Rocket Data Logger

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***Abstract* — The developed module was created to record data during the flight of a rocket and to permit to the user to retrieve the data after it was recovered. The entire structure was designed to withstand high accelerations and an unfriendly environment. The measure parameters are: rocket engine pressure, atmospheric pressure, acceleration and GPS indication on speed and height. A second important function of this logger is to count time and to trigger the ejection of the parachutes after a set time. The value of the time interval between launch and parachute ejection is set from a PC GUI. After recovering the rocket the data from the data logger is retrieved by connecting it to PC thought USB and on the PC side a GUI is used to control the data transfer and store the values in CSV format.**

***Index Terms*— PIC, Embedded, Rocket, Sensors, Data Logger.**

I. Introduction

The presented system was developed with the purpose to record data during the flight of a rocket in order to evaluate the performance parameters of the engine and the aerodynamic structure. A series of commercial solution exist but they even record only maximum figure or are too large to fit in small rocket model. On this design focus was to acquire data accurate and fast to be able to measure parameters that vary fast in time.

The entire system was designed around a 16bit PIC24FV32KA302 chosen to keep a common 5V voltage for power mainly dictate by the industrial pressure sensor used for rocket engine pressure measurement. For accurate atmospheric pressure measurements an external 22bit ADC was used.

To control the ejection of the parachute two MOS transistors were added in case double deployment will be used. The transistors are be opened at an interval of time set from a PC program and counted by a timer from the moment of start. For safety reasons the ejection of the parachute happens only if the on board switch is in a right position

The communication with the PC is done thought a virtual com port created by the FT232RL circuit.

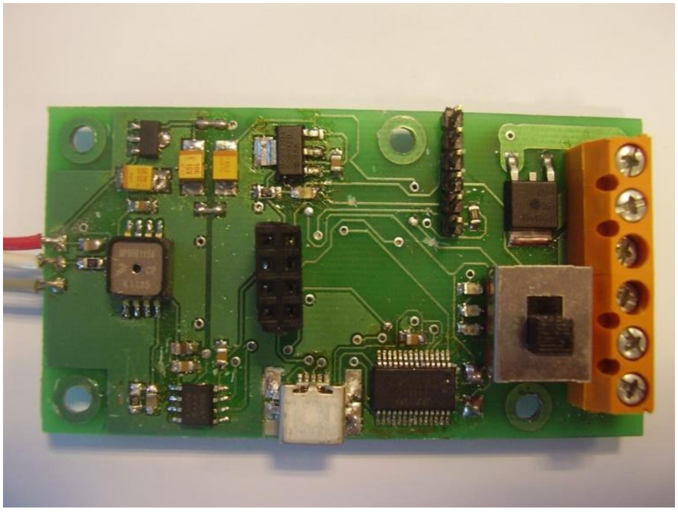

Figure 1: Data Logger

The recoded data is stored into a 1Mb EEPROM large enough to record 40s of data. Simulations indicated a much shorter flight time on the ascendant trajectory. And Ds card was avoided because of the expected high vibrations and acceleration that might have caused unreliable connections between card and MCU. The GPS attached to the MCU is used to get coordinates, speed and altitude information.

For safety reasons a 2.4GHz RC receiver was used to trigger the ejection of the parachutes before the timer would, i case something goes wrong.

The dimensions of the logger had to fit the diameter of the rocket 70mm, internal structure limited the size of the board even more. In a section between engine and parachute compartment it was just enough space to fir the Data Logger GPS, RC receiver, a small camera and battery.

Figure 2: Rocket internal structure and on launch pad

II. DATA LOGGER STRUCTURE

A. The MCU

The data logger was designed around the PIC24FV32KA302. The reasons for which this MCU was used are: power supply up to 5V, core on 16bit and 16MIPS least but not last, the internal SAR ADC has 12bits.

The MCU need to acquire data from the internal ADC, get extra one from SPI from the external ADC, and also from the UART that communicates with the GPS. This data is formatted and send to the external EEPROM thought SPI2.

The data from the internal ADC is averaged to increase the resolution of the indication from 12 to ~14bits. The numbers will be saved on 16bits inside the EEPROM.

The data logging is triggered by the acceleration value when take-off is detected. This detection is done by comparing the Acceleration indication with a threshold value around 2g. It is important to have data stored before this value also to correctly process the data after is retrieved. For this reason a circular buffer with a length of 128points to be able to record the increase of acceleration before reaching the threshold value.

B. Rocket Engine Pressure Sensor

One of the key parameters that had to be measured is the engine pressure during flight. From this and from the Acceleration of the rocket is possible to estimate the average ISP (specific impulse) of the fuel and the total impulse the engine.

