Acta Avionica
Volume XVII, 32-No.2, 2015

DESIGN OF ALTIMETER MODULE FOR USE ON BOARD OF UAV

Bc. Pavol LIPTÁK
Faculty of Aeronautics, Technical University of Košice, Rampová 7, 04121 Košice
**Corresponding author*. E-mail: pavolliptak0@gmail.com

Summary. The aim of my work was to design an altimeter module for an unmanned aerial vehicle. At first, there have to be analyzed possible methods of measuring altitude. Based on the chosen solution, the selection of the sensors needed for the height measurement was performed. After the selection, design of specific solutions to the electric scheme together with the board using the selected sensors had to be made and the algorithm for data processing was developed. The designed altimeter module can serve to stabilize the unmanned aerial machine in flight space but also, as a sensing element landing system.

Keywords: design, altimeter module, unmanned aerial vehicle, microcontroller

1. INTRODUCTION

Altimeters history goes back to the deep past, when in 1924 Lloyd Espenschied invented first radio altimeter, and up to four years later, in 1928, German inventor Paul Kollsman invented the first barometric altimeter. Later, of course, these devices were upgraded and enhanced, but the principle of the measurement remained almost unchanged up to these days.

However, nowadays with the advent of more powerful electronics based on miniaturized microprocessors can see a big boom of unmanned air vehicles (UAVs). Since the intelligent sensoric systems are necessary to UAVs for different physical quantities sensing, these sensors need to be designed and made.

It is necessary to analyze the various methods of measuring the height and then carry out a selection of the most suitable module for altimeter module. After selecting the appropriate methods for measurement of height it is necessary to select specific sensors and create a system with a microcontroller that can process the measured data and then send it to upper intelligent control system. After selecting the appropriate sensors with the required technical parameters it is necessary to implement the proposal peripheral solutions with electrical diagram of each circuit. Consequently, it is necessary to program the microcontroller and load the program - data processing algorithm, optimized according to the needs.

2. CHOSEN METHODS AND SENSORS

The first method chose for the measurement is the pulse ultrasonic sensing. The concertly chosen device is MB7360 MaxSonar-WR [1]. From the Table 1 it is possible to read the technical specifications of the sensor. The sensor has very good resolution and multiple output signal types.

Relatively small ultrasonic sensor with a height of only 3.5 cm and 3.8 cm length is the perfect solution. Similarly, it is has the low supply current consumption, only 2.9 mA and the ability to use 3.3V voltage that ensures compatibility with on board UAVs electronics and certainly these factors are important when considering the battery life of the UAV. 7.5 Hz refresh rate means sending the height information every 133 ms. This value is sufficient for slow speed flights and precise maneuvering needed by the multicopter UAVs.

Table 1 Technical parameters MB7360 MaxSonar-WR

Refreshing rate	7.5 Hz	
Supply voltage	2.7 – 5.5 V	
Supply current	2.9 mA	
Range	300 - 5000 mm	
Resolution	1 mm	
Outputs:	Analog	
	Serial (RS232)	
	PWM	
Dimensions :	A	34.7 mm
	B	17.9 mm
	C	14.4 mm
	D	7.9 mm
	E	5.8 mm
	F	2.54 mm
Operating temperature	-40°C to +65°C	

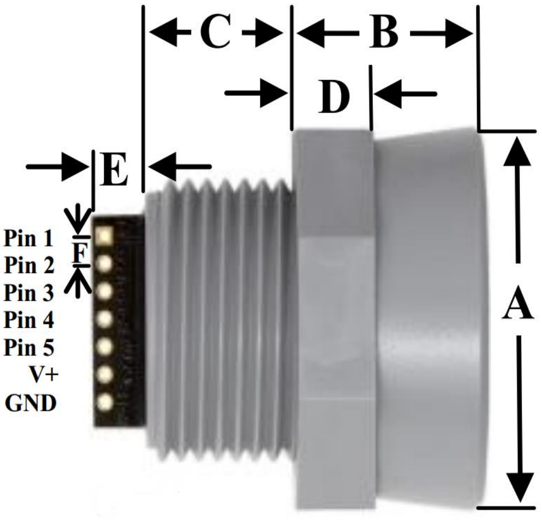

Figure 1 Ultrasound sensor BM7360

Since the measurement range of the ultrasonic sensor is physically limited by the possibility of rebounding waves, the maximum measuring range of the sensor is set at 5 m. However, if you need to measure the height greater than the maximum range of the ultrasonic sensor, the appropriate choice is to use the second method - barometric.

