mouseDriver_idle()\n");

```

```

27 test &= test_mouseDriver_idle();
28 printf("TESTING mouseDriver_getTime()\n");
29 test &= test_mouseDriver_getTime();
30 printf("TESTING mouseDriver_send_status_msg()\n");
31 test &= test_mouseDriver_send_status_msg();
32 printf("TESTING mouseDriver_control_idle()\n");
33 test &= test_mouseDriver_control_idle();
34 /*printf("-----\n");
35 printf("TESTING mouseDriver.c\n");
36 if (! test_mouseDriver_init()) printf(RED"ERRORS IN mouseDriver_init\n"END);*/
37
38
39 if (test == 1){
40     printf("ALL TEST PASSED SUCCESSFULLY\n");
41 }
42 else{
43     printf("===== SOME TESTS NOT PASSED =====\n");
44     printf("!!!!!! SOME TESTS NOT PASSED !!!!!!!\n");
45     printf("===== \n");
46 }
47
48 return test;
49 }

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){stop_motor = 0;};
43 static inline void main_stop_motors(void){stop_motor = 1;};
44 static inline int main_get_huart_tx_state(void){return 1;};
45 static inline void HAL_Delay(int delay){};
46 static inline void main_transmit_buffer(uint8_t * outbuffer, int msg_size){};

47
48 static inline void sensorDriver_motion_read_speed(mavlink_raw_sensor_t actual_raw_sensor[2],
49     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 /*! \file mock_sensorDriver.h
2 \brief In this file mock functions are defined for the sensor driver unit tests
3
4 \author Didier Negretto
5 */
6
7
8 #ifndef MOCK_SENSORDRIVER_H_
9 #define MOCK_SENSORDRIVER_H_
10
11 /**
12 * A mock structure to represent one sensor
13 */
14 typedef struct SENSOR{
15     /*@{*/
16     int cs_port; /*< the chip select port for the sensor */
17     uint8_t cs_pin; /*< the chip select pin for the sensor */
18     int pw_port; /*< the power port for the sensor */
19     uint8_t pw_pin; /*< the power pin for the sensor */
20     uint8_t status; /*< the sensor status. This is the SROM_ID after the upload of the
21     firmware. This value should not be 0 otherwise the upload of the SROM is failed. */
22     /*@}*/
23 } sensor_t;
24
25 #define CS_0_GPIO_Port 0
26 #define CS_0_Pin 0
27 #define PW_0_GPIO_Port 0
28 #define PW_0_Pin 0
29
30 #define CS_1_GPIO_Port 1
31 #define CS_1_Pin 1
32 #define PW_1_GPIO_Port 1
33 #define PW_1_Pin 1
34
35 #define GPIO_PIN_SET 1
36 #define GPIO_PIN_RESET 0
37
38 static int firmware_length = 3;
39 static int firmware_data[3] = {1,2,3};

```

```

40
41 static inline void main_wait_160us(void){};
42 static inline void main_wait_20us(void){};
43 static inline uint8_t main_read_sensor(sensor_t sensor, uint8_t adress ){return adress;};
44 static inline void main_write_sensor(sensor_t sensor, uint8_t adress, uint8_t value){};
45 static inline void main_read_sensor_motion_burst(uint8_t* buffer){};
46 static inline void main_write_sensor_burst(uint8_t adress){};
47 static inline void HAL_Delay(int delay){};
48 static inline void HAL_GPIO_WritePin(int port, int pin, int state){};
49 static inline uint32_t mouseDriver_getTime(void){
50     static uint32_t i = 0;
51     i++;
52     return i;
53 }
54
55 #endif /* MOCK_SENSORDRIVER_H_ */

1 /*
2 * test.h
3 *
4 * Created on: Nov 24, 2019
5 * Author: Didier
6 */
7
8 #ifndef TEST_MOUSEDRIVER_H_
9 #define TEST_MOUSEDRIVER_H_
10
11 #include <stdio.h>
12 #include <stdlib.h>
13 #include <stdbool.h>
14 #include <math.h>
15 #include "mavlink.h"
16
17 /* Define testing functions*/
18 bool test_mouseDriver_init(void);
19 bool test_mouseDriver_idle(void);
20 bool test_mouseDriver_getTime(void);
21 bool test_mouseDriver_send_status_msg(void);
22 bool test_mouseDriver_control_idle(void);
23
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 == 0), "actual_motor_signal initialization");
49
50     return test;
51 }

52
53 bool test_mouseDriver_idle(void){
54     bool test = false;
55     actual_speed_measure.speed_x = -10;
56     actual_speed_measure.speed_y = -10;
57     actual_speed_measure.valid = 1;

```

```

58     actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
59     actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
60     actual_point_start_time = 0;
61     actual_point = 0;
62     points[0].duration = 100;
63     points[0].setpoint_x = 10;
64     points[0].setpoint_y = 10;
65     points[0].point_id = 0;
66
67     /* Test reading of sensors in SPEED mode */
68     actual_mode = MOUSE_MODE_SPEED;
69     sensor_read_x = 0;
70     sensor_read_y = 0;
71     stop_motor = 1;
72     mouseDriver_idle();
73     test = display(sensor_read_x == 1, "read sensor x in MOUSE_MODE_SPEED");
74     test &= display(sensor_read_y == 1, "read sensor y in MOUSE_MODE_SPEED");
75     test &= display(stop_motor == 0, "motor started in MOUSE_MODE_SPEED");
76
77     /* Test reading of sensors in MOUSE_MODE_AUTO_RUN mode */
78     actual_mode = MOUSE_MODE_AUTO_RUN;
79     sensor_read_x = 0;
80     sensor_read_y = 0;
81     stop_motor = 1;
82     mouseDriver_idle();
83     test &= display(sensor_read_x == 1, "read sensor x in MOUSE_MODE_AUTO_RUN");
84     test &= display(sensor_read_y == 1, "read sensor y in MOUSE_MODE_AUTO_RUN");
85     test &= display(stop_motor == 0, "motor started in MOUSE_MODE_AUTO_RUN");
86     return test;
87 }
88 bool test_mouseDriver_getTime(void){
89     bool test = 1;
90     uint32_t start = HAL_GetTick();
91     test &= mouseDriver_getTime() == start+1;
92     test &= mouseDriver_getTime() == start+2;
93     test &= mouseDriver_getTime() == start+3;
94     test &= mouseDriver_getTime() == start+4;
95     test &= mouseDriver_getTime() == start+5;
96     display(test, "time update");
97
98     return test;
99 }
100 bool test_mouseDriver_send_status_msg(void){
101     bool test = false;
102     send_msg = 0;
103
104     mouseDriver_send_status_msg();
105
106     test = send_msg;
107     display(test, "status message send request");
108     return test;
109 }
110 bool test_mouseDriver_control_idle(void){
111     bool test = 1;
112     stop_motor = 0;
113     actual_speed_measure.speed_x = -10;
114     actual_speed_measure.speed_y = -10;
115     actual_motor_signal.motor_x = 10;
116     actual_motor_signal.motor_y = 10;
117     actual_mode = MOUSE_MODE_STOP;

```

```

118
119 /* Case actual mode == STOP */
120 printf("if (actual_mode == MOUSE_MODE_STOP)\n");
121 mouseDriver_control_idle();
122 test &= display((actual_motor_signal.motor_x == 0)&& (actual_motor_signal.motor_y == 0), "actual_motor_signal reset");
123 test &= display(stop_motor == 1, "motor stop");
124
125 /* Case actual mode == SPEED */
126 actual_mode = MOUSE_MODE_SPEED;
127 stop_motor = 1;
128 actual_speed_setpoint.setpoint_y = 0;
129 actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
130 actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
131 actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
132 printf("if (actual_mode == MOUSE_MODE_SPEED)\n");
133 mouseDriver_control_idle();
134 test &= display(stop_motor == 0, "motor_x speed changed");
135 for(int i = 0; i < 100; i++)
136     mouseDriver_control_idle();
137 test &= display(actual_motor_signal.motor_x <= MAX_MOTOR_SIGNAL, "motor_x with MAX_MOTOR_SIGNAL limit");
138
139 stop_motor = 1;
140 actual_speed_setpoint.setpoint_x = 0;
141 actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
142 actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
143 actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
144 mouseDriver_control_idle();
145 test &= display(stop_motor == 0, "motor_y speed changed");
146 for(int i = 0; i < 100; i++)
147     mouseDriver_control_idle();
148 test &= display(actual_motor_signal.motor_y <= MAX_MOTOR_SIGNAL, "motor_y with MAX_MOTOR_SIGNAL limit");
149
150 actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
151 actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
152 actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
153 actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
154 mouseDriver_control_idle();
155 test &= display(stop_motor == 0, "motor_y and motor_x speed changed");
156 for(int i = 0; i < 100; i++)
157     mouseDriver_control_idle();
158 test &= display((actual_motor_signal.motor_y <= MAX_MOTOR_SIGNAL) && (actual_motor_signal.motor_x <= MAX_MOTOR_SIGNAL), "motor_y and motor_x with MAX_MOTOR_SIGNAL limit");
159
160 /* Reaction to invalid measures */
161 actual_speed_setpoint.setpoint_x = 0;
162 actual_speed_setpoint.setpoint_y = 0;
163 actual_speed_measure.speed_x = 1000;
164 actual_speed_measure.speed_y = 1000;
165 actual_motor_signal.motor_x = 10;
166 actual_motor_signal.motor_y = 10;
167 bool test_stop = true;
168 actual_speed_measure.valid = 0;
169 for(int i = 0;i < MAX_MISSING_MEASURES-1; i++ ){
170     test_stop &= (actual_motor_signal.motor_x == 10);
171     test_stop &= (actual_motor_signal.motor_y == 10);
172     mouseDriver_control_idle();
173 }

```

```

174 mouseDriver_control_idle();
175 test &= display(test_stop, "constant motor signal if invalid measure");
176 test &= display(actual_mode == MOUSE_MODE_STOP, "stop motor after too many invalid measures");
177
178
179
180 /* Case actual mode == SPEED */
181 actual_mode = MOUSE_MODE_AUTO_RUN;
182 stop_motor = 1;
183 actual_speed_setpoint.setpoint_y = 0;
184 actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
185 actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
186 actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
187 actual_speed_measure.valid = 1;
188 printf("if (actual_mode == MOUSE_MODE_AUTO_RUN)\n");
189 mouseDriver_control_idle();
190 test &= display(stop_motor == 0, "motor_x speed changed");
191 for(int i = 0; i < 100; i++)
192     mouseDriver_control_idle();
193 test &= display(actual_motor_signal.motor_x <= MAX_MOTOR_SIGNAL, "motor_x with
194     MAX_MOTOR_SIGNAL limit");
195
196 stop_motor = 1;
197 actual_speed_setpoint.setpoint_x = 0;
198 actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
199 actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
200 actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
201 mouseDriver_control_idle();
202 test &= display(stop_motor == 0, "motor_y speed changed");
203 for(int i = 0; i < 100; i++)
204     mouseDriver_control_idle();
205 test &= display(actual_motor_signal.motor_y <= MAX_MOTOR_SIGNAL, "motor_y with
206     MAX_MOTOR_SIGNAL limit");
207
208 actual_speed_setpoint.setpoint_x = MAX_MOTOR_SIGNAL * 1000;
209 actual_speed_setpoint.setpoint_y = MAX_MOTOR_SIGNAL * 1000;
210 actual_motor_signal.motor_x = MAX_MOTOR_SIGNAL * 1000;
211 actual_motor_signal.motor_y = MAX_MOTOR_SIGNAL * 1000;
212 mouseDriver_control_idle();
213 test &= display(stop_motor == 0, "motor_y and motor_x speed changed");
214 for(int i = 0; i < 100; i++)
215     mouseDriver_control_idle();
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 }

```

C.5 Build script

```

1#!/bin/bash
2# Script for compiling and running test before compilation
3# of the STM32 code and upload.
4echo PRE-BUILD STEPS
5echo CLEANING TESTS
6make clean -C ../../CodeSTM32/test/Debug/
7echo COMPILING TESTS
8make all -C ../../CodeSTM32/test/Debug/
9echo RUNNING TESTS
10./../../CodeSTM32/test/Debug/test

```

D Code for PC

D.1 GUI

```

1
2 import serial
3 import os
4 import sys
5 import numpy as np
6 #import matplotlib as plt
7 from appJar import gui
8 import time
9 import json
10 from tqdm import tqdm
11 import routine_sin as mouseRoutine
12 from pymavlink.dialects.v20 import mouse as mouseController
13
14 SENSOR_STATUS_MSG = ["SENSOR STATUS", "ID 66 = ", "LIFT 0 = ", "SQUAL > 20 = ", "ROM 4 = "]
15 MODES = ["STOP", "SPEED", "AUTO", "RUNNING"]
16 MODES_NUM = {"STOP": int(0), "SPEED": int(1), "AUTO": int(2), "RUNNING": int(3)}
17 DATA = { "HEARTBEAT": { "time": [], "mode": []},
18         "SPEED_SETPOINT": { "time": [], "setpoint_x": [], "setpoint_y": [], "start": 0},
19         "SPEED_INFO": { "time": [], "speed_x": [], "speed_y": [], "start": 0},
20         "MOTOR_SETPOINT": { "time": [], "motor_x": [], "motor_y": [], "start": 0}}
21
22 MAX_SAMPLES_ON_SCREEN = 200
23 #print(mouseController.MAVLink_speed_info_message.fieldnames)
25 port = "/dev/cu.usbmodem14102"
26 #port = "/dev/stdout"
27

```