On ground tests an identical sensor was used also to check if pressure inside the engine is under the threshold limit of the material out of which the engine is being built.

The chosen sensor had to be solid to wit stand great pressure, temperature and vibrations, so an industrial model was selected: Honeywell MLH02KPSB06A.

Using to adaptors from 1/8NPT to 1/4NPT and then to the engines 1/4G it was connected to the engine. Since pressure indie the rocket engine can go higher than 1000psi a 2000psi model was used.

The sensors had voltage output 0.5-4.5V and require 5V as power supply. The SAR ADC from the MCU acquires data from this sensor, and small RC anti-aliasing filter was placed between the sensor and ADC input.

Figure 3: 2000psi Pressure sensor

C. Accelerometer

According to the simulation performed before flight acceleration up to 30g was expected. Based on this figure and accelerometer able to withstand this value had to be used.

To keep power supply to 5V and to make use of the ADC integrated in the MCU the MMA3202 Accelerometer was selected.

To have complete data about movement in space is required a system with 6 degrees of freedom: 3 for acceleration and three fro rotation. To keep cost reduced and design to minimum on the first rocket we build we decided to measure acceleration on only one axe. During the flight is visible that the trajectory was close to vertical so the accuracy of the readings is good even in this situation.

The MMA3202 integrates two accelerometers on X axe able to measure up to 100g and Y able to measure up to 50g. Only the data from the accelerometer on axe Y was used

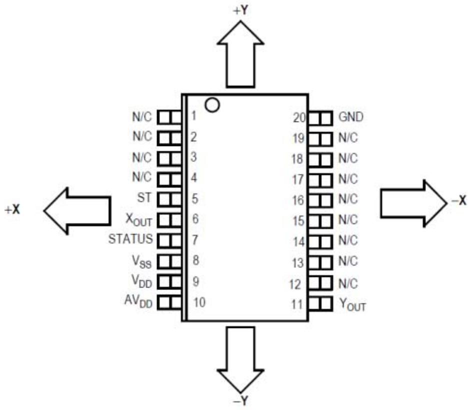

Figure 4: MMA3202 Accelerometer

D. Barometer

To measure altitude reached by the rocket there are more options, to be able to check the quality of the data is good to have more sensors to give the same information and check if they correlate. On our data logger we have the accelerometer, GPS and the barometer.

The model used is an MPXH6115A6 model was used. It is a model with analog output. Commercially many models with integrate ADC exists but for bet accuracy a solution that implied external ADC was implemented.

Figure 5. Barometer

E. GPS receiver

The logger also has the ability to record data from a GPS receiver. There were doubts about the ability of a GPS to run in a highly dynamic environment as a rocket but it was worth trying it. Also is not excluded that a lost connection of the GPS during the active section of the trajectory to be restored around apogee when acceleration and speed of the rocket are much smaller and thus to have a GPS recording of the apogee. The model used was based on uBlox GPS chip.

Figure 6: GPS receiver

F. Memory and PC GUI

All acquired data has to be stored on a nonvolatile memory. To be absolutely sure that no electrical problems would appear during the high accelerations and vibrations a 1Mb EEPROM was used.

The memory of the EEPROM was partitioned in 4 areas: one was storing data relating timers values, sampling speed, record duration, status of the operations, etc. the rest of the memory was split in three areas one for each data source: external ADC, internal ADC and GPS.

After the flight the data from the EEPROM was downloaded to PC though a GUI and saved in CSV format for latter processing of the data.

To set the parameters of the logger and to read data recorded during flight a PC GUI was developed in LabView.

III. Results

The data logger was used on the flight of the ICARUS rocket. The engine performed as expected as the rocket was aerodynamically, having a straight trajectory.

Acceleration matched the readings of from ground test on the load cell. The very firsts point from the reading are indicating the ADC output at 0g and that can be used to set the offset of the system. The curves slowly increases o the 2g value that triggers the start of the timers for parachute deployment. Maximum reading was 302 m/s^2.