Barometric height measurement allows us to measure the height of the UAV at a significantly higher rate than the reflection method would have in big heights. Order of this distance from the Earth's surface to the UAV has the values of units of kilometers. This range is for a small UAV fully sufficient.

To use this method was chosen barometric sensor T5403 from EPCOS company [2]. It's a MEMS barometric sensor, its dimensions are only 2.78 mm x 2.23 mm. For our purposes (mainly modularity and future upgrades possibility) we used breakout board with this sensor that has dimensions of 2.6 cm x 1.8 cm. The sensor was selected mainly because of its technical qualities, as listed in the Table 2.

Table 2 Technical parameters T5403

Refreshing rate	15 - 100 Hz	
Supply voltage	1,7 - 3,6 V	
Supply current	0.8 mA	
Range	300 - 1100 hPa	
Resolution	2,9 Pa	
Outputs:	Digital:	
	SPI	
	I^2C	
Dimensions	Width	1,8 cm
	Height	2,6 cm
Operating temperature	-30°C to +85°C	

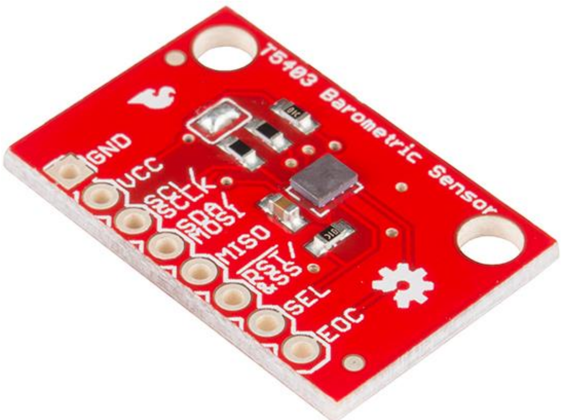

Figure 2 Barometric sensor T5403

3. ELECTRICAL SCHEME AND PCB

Since the development kit of the microcontroller is not suitable for our use, there had to be designed special printed circuit board (PCB) with required technical parameters.

After drawing up the sketch of the scheme, there had to be created a design project for the PCB in the appropriate software, and it can be seen in Figure 3. It is necessary to note that when the PCB is designed, there has to be respected the conditions and principles of PCB design, in other words the design rules in the sake of preventing future problems when testing and using the PCB.

Since the PCB is relatively simple, in the designed was used 2-layer PCB. The reason is also economic, for our particular application are sufficient for two layers and so the production costs are reduced.

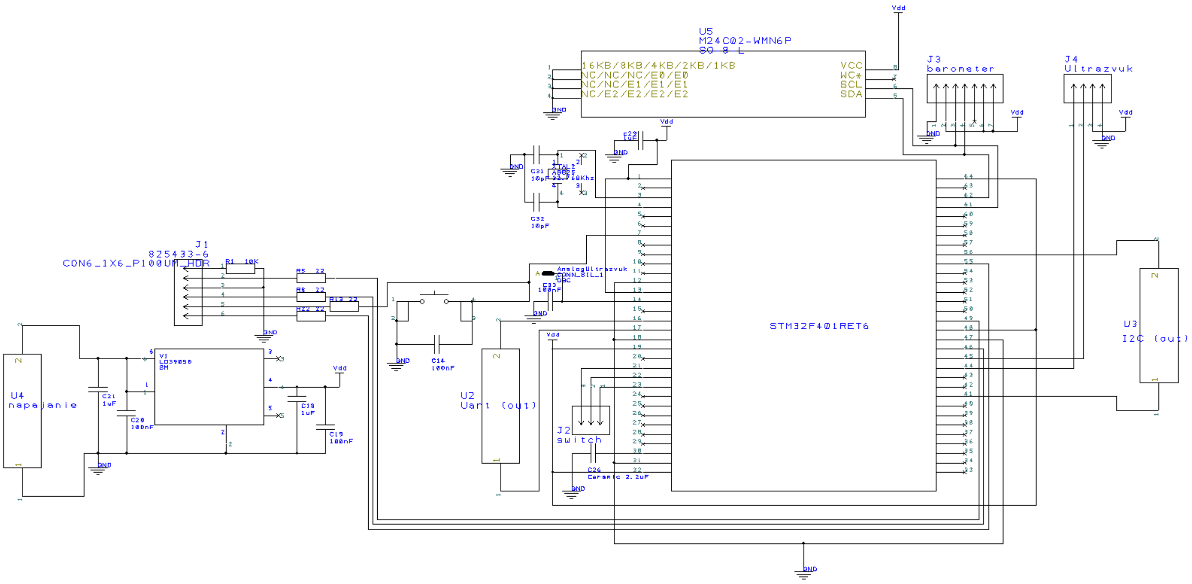

Figure 3 Electrical scheme

To clarify the below information, the color coding scheme: red - the top layer PCB, turquoise - bottom layer PCB, grey - holes for mounting screws or pins, green - the border part of PCB, yellow - electrically nonconductive label components, roads, etc.