```

28 class MyApplication():
29     LOG = []
30     actualMode = 0
31     actualTime = 0
32     actualSpeedSetpoint = [None, None]
33     actualMotorSetpoint = [None, None]
34     actualSpeedInfo = [None, None]
35     connection = serial.Serial(port, baudrate = 230400, timeout = 50)
36     mavlink = mouseController.MAVLink(file = connection )
37     setpointX = 0.0
38     setpointY = 0.0
39
40     def commSTM32 (self):
41         # Init variables
42         m = None
43         while(self.connection.in_waiting>0):
44             # Recive messages
45             try:
46                 m = self.mavlink.parse_char(self.connection.read())
47             except:
48                 pass
49             if m:
50                 self.LOG.append(m)
51                 if m.name == "HEARTBEAT":
52                     self.actualTime = m.time
53                     self.actualMode = m.mode
54                     DATA["HEARTBEAT"]["time"].append(self.actualTime)
55                     DATA["HEARTBEAT"]["mode"].append(self.actualMode)
56                 elif m.name == "SPEED_SETPOINT":
57                     self.actualSpeedSetpoint[0] = m.setpoint_x
58                     self.actualSpeedSetpoint[1] = m.setpoint_y
59                     DATA["SPEED_SETPOINT"]["time"].append(self.actualTime)
60                     DATA["SPEED_SETPOINT"]["setpoint_x"].append(self.actualSpeedSetpoint[0])
61                     DATA["SPEED_SETPOINT"]["setpoint_y"].append(self.actualSpeedSetpoint[1])
62                     #DATA["SPEED_SETPOINT"]["setpoint_z"].append(self.actualSpeedSetpoint[2])
63                 elif m.name == "MOTOR_SETPOINT":
64                     self.actualMotorSetpoint[0] = m.motor_x
65                     self.actualMotorSetpoint[1] = m.motor_y
66                     DATA["MOTOR_SETPOINT"]["time"].append(m.time)
67                     DATA["MOTOR_SETPOINT"]["motor_x"].append(self.actualMotorSetpoint[0])
68                     DATA["MOTOR_SETPOINT"]["motor_y"].append(self.actualMotorSetpoint[1])
69                     #DATA["SPEED_SETPOINT"]["motor_z"].append(self.actualMotorSetpoint[2])
70                 elif m.name == "SPEED_INFO":
71                     #print(m)
72                     DATA["SPEED_INFO"]["time"].append(m.time_x)
73                     DATA["SPEED_INFO"]["speed_x"].append(m.speed_x)
74                     DATA["SPEED_INFO"]["speed_y"].append(m.speed_y)
75                 elif m.name == "RAW_SENSOR":
76                     if m.sensor_id == 0:
77                         status_x = []
78                         status_x.append(m.product_id)
79                         status_x.append(m.lift)
80                         status_x.append(m.squal)
81                         status_x.append(m.srom_id)
82                     elif m.sensor_id == 1:
83                         status_y = []
84                         status_y.append(m.product_id)
85                         status_y.append(m.lift)
86                         status_y.append(m.squal)
87                         status_y.append(m.srom_id)

```

```

88     try:
89         if (len(status_x) == 4) and (len(status_y) == 4):
90             self.app.setLabel("sensorStatus1",SENSOR_STATUS_MSG[1]+str(status_x[0])+"|"+str(
91                 status_y[0]))
92             self.app.setLabel("sensorStatus2",SENSOR_STATUS_MSG[2]+str(status_x[1])+"|"+str(
93                 status_y[1]))
94             self.app.setLabel("sensorStatus3",SENSOR_STATUS_MSG[3]+str(status_x[2])+"|"+str(
95                 status_y[2]))
96             self.app.setLabel("sensorStatus4",SENSOR_STATUS_MSG[4]+str(status_x[3])+"|"+str(
97                 status_y[3]))
98         except:
99             pass
100
101
102     elif m.name == "POINT":
103         print(m)
104     else:
105         pass
106     m = None
107 def refreshPlot(self):
108
109     # Clear plot
110     for i in range(3):
111         self.ax[i].clear()
112
113     # Define labels
114     """
115     self.ax[2].set_xlabel("Time")
116     self.ax[2].set_ylabel("Measured speed [m/s]")
117     self.ax[1].set_ylabel("Speed setpoint [m/s]")
118     self.ax[0].set_ylabel("Motor signal [ ]")
119     """
120
121
122     # Limit max amount of points on one graph
123     if len(DATA["SPEED_INFO"]["time"])[DATA["SPEED_INFO"]["start"]:] - 1 >
124         MAX_SAMPLES_ON_SCREEN:
125         DATA["SPEED_INFO"]["start"] = -MAX_SAMPLES_ON_SCREEN
126         DATA["SPEED_SETPOINT"]["start"] = -MAX_SAMPLES_ON_SCREEN
127         DATA["MOTOR_SETPOINT"]["start"] = -MAX_SAMPLES_ON_SCREEN
128
129     # Re-plot all graphs
130     self.ax[2].plot(DATA["SPEED_INFO"]["time"][DATA["SPEED_INFO"]["start"]:], DATA["SPEED_INFO"]["
131     speed_x"][DATA["SPEED_INFO"]["start"]:], 'b.')
132     self.ax[2].plot(DATA["SPEED_INFO"]["time"][DATA["SPEED_INFO"]["start"]:], DATA["SPEED_INFO"]["
133     speed_y"][DATA["SPEED_INFO"]["start"]:], 'r.')
134     self.ax[1].plot(DATA["SPEED_SETPOINT"]["time"][DATA["SPEED_SETPOINT"]["start"]:], DATA["
135     SPEED_SETPOINT"]["setpoint_x"][DATA["SPEED_SETPOINT"]["start"]:], 'b.')
136     self.ax[1].plot(DATA["SPEED_SETPOINT"]["time"][DATA["SPEED_SETPOINT"]["start"]:], DATA["
137     SPEED_SETPOINT"]["setpoint_y"][DATA["SPEED_SETPOINT"]["start"]:], 'r.')
138     self.ax[0].plot(DATA["MOTOR_SETPOINT"]["time"][DATA["MOTOR_SETPOINT"]["start"]:], DATA["
139     MOTOR_SETPOINT"]["motor_x"][DATA["MOTOR_SETPOINT"]["start"]:], 'b.')
140     self.ax[0].plot(DATA["MOTOR_SETPOINT"]["time"][DATA["MOTOR_SETPOINT"]["start"]:], DATA["
141     MOTOR_SETPOINT"]["motor_y"][DATA["MOTOR_SETPOINT"]["start"]:], 'r.')
142     self.ax[0].set_adjustable('box',True)
143     self.app.refreshPlot("plot")
144
145 def resetPlot(self):
146     DATA["SPEED_INFO"]["start"] = len(DATA["SPEED_INFO"]["time"]) - 3
147     DATA["SPEED_SETPOINT"]["start"] = len(DATA["SPEED_SETPOINT"]["time"]) - 3
148     DATA["MOTOR_SETPOINT"]["start"] = len(DATA["MOTOR_SETPOINT"]["time"]) - 3

```

```

137
138     def refreshGUI(self):
139         self.commSTM32()
140
141         # Refresh status bar
142         self.app.setStatusbar("Time: "+str(self.actualTime)+" [ms]", 0)
143         self.app.setStatusbar("Modes: "+str(MODES[self.actualMode]), 1)
144         self.refreshPlot()
145         """
146         self.app.setLabel("speedSetpointX", str(self.actualSpeedSetpoint[0]))
147         self.app.setLabel("speedSetpointY", str(self.actualSpeedSetpoint[1]))
148         self.app.setLabel("motorSetpointX", str(self.actualMotorSetpoint[0]))
149         self.app.setLabel("motorSetpointY", str(self.actualMotorSetpoint[1]))
150         """
151
152     def setMode(self):
153         self.mavlink.mode_selection_send(MODES_NUM[self.app.getRadioButton("optionMode")])
154         while(self.connection.out_waiting > 0):
155             time.sleep(0.001)
156             time.sleep(0.001)
157             if self.actualMode == mouseController.MOUSE_MODE_STOP:
158                 self.setpointX = 0
159                 self.setpointY = 0
160
161
162     def setSpeedX(self):
163         if self.actualMode == mouseController.MOUSE_MODE_SPEED:
164             self.setpointX = self.app.getEntry("speedX")
165             if self.setpointX is None or self.setpointY is None :
166                 pass
167             else:
168                 self.mavlink.speed_setpoint_send(float(self.setpointX), float(self.setpointY))
169                 while(self.connection.out_waiting > 0):
170                     time.sleep(0.001)
171                     time.sleep(0.001)
172
173     def setSpeedY(self):
174         if self.actualMode == mouseController.MOUSE_MODE_SPEED:
175             self.setpointY = self.app.getEntry("speedY")
176             if self.setpointX is None or self.setpointY is None :
177                 pass
178             else:
179                 self.mavlink.speed_setpoint_send(float(self.setpointX), float(self.setpointY))
180                 while(self.connection.out_waiting > 0):
181                     time.sleep(0.001)
182                     time.sleep(0.001)
183
184     def loadRoutine(self):
185         if (len(mouseRoutine.ROUTINE["duration"])>254 or len(mouseRoutine.ROUTINE["setpoint_x"])>254 or len(
186             mouseRoutine.ROUTINE["setpoint_y"])>254):
187             raise ValueError("mouseRoutine too long")
188             if not (len(mouseRoutine.ROUTINE["duration"]) == len(mouseRoutine.ROUTINE["setpoint_x"]) == len(
189                 mouseRoutine.ROUTINE["setpoint_y"])):
190                 raise ValueError("not all components of mouseRoutine have the same lenght")
191
192
193     # TODO add verification on max speed and min speed
194
195     for i in tqdm(range(len(mouseRoutine.ROUTINE["duration"]))):

```

```

195     self.mavlink.point_send(mouseRoutine.ROUTINE["duration"][i],i,mouseRoutine.ROUTINE["setpoint_x"][i]
196 ], mouseRoutine.ROUTINE["setpoint_y"][i])
197     stop = True
198     while(self.connection.in_waiting>0 or stop):
199         # Recive messages
200         try:
201             m = self.mavlink.parse_char(self.connection.read())
202         except:
203             pass
204         if m:
205             #print(m)
206             if m.name == "POINT_LOADED":
207                 if m.point_id == i:
208                     stop = False
209                 else:
210                     print ("ERROR LOADING DATA, wrong msg_id received, STOP MODE instead.")
211                     self.mavlink.mode_selection_send(MODES_NUM[0])
212                     while(self.connection.out_waiting > 0):
213                         time.sleep(0.001)
214                         time.sleep(0.001)
215                         stop = False
216 def saveLog(self):
217     log_name = "log/log_"+str(time.time_ns())+".txt"
218     with open(log_name, 'w+') as f:
219         for item in self.LOG:
220             f.write("%s\n" % item)
221     self.LOG = []
222
223 def runRoutine(self):
224     if self.actualMode == mouseController.MOUSE_MODE_AUTO_LOAD:
225         self.mavlink.mode_selection_send(mouseController.MOUSE_MODE_AUTO_RUN)
226         while(self.connection.out_waiting > 0):
227             time.sleep(0.001)
228             time.sleep(0.001)
229
230 def Prepare(self, app):
231     self.ax = []
232
233     app.setTitle("Mouse treadmill GUI")
234     app.setFont(12)
235     row = 0
236     column = 0
237
238     # Mode Selection
239     app.startFrame("modeSelection",row = row, column = column, colspan=4, rowspan = 1)
240     app.addLabel("optionModeLabel", "Mode",0,0,1,1)
241     app.addRadioButton("optionMode",MODES[0],0,1,1,1)
242     app.addRadioButton("optionMode",MODES[1],0,2,1,1)
243     app.addRadioButton("optionMode",MODES[2],0,3,1,1)
244     app.setRadioButtonChangeFunction("optionMode",self.setMode)
245     app.stopFrame()
246     row = row+1
247
248     # Speed entry
249     app.startFrame("speedEntry",row = row, column = column, colspan=4, rowspan=2)
250     app.addLabel("speedXLabel", "Speed X", 0,0,2,1)
251     app.addNumericEntry("speedX",1,0,2,2)
252     app.setEntry("speedX", 0.0)
253     app.setEntryChangeFunction("speedX", self.setSpeedX)
254     app.addLabel("speedYLabel", "Speed Y",0,2,2,1)

```