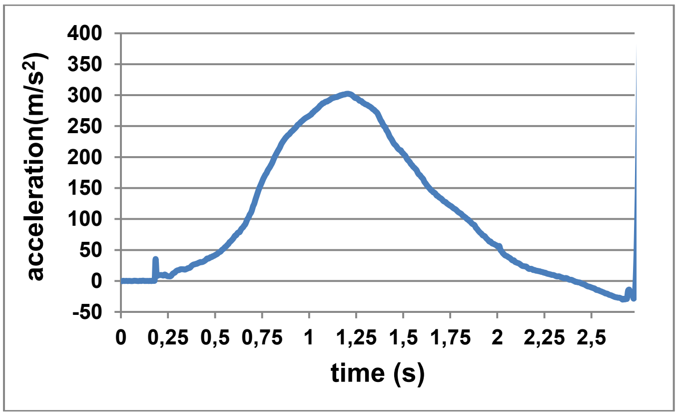

Figure 7: Acceleration readings

At the moment of the maximum acceleration the rocker had mass of almost 4.5kg and thus indicating that the engine had a thrust force of 1359N if we neglect the aerodynamic drag.

As the engine force decreases the acceleration becomes negative this is because at this point the rocker has very big speed and the aerodynamic drag is higher than the engine thrust. If engine thrust is known or is zero is possible to measure the aerodynamic drag and to measure the drag coefficient without using an wind tunnel. By integrating once the curve from figure 1 speed information is obtained

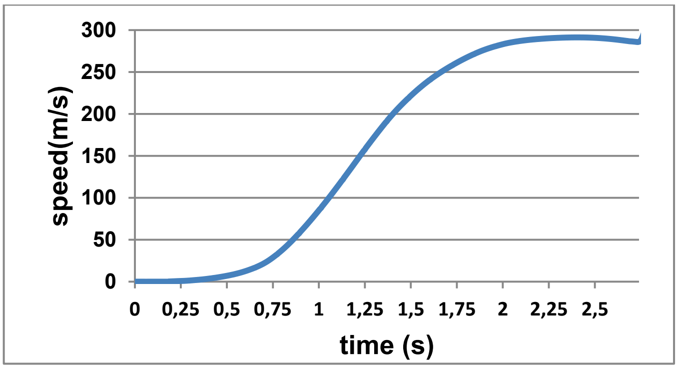

Figure 8: Speed

By integrating twice the acceleration information the height values can be obtained. The same information can be extracted from the barometer data. This can be a method to determine if measurements have been accurate.

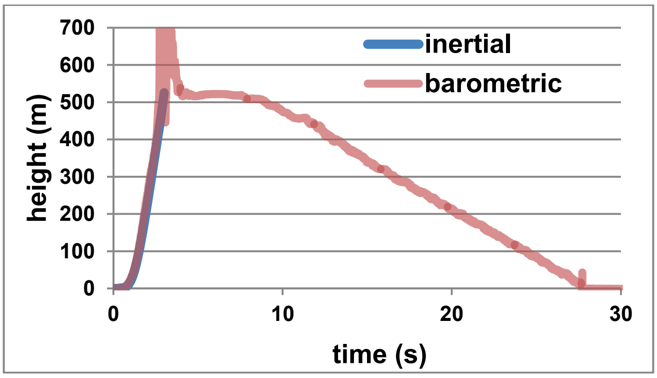

Figure 9: height obtained from two sensors: accelerometer and barometer

The rocket engine pressure sensor is another way to evaluate if the engine worked as expected. By acquiring both acceleration and pressure, special parameters of the engine combustion can be estimated and thus check if it worked at it maximum potential

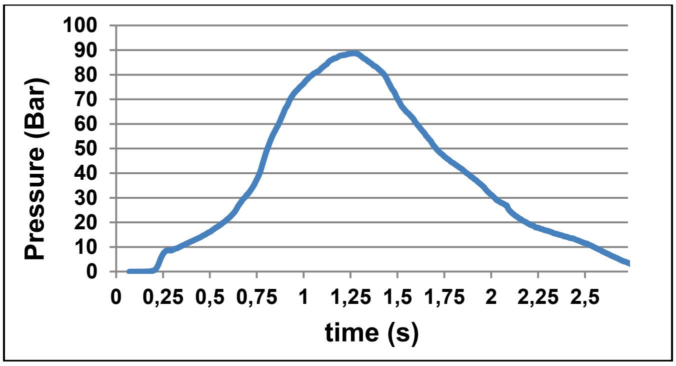

Figure 10: Rocket engine pressure

The great surprise of this flight was the GPS. Because of the high acceleration it didn't provides any clear data. Apparently the 4g limit specified in the datasheet is real limit. For future projects special GPS able to measure high acceleration needs to be purchased.

IV. Conclusions

By using commercilay available chips rocket grate data logers can be designed. Extra care nneds to be given a the mechanical solicitation during the flight and the rigorous testing of the programs. Fro future projects special GPS reeivers able to work at high acceleration will be used.

Acknowledgment

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