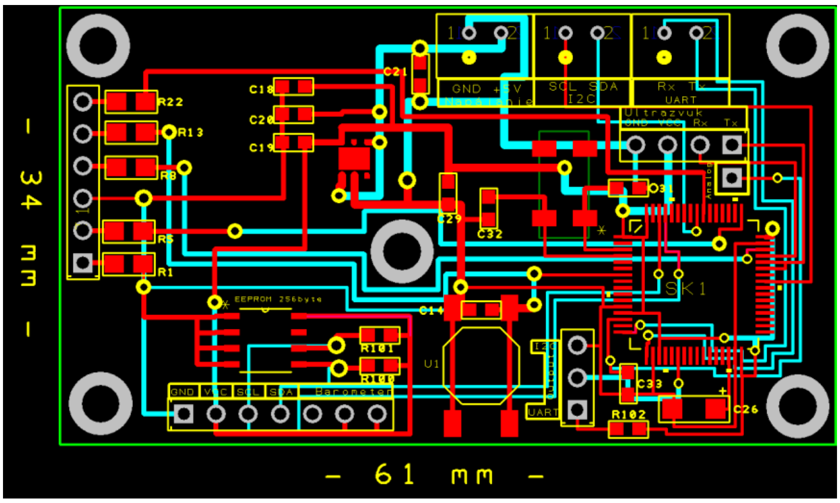

Figure 4 Printed circuit board

4. PROGRAM ALGORITHM

After designed the scheme itself with PCB is our module of altimeter system needed to revive. The program for the microcontroller STM32F401RE [4] was developed in the IDE online at http://developer.mbed.org/compiler/. The developed algorithm can be viewed in Figure 5.

The algorithm is designed for initializing the device with the EEPROM calibration constants and other required constants for proper system operation are loaded during the initialization, too. Then the program starts communication with the barometric sensor and reads its own integrated calibration constants that are later needed to calculate pressure. An endless loop starts after all of the constants are loaded and ready and the data are measured cyclically. After exceeding the 5 m height, there is no need to process the height obtained from the ultrasound sensor.

At first the program in the microcontroller determines whether the host system does have to send commands to adjust the constants, modification or other operation modes described below in this paragraph. After this the height is read via the UART bus. Subsequently, according to the read mode to the barometric sensor is fed temperature data because of the calibration pressure. After reading the temperature starts measurement of the pressure from the barometer. After processing of the integrated constants we can calculate the pressure data and use the additive and multiplicative constants for the barometer as well as for ultrasound. Depending on the engagement pin connection on the module, the data will be sent via UART or I2C bus.

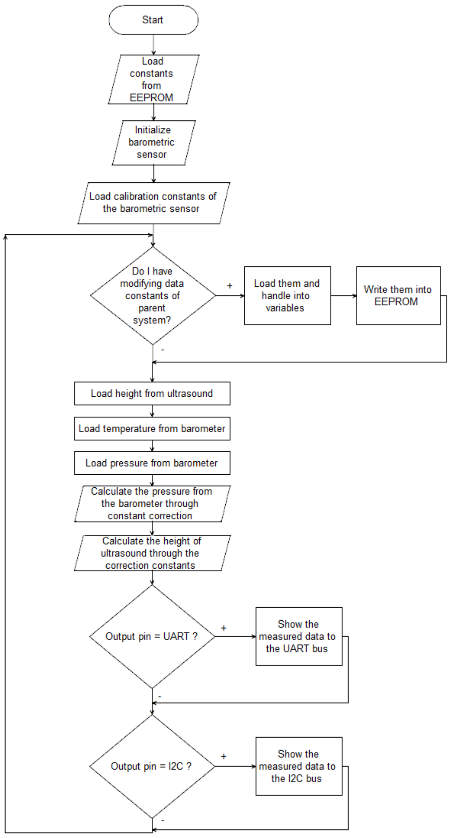

Figure 5 Program algorithm

5. TEST MEASUREMENTS

There was performed only the barometric sensor's test, since there were complications with the supplier of the ultrasound sensor in the time of writing this article. The ultrasound sensor should be evaluated in the future.