```

254     app.addNumericEntry("speedY",1,2,2,2)
255     app.setEntry("speedY", 0.0)
256     app.setEntryChangeFunction("speedY", self.setSpeedY)
257     app.stopFrame()
258     row = row+2
259
260     # Reset plot button
261     app.startFrame("GUIButtons", row = row, column = column, colspan=2, rowspan=2)
262     self.app.addButton("RESET PLOTS", self.resetPlot, 0,0,1,1)
263     self.app.addButton("LOAD POINTS", self.loadRoutine, 1,0,1,1)
264     self.app.addButton("RUN ROUTINE", self.runRoutine,1,1,1,1 )
265     self.app.addButton("SAVE LOG",self.saveLog,0,1,1,1)
266     row = row+1
267
268     # Sensor Status
269     app.startFrame("sensorStatus", row = row, column = 0)
270     self.app.addLabel("sensorStatus0",SENSOR_STATUS_MSG[0], 0,0,1,1)
271     self.app.addLabel("sensorStatus1",SENSOR_STATUS_MSG[1], 1,0,3,1)
272     self.app.addLabel("sensorStatus2",SENSOR_STATUS_MSG[2], 2,0,3,1)
273     self.app.addLabel("sensorStatus3",SENSOR_STATUS_MSG[3], 3,0,3,1)
274     self.app.addLabel("sensorStatus4",SENSOR_STATUS_MSG[4], 4,0,3,1)
275     row = row+4
276
277     # Real-time data plotting
278     app.startFrame("realTimePlot", row = row, column = column, colspan = 4, rowspan = 4)
279     self.fig = app.addPlotFig("plot",0,0,4,4, showNav = True )
280     self.ax.append(self.fig.add_subplot(311))
281     self.ax.append(self.fig.add_subplot(312))
282     self.ax.append(self.fig.add_subplot(313))
283     app.stopFrame()
284     row = row+4
285
286
287     # Add status bar
288     app.addStatusbar(fields = 2, side=None)
289     app.setStatusbar("Time: 0", 0)
290     app.setStatusbar("Mode: "+MODES[0], 1)
291
292     # refresh funciton
293     app.setPollTime(100)
294     app.registerEvent(self.refreshGUI)
295
296     # Window for sensor status
297     app.startSubWindow("sensorStatus")
298     app.addLabel("status", "SENSOR_X")
299     app.stopSubWindow()
300     app.openSubWindow("sensorStatus")
301
302     return app
303     # Build and Start your application
304     def Start(self):
305         app = gui()
306
307         self.app = app
308
309         # Run the prebuild method that adds items to the UI
310         self.app = self.Prepare(self.app)
311         self.app.showAllSubWindow()
312         # Start appJar
313         self.app.go()

```

```

314
315 if __name__ == '__main__':
316     print("====")
317     print("Running GUI for mouse treadmill")
318     print("====")
319
320 # Create an instance of your application
321 App = MyApplication()
322
323 # Start your app !
324 App.Start()

```

D.2 Routine example

```

1 ROUTINE = {
2     "duration": [500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
3                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
4                  500, 500, 100, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
5                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
6                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
7                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
8                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
9                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500],
10    "setpoint_x": [500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
11                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
12                  500, 500, 100, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
13                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
14                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
15                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
16                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500],
17    "setpoint_y": [500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500,
18                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
19                  500, 500, 100, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
20                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
21                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
22                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
23                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
24                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500,
25                  500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500, 500, 500, 100,500],
26 }

```

E Data-sheets

E.1 Sensor Data-sheet

PMW3360DM-T2QU: Optical Gaming Navigation Chip

General Description:

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

Key Features:

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

Key Chip Parameters:

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

Ordering Information:

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



Applications:

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

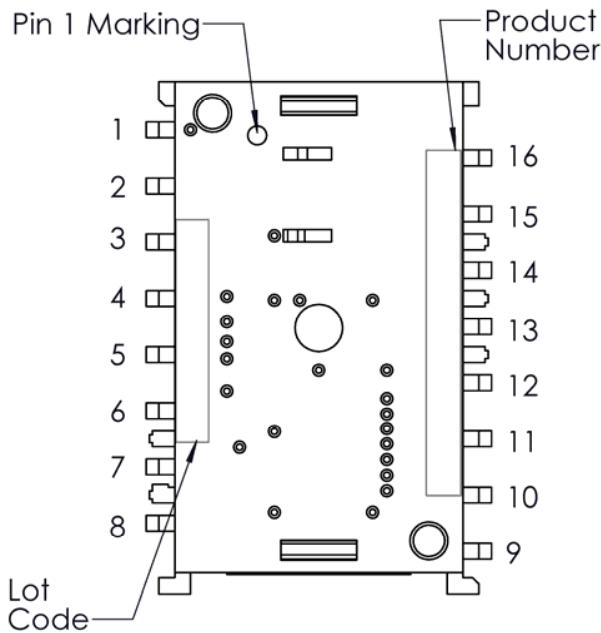
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1.0 System Level Description

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

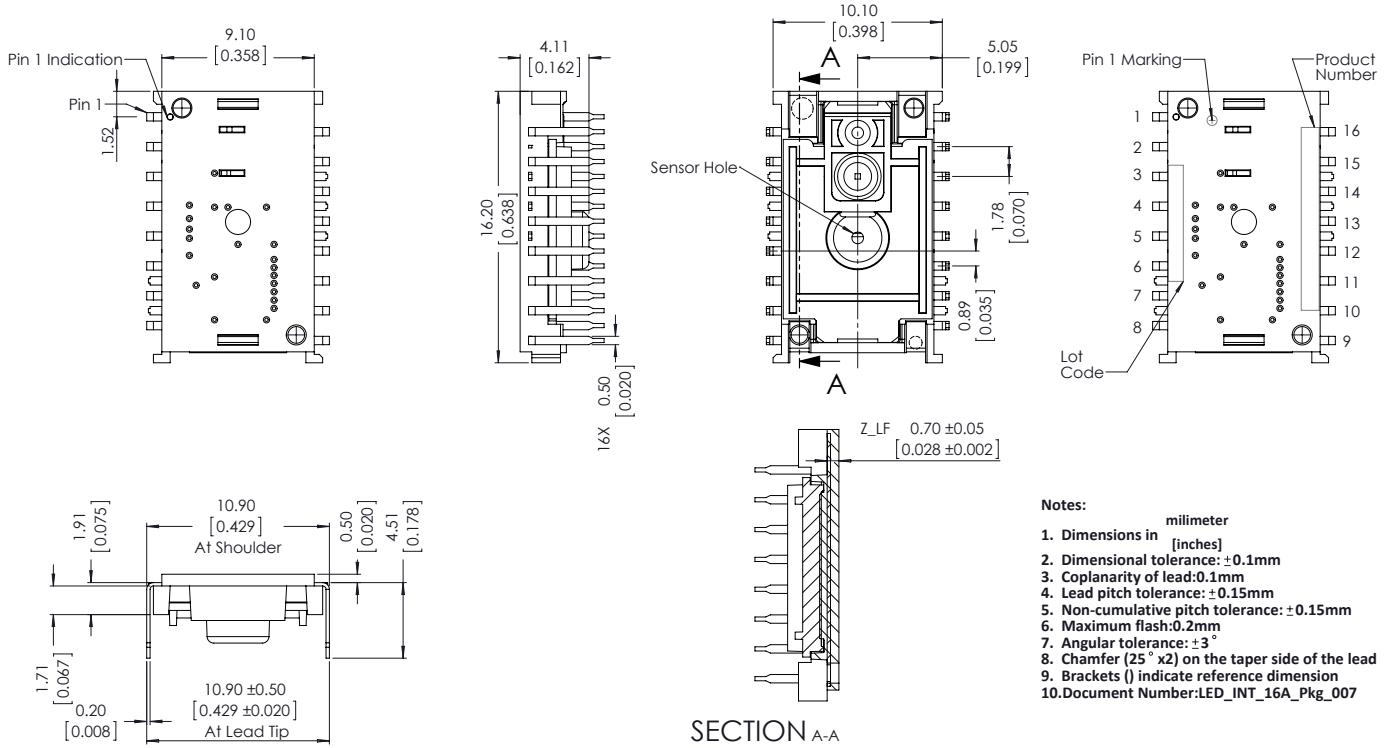


Figure 2. Package Outline Drawing

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

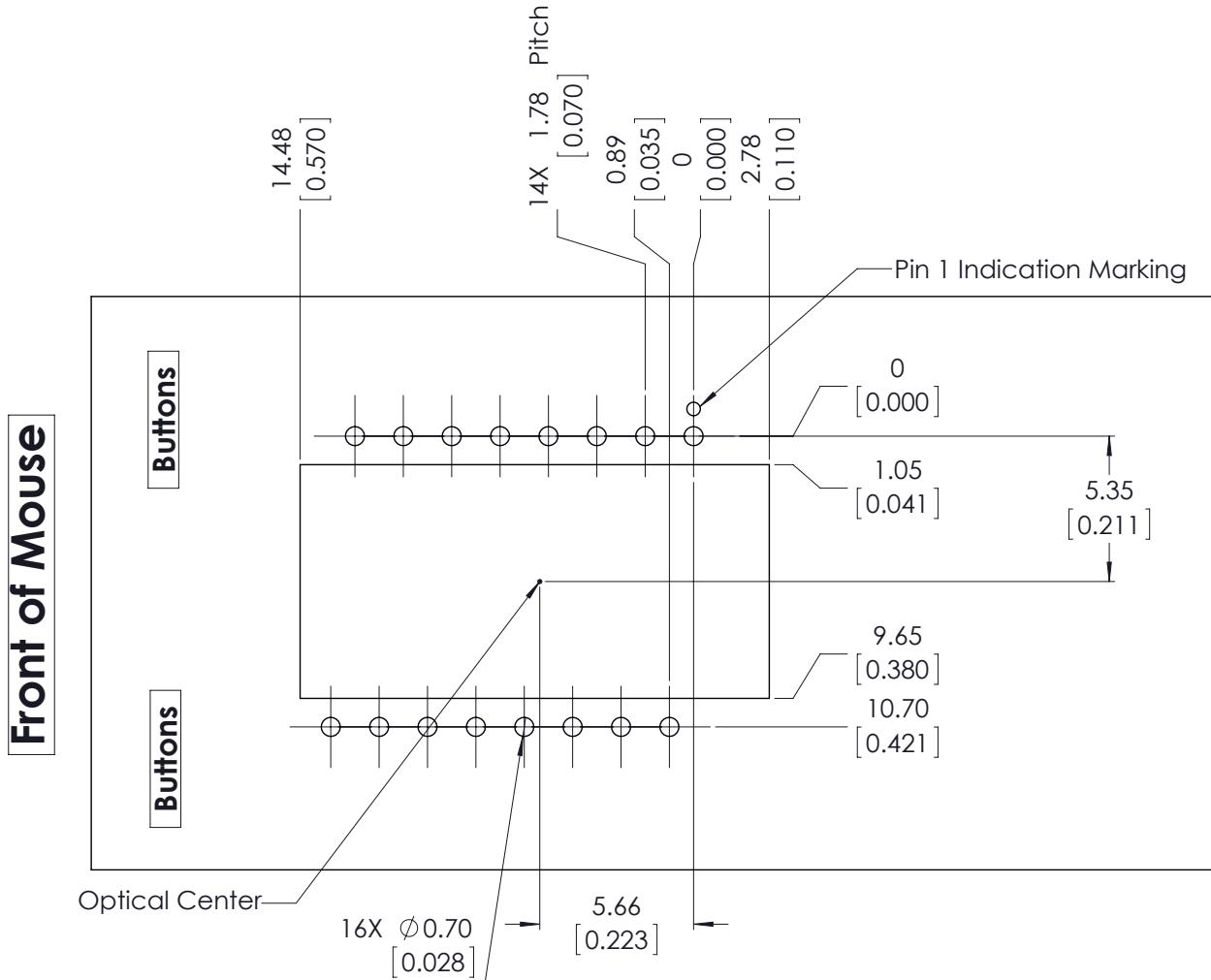


Figure 3. Recommended chip orientation, mechanical cutouts and spacing (Top View)

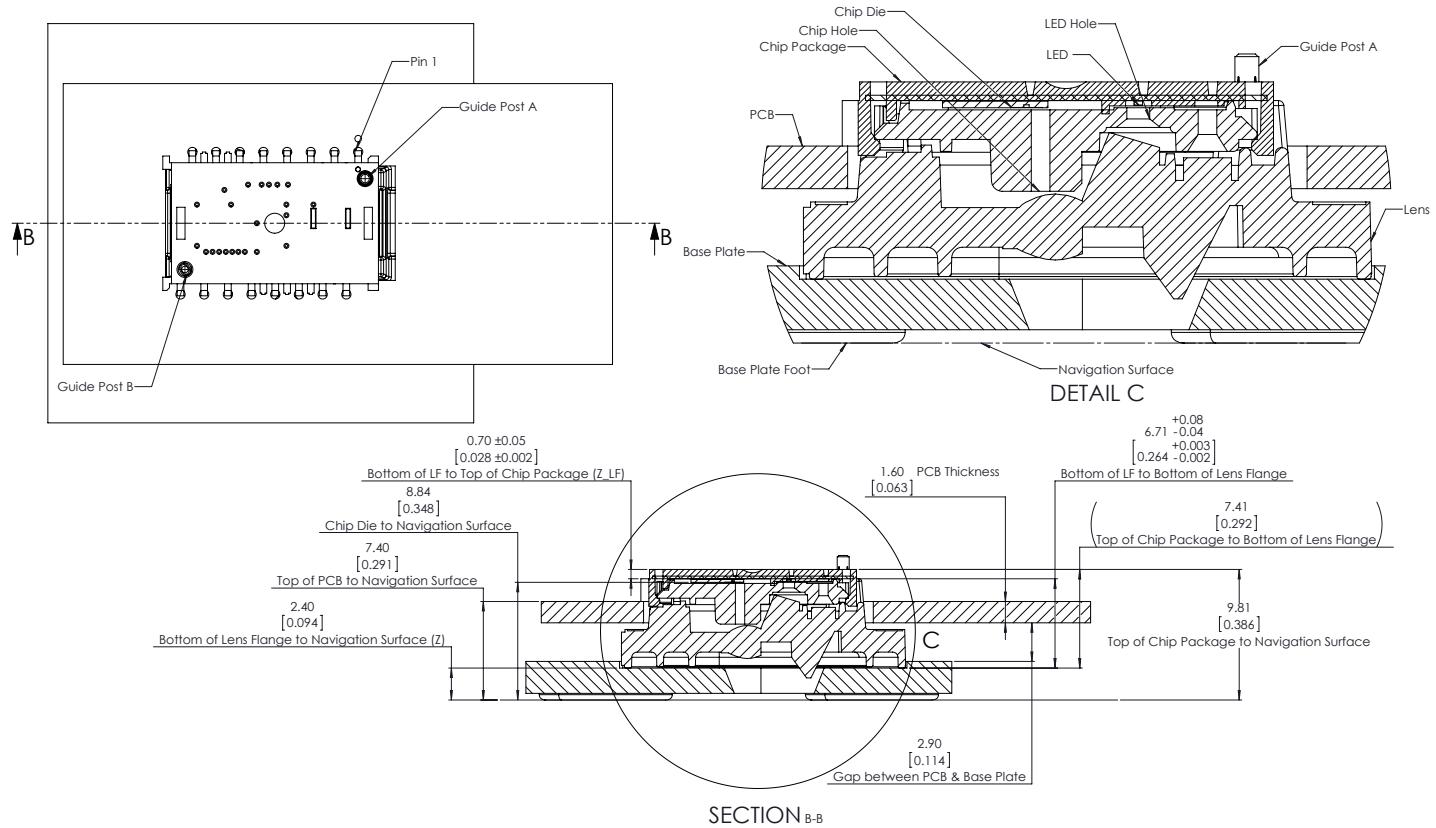


Figure 4. Assembly drawing of PMW3360DM-T2QU and distance from lens reference plane to tracking surface (Z)

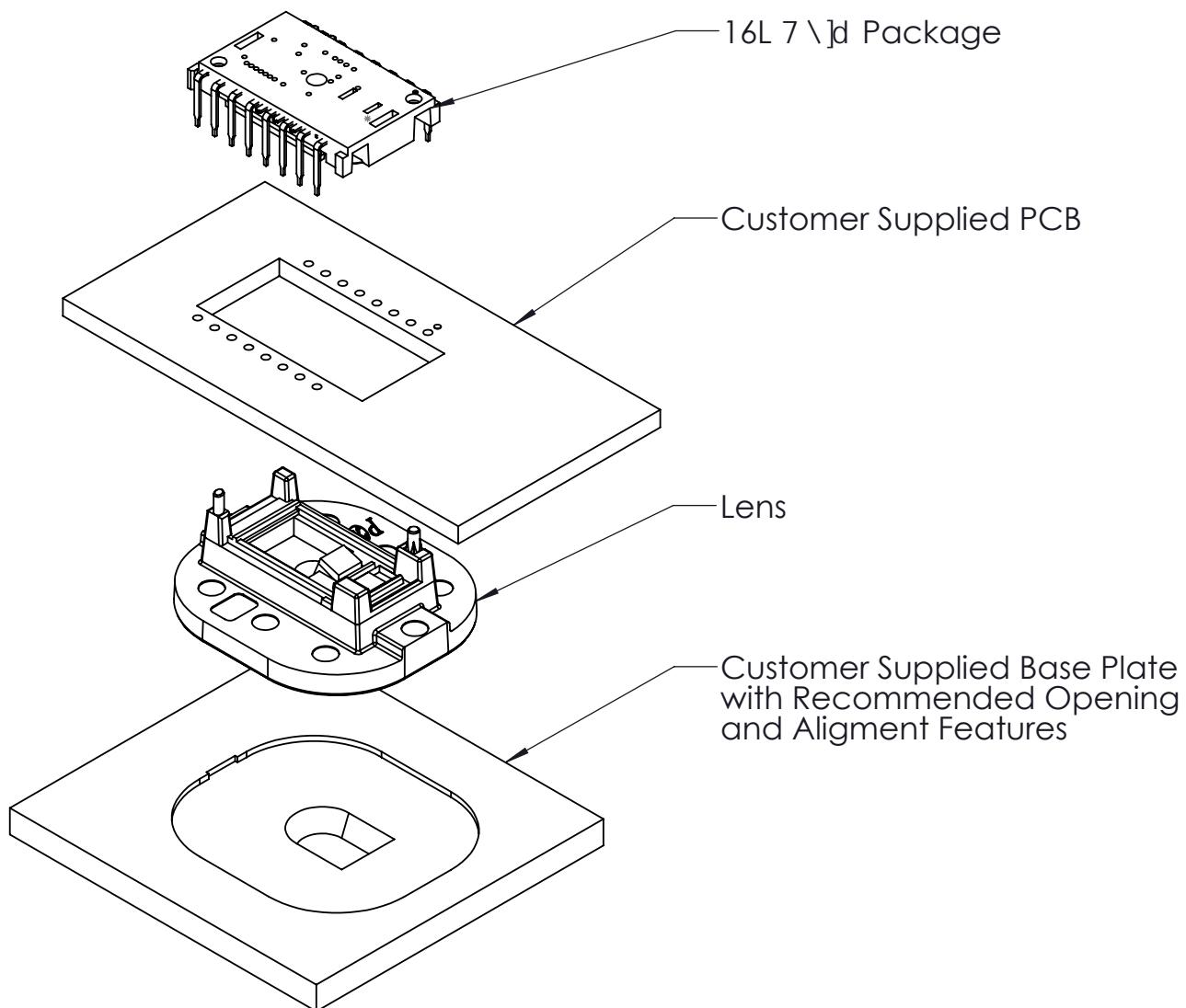
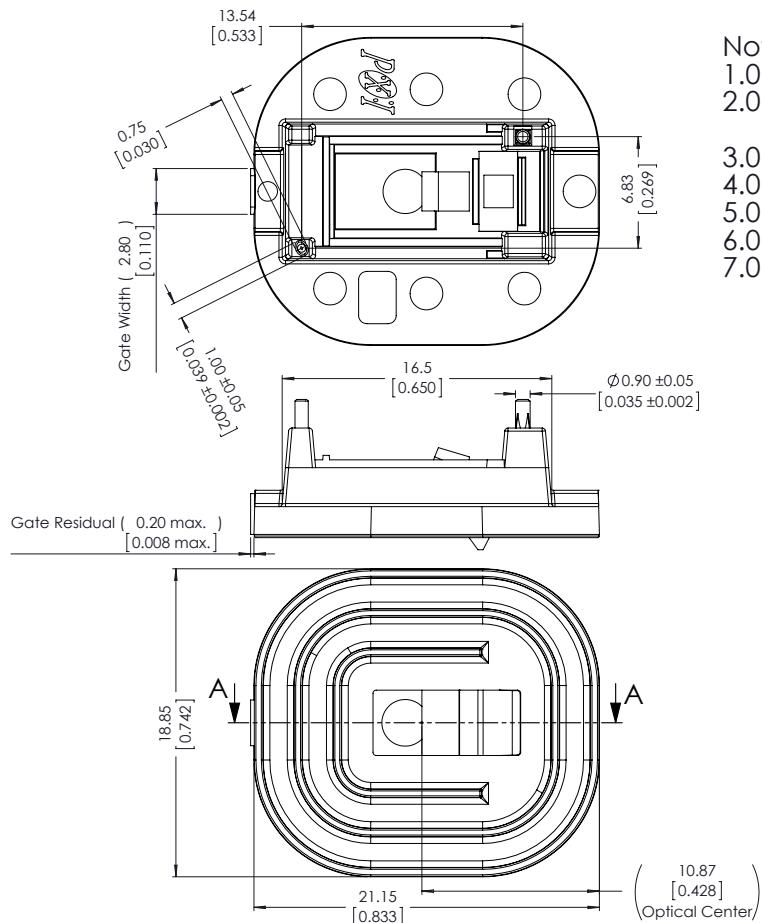


Figure 5. Exploded Assembly View



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

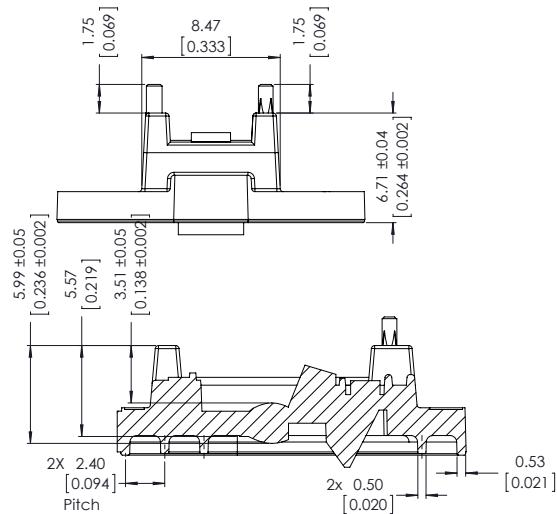


Figure 6. Lens Outline Drawing

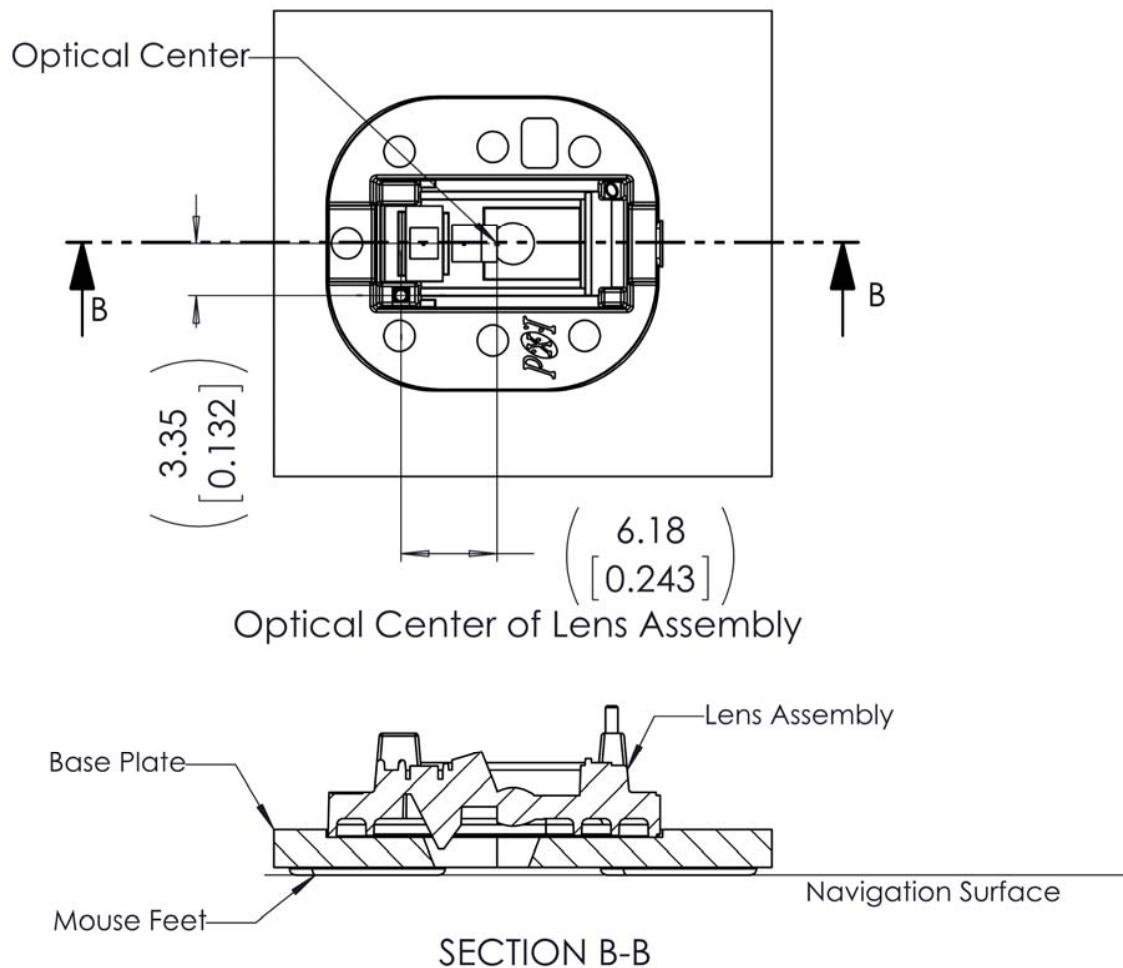


Figure 7. Cross section view of lens assembly

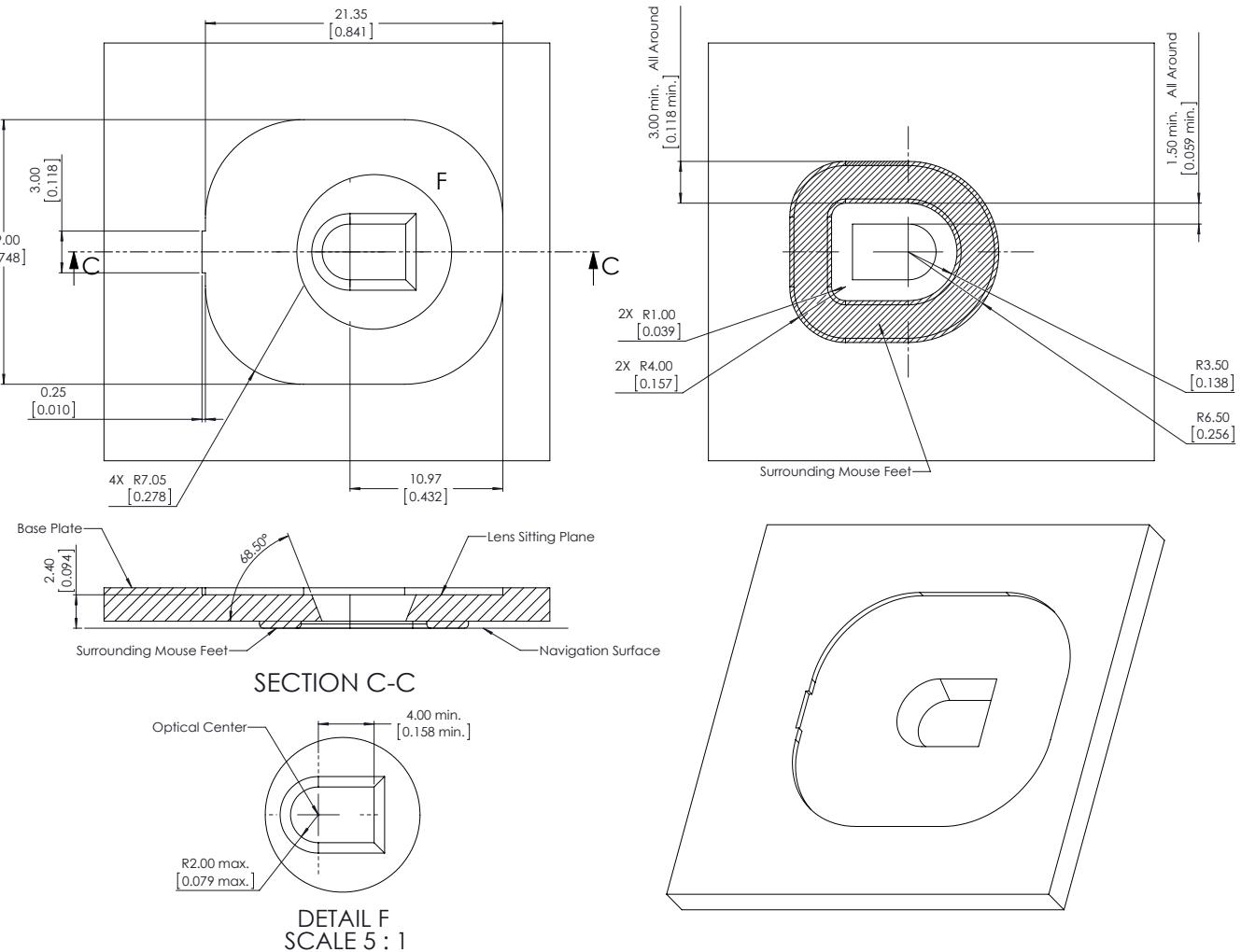


Figure 8. Recommended Base Plate Opening

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.

Chip Block Diagram

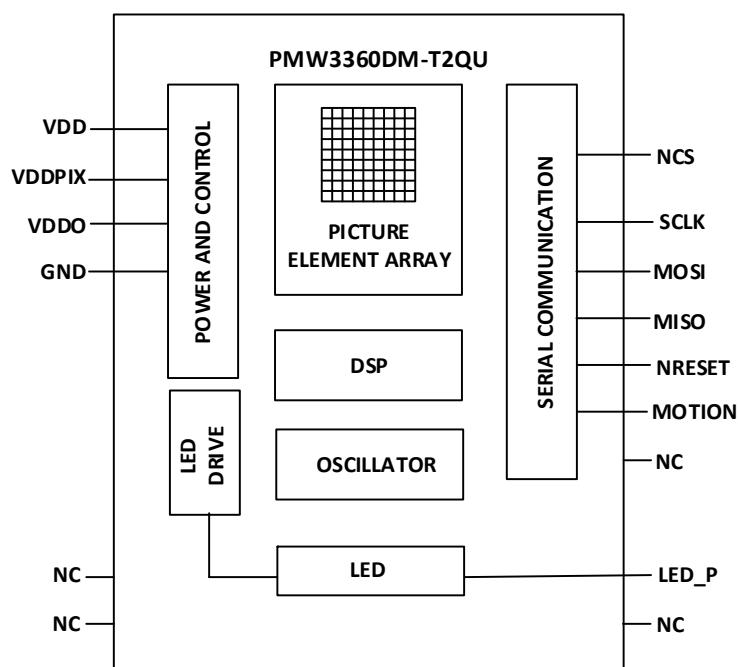


Figure 9. Block diagram of PMW3360DM-T2QU

1.5 Reference Schematics

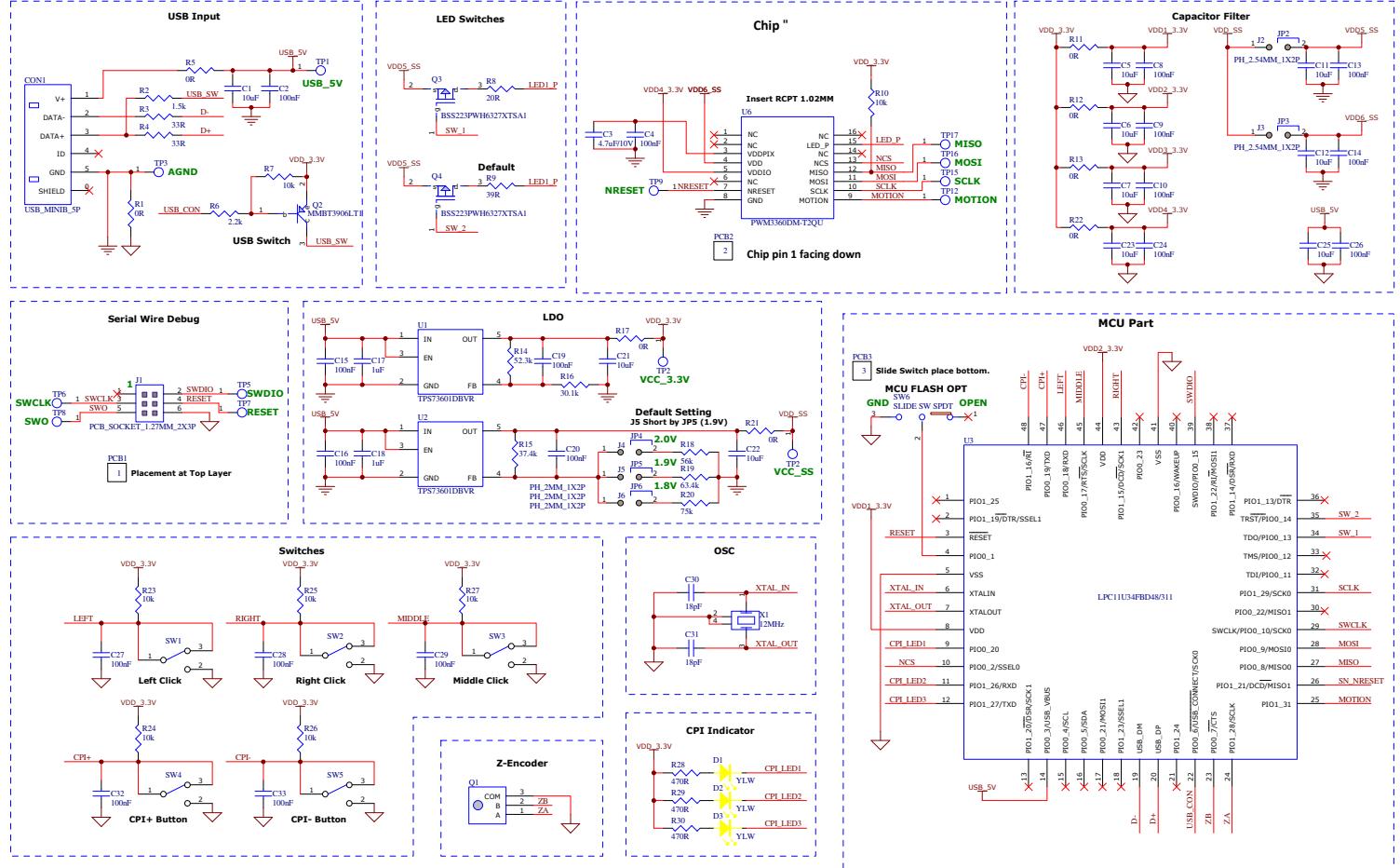


Figure 10. Schematic diagram for interface between PMW3360DM-T2QU and microcontroller on a wired solution

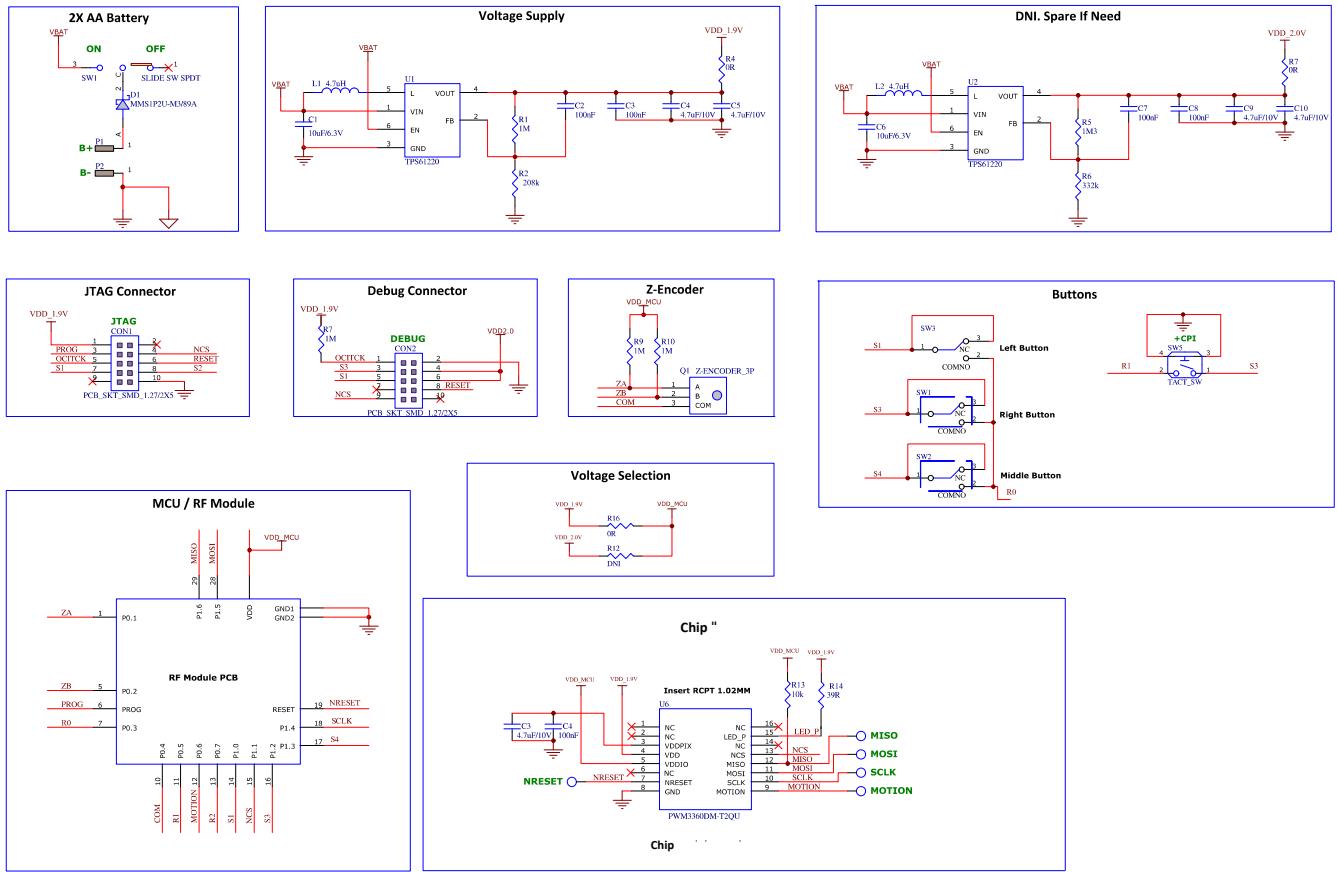


Figure 11. Schematic diagram for interface between PMW3360DM-T2QU and microcontroller on a wireless solution

2.0 Electrical Specifications

Regulatory Requirements

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

2.1 Absolute Maximum Ratings

Table 2: Absolute Maximum Ratings