Laboratory test of the barometric sensor was performed after programming the source code for the microcontroller. Barometric sensor was tested according to ISO 2533 standard atmosphere [5]. The measurements were made in the vacuum chamber at the Department of Avionics at the Faculty of Aeronautics. The measurements were carried out 3 times with different settings of the simulated height. The simulated height was picked systematically, bearing in mind possible heights the UAV could achieve.

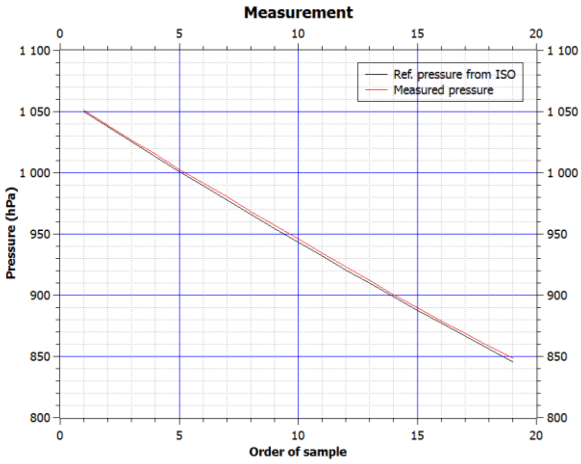

Figure 5 Measured data

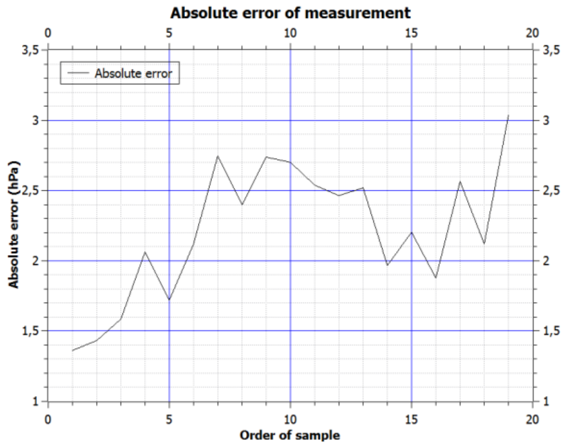

Figure 6 Absolute error

From these measurements, the slightest error occurred during the range of heights from 0 to 500 meters above sea level which are very favorable results because these altitudes above the sea level is very often used by multicopter UAVs. It is necessary to minimize the absolute error, which is located on the total pressure measurement range. After processing [6][7], measuring and verifying of the test data, the calibration constants based on measurements are: multiplicative constant of the barometer T5403_KM = 0.99794 Pa/digit and additive constant of the barometer T5403_KA = 1.98314 Pa.

6. CONCLUSION

The aim was to design a functional module altimeter system based on the selected methods of height measurement. The modular altimeter system based on barometric and ultrasound (reflective) height measurement was designed and tested.

Despite the unavailability of the ultrasound device, according to the datasheet the simulation was performed successfully, following there is a presumption of a high probability that the sensor will work without complications.

This altimeter module can be used as the sensing element for unmanned systems with the intelligent application in the area of autonomous UAVs. The designed modular altimeter system can serve primarily to help to stabilize the multicopter UAVs (but not only this type of UAV), navigation in an unfamiliar environment or as part of a landing system. The advantage of this module is that at low speeds the UAV using this system will be able to copy the terrain, which is a significant benefit for practical autonomy means.

ACKNOWLEDGEMENT

This work has been supported by the grant agencies of Slovak Republic under the grants KEGA 028TUKE-4/2013, VEGA 1/0286/13 and APVV-0266-10.

LITERATURE LIST

References

[1] Datasheet MB7360. Reachable in internet: <http://www.maxbotix.com/documents/HRXL-MaxSonar-WR_Datasheet.pdf>
[2] Datasheet T5403. Reachable in internet: <http://cdn.sparkfun.com/datasheets/Sensors/Weather/T5400.pdf>
[3] Vít Záhlava: Návrh a konstrukce DPS, princípy a pravidla praktického návrhu. Technická literatura BEN, 2010. 128s. ISBN 978-80-7300-266-4
[4] Datasheet NUCLEO STM32F401RE. Reachable in internet: <http://www.st.com/st-web-ui/static/active/en/resource/technical/document/user_manual/DM00105823.pdf>
[5] ISO 2533:1975, Standard Atmosphere, 114 p.
[6] EVANS, J.R., running median filters and a general despiker. Bulletin of the Seismological Society of America, 1982. p. 331-338.
[7] STONE, C.D., Application of median filtering to noisy data. Canadian Journal of chemistry, 1995. Reachable in internet: <http://www.nrcresearchpress.com>, p.1573-1581.