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

2.2 Recommended Operating Conditions

Table 3: Recommended Operating Condition

Parameter	Symbol	Min	Typ.	Max	Units	Notes
Operating Temperature	T _A	0		40	°C	
Power Supply Voltage	V _{DD}	1.80	1.90	2.10	V	excluding supply noise
	V _{DDIO}	1.80	1.90	3.60	V	excluding supply noise. (VDDIO must be same or greater than VDD)
Power Supply Rise Time	t _{RT}	0.15		20	ms	0 to VDD min
Supply Noise (Sinusoidal)	V _{NA}			100	mVp-p	10 kHz — 75 MHz
Serial Port Clock Frequency	f _{SCLK}			2.0	MHz	50% duty cycle
Distance from Lens Reference Plane to Tracking Surface	Z	2.2	2.4	2.6	mm	
Speed	S		250		ips	300ips on QCK, Vespa Speed, Vespa 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 V, V_{DDIO} = 1.9V.

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

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

2.4 DC Electrical Specifications

Table 5. DC Electrical Specifications

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

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

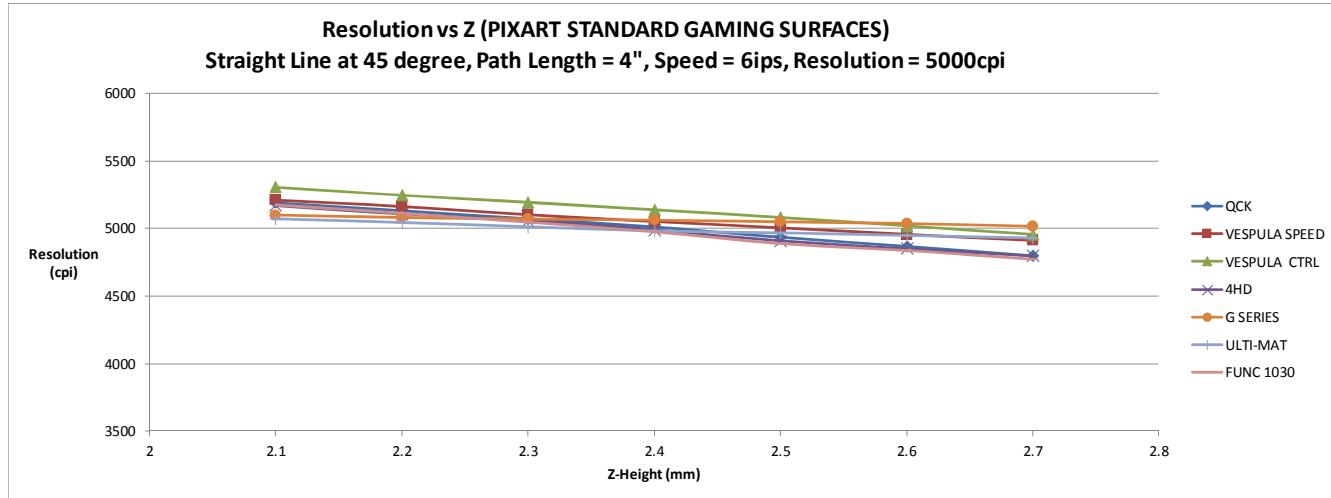


Figure 12 Mean Resolution vs. Z at default resolution at 5000cpi

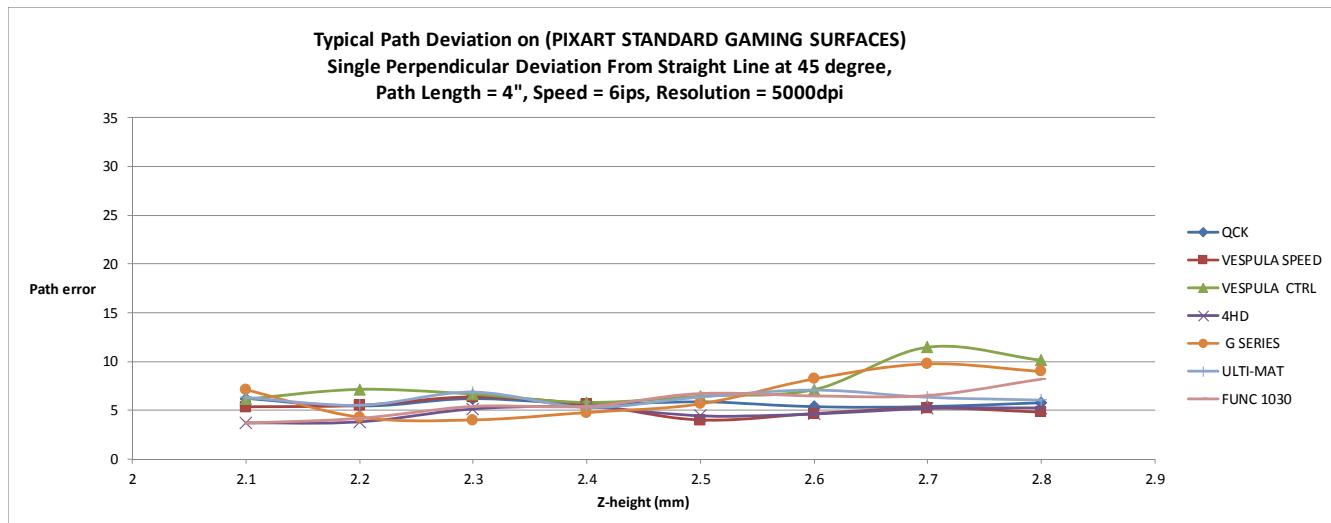


Figure 13 Path error vs. Z-height at default resolution at 5000cpi (mm)

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.

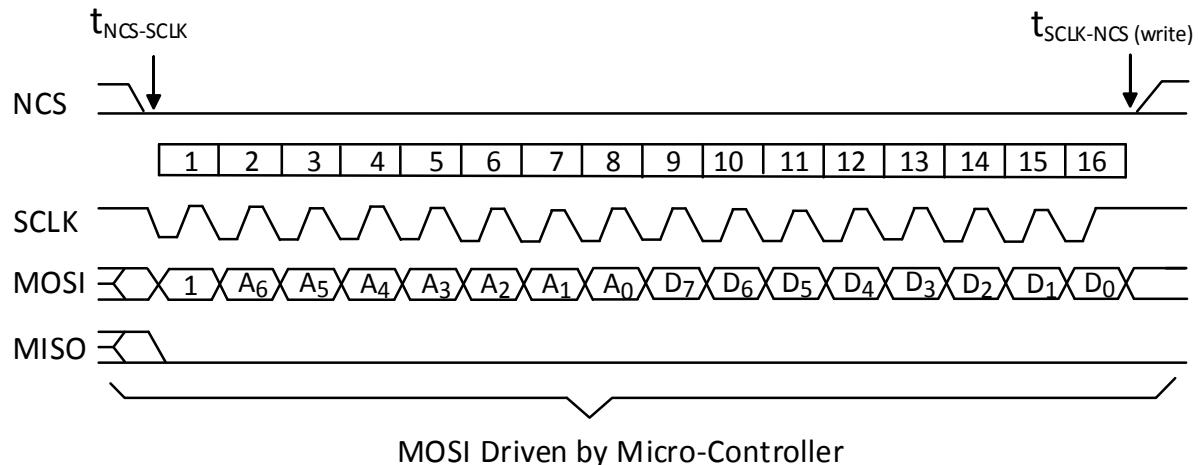


Figure 14. Write operation

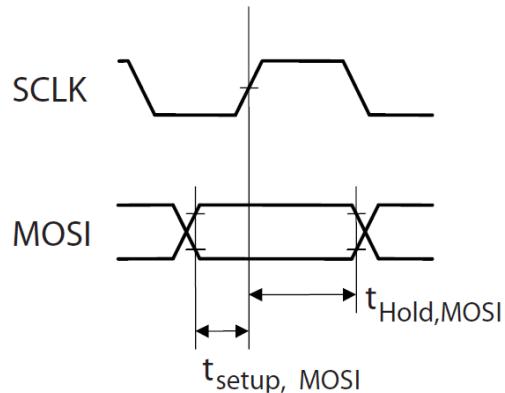


Figure 15. MOSI setup and hold time

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.

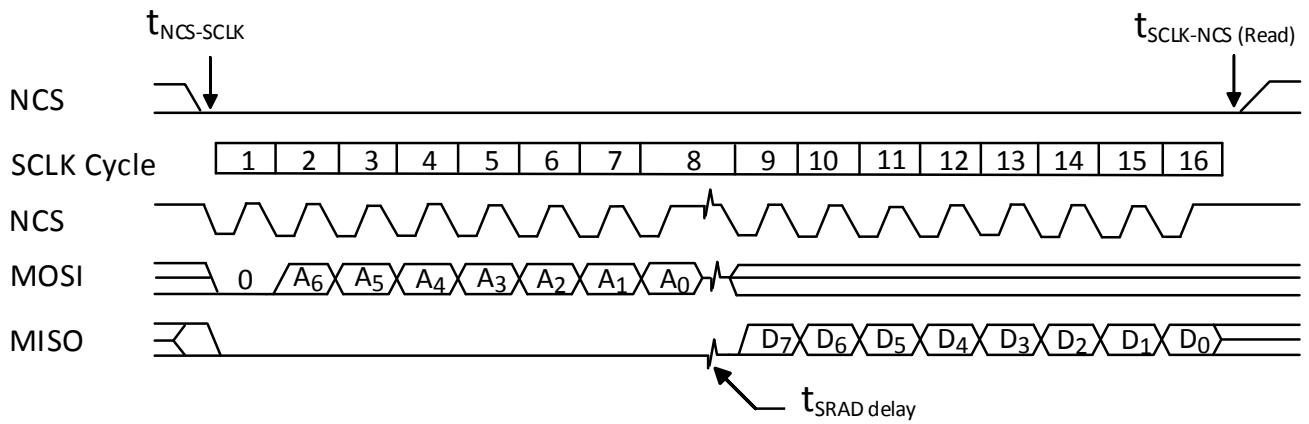


Figure 16. Read operation

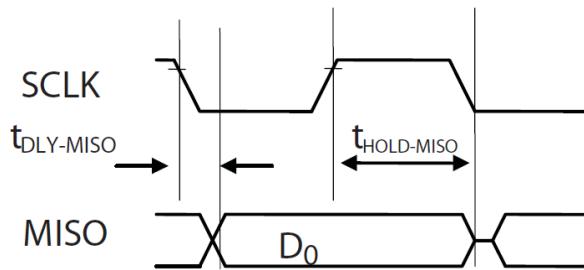


Figure 17. MISO Delay and hold time

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_{sx})

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

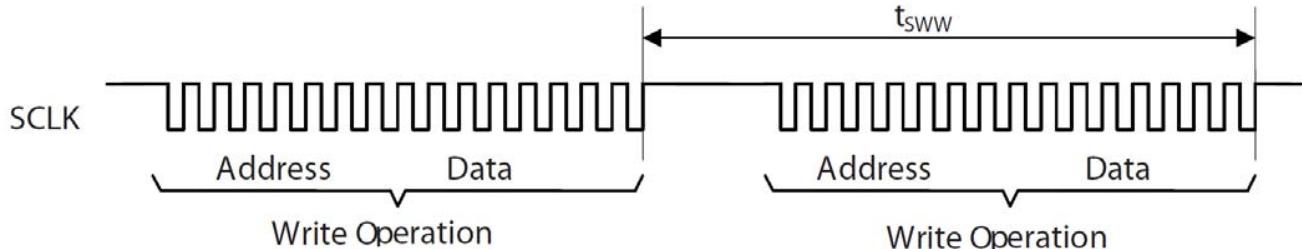


Figure 18. Timing between two write commands

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.

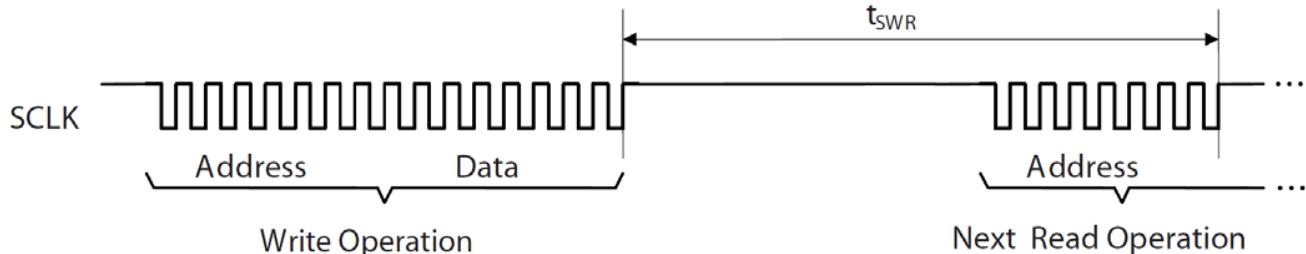


Figure 19. Timing between write and either write or subsequent read commands

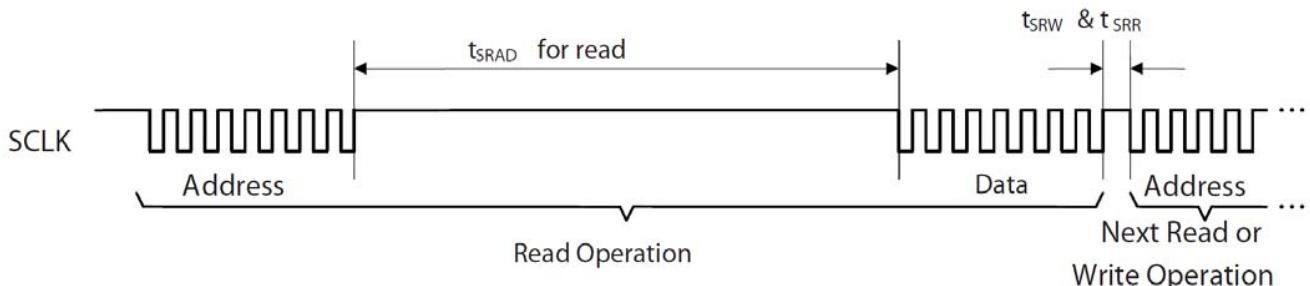


Figure 20. Timing between read and either write or subsequent read commands

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.

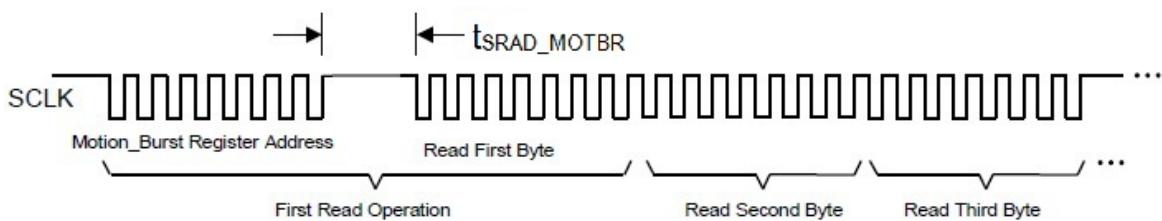


Figure 21. Motion Read sequence for step 3 to 5

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.

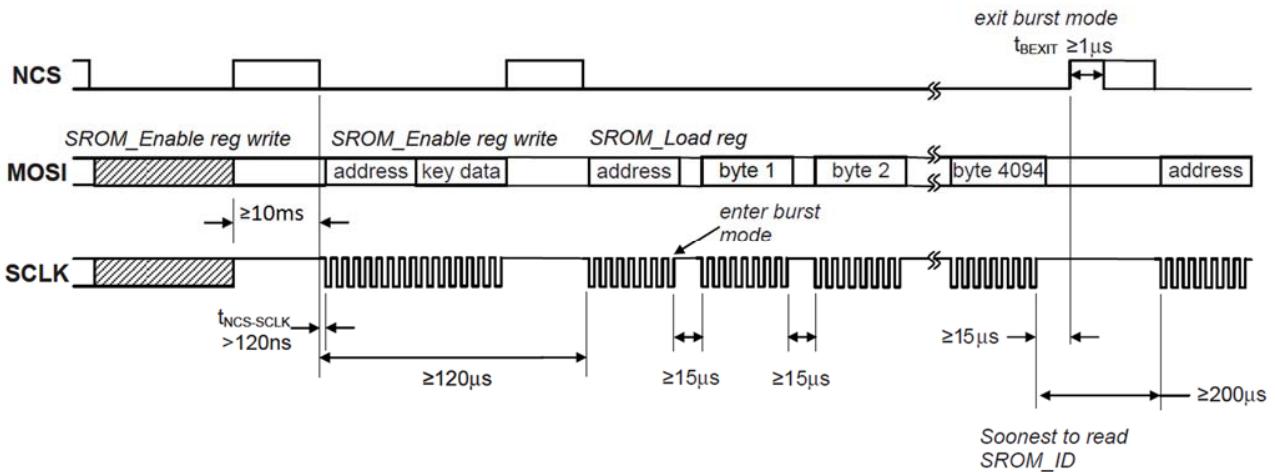


Figure 22. SROM Download Burst Mode

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.

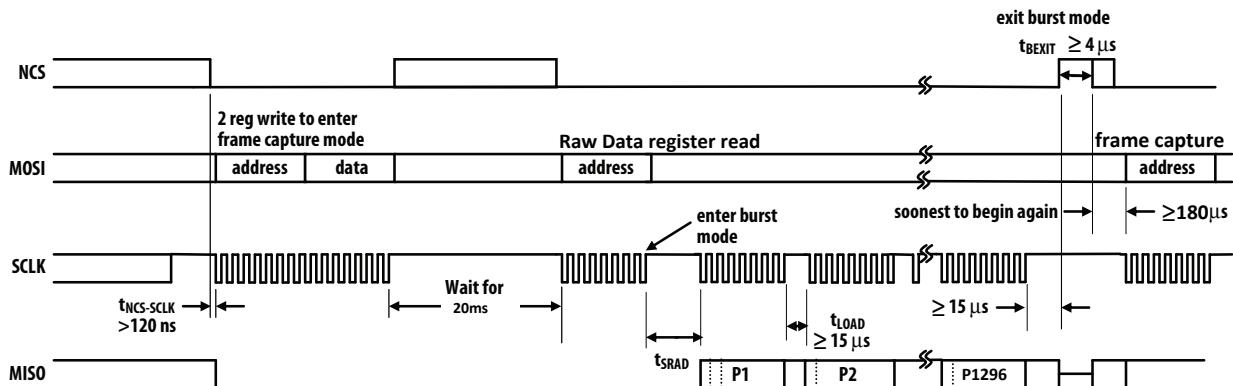


Figure 23. Frame Capture Burst Mode

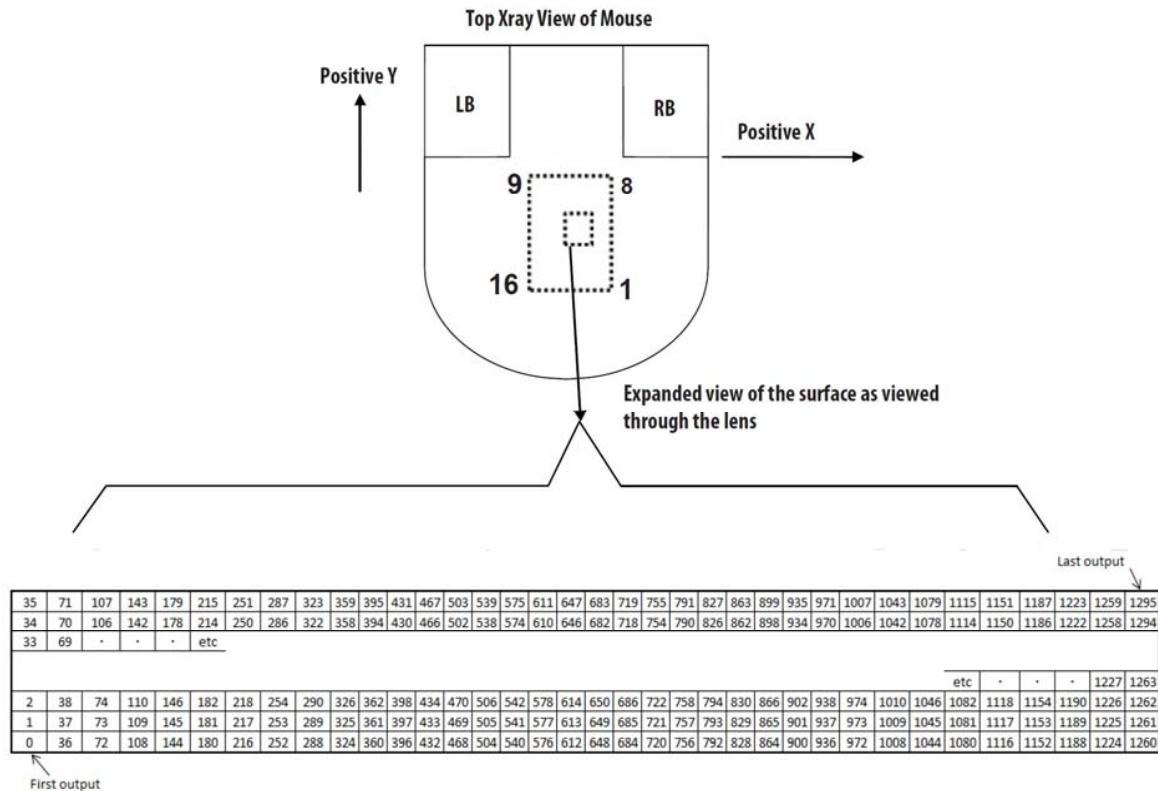


Figure 24. Raw data Map (Surface referenced)

7.0 Power Up

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

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

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

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

NRESET

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

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

8.0 Shutdown

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

To de-assert Shutdown mode:

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

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

*1. NCS pin must be held to 1 (high) if SPI bus is shared with other devices. It is recommended to hold to 1 (high) during Shutdown unless powering up the chip. It must be held to 0 (low) if the chip is to be re-powered up from shutdown (writing 0x5a to register 0x3a).

*2. MISO should be either pull up or down during shutdown in order to meet the low power consumption specification in the datasheet.

*3. SCLK is ignored if NCS is 1 (high). It is functional if NCS is 0 (low).

*4. MOSI is ignored if NCS is 1 (high). If NCS is 0 (low), any command present on the MOSI pin will be ignored except power-up command (writing 0x5a to register 0x3a).

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

9.0 Lift cut off calibration

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

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

1. Ensure that the chip is powered up according to the Power Up Sequence.
2. Ensure that Lift cut off calibration SROM^{*1} is downloaded.
3. Delay for 30ms.
4. Prompt the user that the "Lift cut off calibration" procedure is about to begin to ensure that the mouse is placed nominally on the surface (mouse is not lifted).
5. Start the calibration procedure by setting RUN_CAL register bit to 1. The calibration procedure can be started by a SW prompt to the user or user-initiated through a mouse-click event.
6. Poll CAL_STAT[2:0] to check the status of the calibration procedure. There are three ways to successfully stop the calibration procedure: set RUN_CAL register bit to 0 if either:
 - 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	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:							
	<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. X movement is counts since last report. Absolute value is determined by resolution. Reading it clears the register.							
Usage								

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.								
Motion	-32768	-32767		-2	-1	0	+1	+2	+32766 +32767
Delta_Y	8000	8001	FFFF	FFFF	00	01	02	7FFE	7FFF

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>							

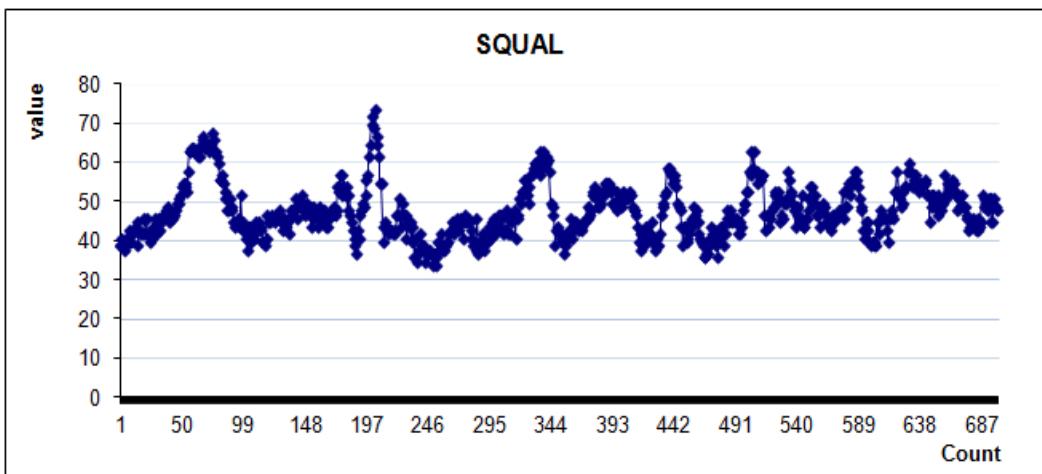


Figure 25. Average SQUAL on white paper

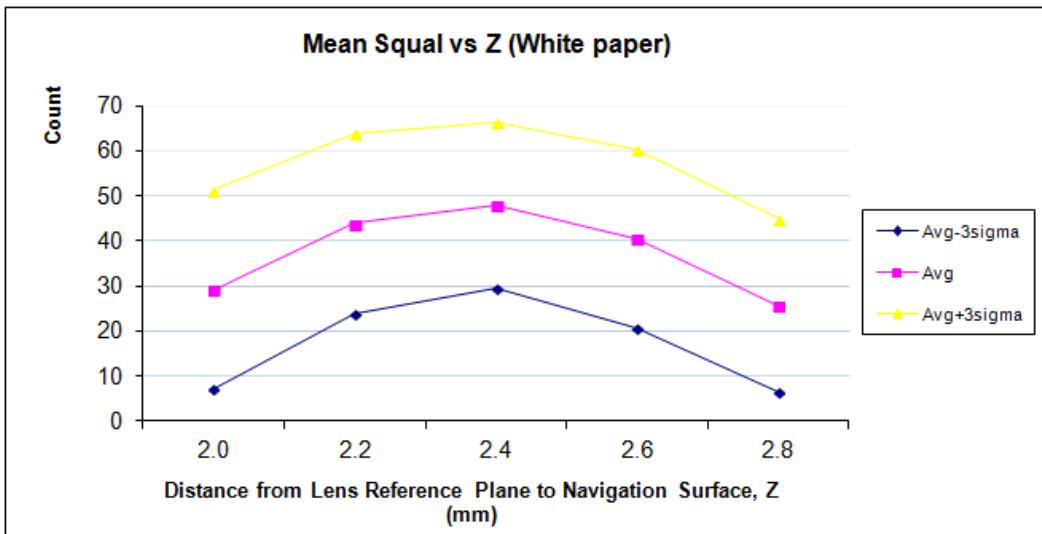


Figure 26. Mean SQUAL vs Z

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> <p>Average Raw Data = Register Value * 1024 / 1296</p> <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	<p>Maximum Raw data value in current frame. Minimum value = 0, maximum value = 127. The maximum raw data value can change every frame</p>							

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	<p>This register defines programmable invert able of XY register scheme.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="background-color: #003366; color: white;">Field Name</th> <th style="background-color: #003366; color: white;">Description</th> </tr> </thead> <tbody> <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> </tbody> </table> <p>Note: For <i>CTRL1_[7:5]</i> please use 0 degree for best performance</p>								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													

Register: 0x0F												
Name: Config1												
Bit	7	6	5	4	3	2	1	0				
Field	RES ₇	RES ₁₆	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	<p>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).</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="background-color: #003366; color: white;">Field Name</th> <th style="background-color: #003366; color: white;">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> $\text{Rest1 frame rate duration} = (\text{R1R}[15:0] + 1) \times 1 \text{ ms}$ $\text{Default} = (0 + 1) \times 1 = 1 \text{ ms}$ <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								
Data Type:								
Usage								

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								
Data Type:								
Usage								

Upper byte of the Rest2 frame rate register. This register sets the Rest2 frame rate duration. Default value is 100 ms. To write to the registers, write Lower first, followed by Upper. Register read can be in any order but must be consecutive.

R2R[15:0] value must not exceed 0x09B0, otherwise an internal watchdog will trigger a reset. Use the formula below for calculation.

Rest2 frame rate duration = (R2R[15:0] + 1) x 1 ms
Default = (99 + 1) x 1 = 100 ms

All the above values are expected to have a +40% and -20% of tolerance.

Register: 0x1A								
Name: Rest2_Downshift								
Bit	7	6	5	4	3	2	1	0
Field	R2D ₇	R2D ₆	R2D ₅	R2D ₄	R2D ₃	R2D ₂	R2D ₁	R2D ₀
Reset Value: 0xBC								
Access: R/W	Read/Write							
Data Type:	8-bit unsigned integer							
Usage	<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) × 1 ms</p> <p>Default = (499 + 1) × 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 $T_{dly_obs} = (500 \times 1.4) + 0.5 = 700.5$msec.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="background-color: #003366; color: white;">Field Name</th> <th style="background-color: #003366; color: white;">Description</th> </tr> </thead> <tbody> <tr> <td>OB6</td> <td>SROM_RUN: Indicates whether SROM is running. 0 = SROM not running 1 = SROM running</td> </tr> <tr> <td>OB[5:0]</td> <td>Set once per frame</td> </tr> </tbody> </table>								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
Field Name	Description													
OB6	SROM_RUN: Indicates whether SROM is running. 0 = SROM not running 1 = SROM running													
OB[5:0]	Set once per frame													

Register: 0x25

Name: Data_Out_Lower

Bit	7	6	5	4	3	2	1	0
Field	DO ₇	DO ₆	DO ₅	DO ₄	DO ₃	DO ₂	DO ₁	DO ₀
Reset Value: 0x00								
Access: R/W	Read Only							
Data Type:	16-bit unsigned integer							
Usage	Lower byte of the Data_Out register							

Register: 0x26

Name: Data_Out_Upper

Bit	7	6	5	4	3	2	1	0
Field	DO ₁₅	DO ₁₄	DO ₁₃	DO ₁₂	DO ₁₁	DO ₁₀	DO ₉	DO ₈
	Reset Value: 0x00							
Access: R/W	Read Only							
Data Type:	16-bit unsigned integer							
Usage	Data in these registers come from the SROM CRC test. The data can be read out in any order. The SROM CRC test is initiated by writing 0x15 to SROM_Enable register.							
	CRC Result	Data_Out_Upper	Data_Out_Lower					
	SROM CRC test	0xBE	0xEF					

Register: 0x29

Name: Raw_Data_Grab

Bit	7	6	5	4	3	2	1	0
Field	Valid	RD_D ₆	RD_D ₅	RD_D ₄	RD_D ₃	RD_D ₂	RD_D ₁	RD_D ₀
	Reset Value: 0x00							
Access: R/W	Read / Write							
Data Type:	8-bit unsigned integer							
Usage	<p>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.</p> <ol style="list-style-type: none"> 1. Write 0 to Bit [5] of register 0x10 (Config2) to disable Rest mode. 2. Write any value to Raw_Data_Grab register to reset the register. 3. Read MOTION register 0x02 & check for Bit [4] for first raw data in raw data grab to be ready. 4. Then continuously reading Raw_Data_Grab register for raw data for 1296 times. Ensure Bit [7] is valid for each raw data read. 5. Write 1 to Bit [5] of register 0x10 (Config2) to enable rest mode if required. 							

Register: 0x2A

Name: SROM_ID

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

Register: 0x2B

Name: Min_SQ_Run

Bit	7	6	5	4	3	2	1	0
Field	MSQR ₇	MSQR ₆	MSQR ₅	MSQR ₄	MSQR ₃	MSQR ₂	MSQR ₁	MSQR ₀
Reset Value: 0x10								
Access: R/W	Read/Write							
Data Type:	Bit Field							
Usage	This register defines the minimum Squel 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	<p>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.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="background-color: #1a3d54; color: white;">Field Name</th> <th style="background-color: #1a3d54; color: white;">Description</th> </tr> </thead> <tbody> <tr> <td>RESX [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	RESX [7:0]	Set resolution with CPI step of 100 cpi 0x00: 100 cpi (Minimum cpi) 0x01: 200 cpi 0x02: 300 cpi : : 0x31: 5000 cpi (default cpi) : : 0x77: 12000 cpi (maximum cpi)
Field Name	Description											
RESX [7:0]	Set resolution with CPI step of 100 cpi 0x00: 100 cpi (Minimum cpi) 0x01: 200 cpi 0x02: 300 cpi : : 0x31: 5000 cpi (default cpi) : : 0x77: 12000 cpi (maximum cpi)											

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

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

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

Register: 0x41								
Name: LiftCuttoff_Tune3								
Bit	7	6	5	4	3	2	1	0
Field	RMSQ ₇	RMSQ ₆	RMSQ ₅	RMSQ ₄	RMSQ ₃	RMSQ ₂	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 Squel run value that replaces the default value in the Min_SQ_Run register to improve lift performance. LiftCuttoff_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						
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. AS_EN = 0 (Angle snap disabled. This is the default value.) 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	<p>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.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="background-color: #003366; color: white;">Field Name</th> <th style="background-color: #003366; color: white;">Description</th> </tr> </thead> <tbody> <tr> <td>RUN_CAL</td> <td>0 = Stop Shutter Calibration procedure (default) 1 = Start Shutter Calibration procedure</td> </tr> <tr> <td>Bit [6:3]</td> <td>Reserved</td> </tr> <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> </tbody> </table>								Field Name	Description	RUN_CAL	0 = Stop Shutter Calibration procedure (default) 1 = Start Shutter Calibration procedure	Bit [6:3]	Reserved	CAL_STAT[2:0]	0x00 = Reserved 0x01 = Calibration in progress. 0x02 = Calibration successfully completed (minimum length met). Surface data collection continues until timeout. Registers LiftCutoff_Tune_Min_Length and LiftCutoff_Tune_Timeout define the minimum length threshold and timeout respectively. 0x03 = Calibration successfully completed (minimum length met) and timeout has triggered. Surface data collection stops automatically. 0x04 = Calibration unsuccessful (minimum length not met) and timeout has triggered. 0x05 - 0x07 = Reserved
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Register: 0x50

Name: Motion_Burst

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

Register: 0x58

Name: LiftCuttoff_Tune_Timeout

Bit	7	6	5	4	3	2	1	0
Field	RMSQ ₇	RMSQ ₆	RMSQ ₅	RMSQ ₄	RMSQ ₃	RMSQ ₃	RMSQ ₁	RMSQ ₀
Reset Value: 0x27								
Access: R/W	Read/Write							
Data Type:	Bit Field							
Usage	<p>This register sets the minimum Lift cut off calibration timeout threshold.</p> <p>Timeout (sec) = (TIMEOUT[7:0] + 1) x 0.5 sec</p> <p>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: LiftCuttoff_Tune_Min_Length

Bit	7	6	5	4	3	2	1	0
Field	MINL ₇	MINL ₆	MINL ₅	MINL ₄	MINL ₃	MINL ₂	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	<p>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.</p>							

Register: 0x63

Name: Lift_Config

Bit	7	6	5	4	3	2	1	0								
Field	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	LIFC1	LIFCO								
Reset Value: 0X02																
Access: R/W	Read/Write															
Data Type:	Bit Field															
Usage	<p>This register defines the lift detection height threshold. The lift status bit is asserted when the chip is above the threshold.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="background-color: #003366; color: white;">LIFC[1:0]</th> <th style="background-color: #003366; color: white;">Description</th> </tr> </thead> <tbody> <tr> <td>00</td> <td>Reserved</td> </tr> <tr> <td>10</td> <td>Lift detection height = nominal height + 2 mm (default value).</td> </tr> <tr> <td>11</td> <td>Lift detection height = nominal height + 3 mm.</td> </tr> </tbody> </table>								LIFC[1:0]	Description	00	Reserved	10	Lift detection height = nominal height + 2 mm (default value).	11	Lift detection height = nominal height + 3 mm.
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	<p>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.</p> <p>Note: Maximum raw data value is 127. PB7 is always zero.</p>							

Register: 0x65												
Name: LiftCuttoff_Tune2												
Bit	7	6	5	4	3	2	1	0				
Field	Reserved	RPTH ₆	RPTH ₅	RPTH ₄	RPTH ₃	RPTH ₃	RPTH ₁	RPTH ₀				
Reset Value:0x00												
Access: R/W	Read Only											
Data Type:	Bit Field											
Usage	<p>This register provides Lift cut off calibration related readout registers. See the Lift cut off calibration section for more details.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="background-color: #003366; color: white;">Field Name</th> <th style="background-color: #003366; color: white;">Description</th> </tr> </thead> <tbody> <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> </tbody> </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.
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12.0 Document Revision History

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