SMALL UAV FLIGHT PARAMETERS REGISTRATION USING SYSTEM BASED ON STM32 MICROCONTROLLER

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Abstract. Along with the analytical and numerical investigations the experimental research of Small and micro UAV is of great interest. It enables to obtain necessary data and to prove or disprove the theoretical and numerical results and theories. Sometimes the experiment is the only possible way to obtain the data required.

One of such experimental researches is the investigation of aircraft disturbed motion. These studies require technical devices able to measure dynamic parameters of aircraft movements and register the position of control surfaces. These data provide information about flight dynamics of apparatus.

Integrated flight parameters registration system is described. Device developed includes three-axis accelerometer and three-axis angular rate sensor, microcontroller as control unit and micro SD flash card to record achieved data.

Calibration procedures were performed to obtain the reliable flight parameters. Operation process is controlled by microcontroller STM32 that achieves data from analog to digital converter connected to sensors, analyses PWP signals that controls servo machines to get servo's position and finally records all parameters to micro SD card with the rate of 200 Hz. This measuring system might be applicable to perform experimental research in the field of dynamics of small unmanned air vehicles, and might be used as a part of autopilot system. Prototype of the device has a weight of 60 gram and it is able to record accelerations up to 3.6g, angular rates up to 500 degrees per second and 4 channel servo-machines position. These characteristics turned out to be enough for the research of UAV dynamics.

Experimental results of disturbed unsteady movement of small UAVs are presented. Experimental series include observations of small helicopter interaction with horizontal surface ("ground effect").

Keywords. Small UAV dynamics, flight parameter registration.

1. Introduction

Small unmanned aircrafts have been concerned as models for a long time and were used in sport and entertaining activities. Grate progress of its performance was achieved through numerous competitions between aircraft models sportsmen. A model design is based on compromise of general aerodynamics, dynamics principles and great usage experience. Past decades small unmanned air vehicles (UAVs) started to be interesting for civil and military uses. In this case new demands arose concerning UAV's flight endurance, autonomy and maneuverability.

Progress of microelectronic devices made it possible to accomplish onboard measurements and data storage using small, low power consumption, high speed microcontrollers, which provides the efficient 32-bit calculations. These microchips equipped with wide range of peripheral units such as timers, build in data transfer interfaces (USART, SPI, SDIO), analog to digital converters and considerable amount of flash memory enable developers to create system on chip devices suited to serve researcher needs. In addition late progress of MEMS devices result in appearance of numerous tiny accelerometers and angular rate sensors at the markets. These two technology achievements plays important role in aircraft research and development where critical parameters are weight and size of onboard equipment.

Small unmanned air vehicles development is connected with different researches. One application of small size and low cost registration system is the investigation of unsteady movement of UAV.

2. Measurement system description

STM32F103 microchip is a main operating unit of our system. This RISC processor is built on ARM Cortex M3 architecture. Its operating frequency (up to 72 MHz), considerable amount of programming Flash memory (512 Kbytes) and 48 Kbytes of SRAM provides good asset for data achieving, handling and storing.

Movement sensitive devices are set up on board IMU from commercially produced autopilot system ArduPilot from DIY Drones[1]. It includes small, low power, 3-axis ±3g accelerometer ADXL335[2], yaw angular rate sensor, ±500 ^{o}/sec ISZ-500[3] single-axis Z-Gyro, and ±500 ^{o}/sec IDG-500 dual-axis Z-Gyro. Board is also equipped with 12-bit, 8-channel analog to digital converter (ADC) ADS7844[4]. Inertial sensors are connected to ADC which is connected to microcontroller via 4-wire SPI interface. Build-in timers of microcontroller are included into PWM registration unit of registration system. Outputs of the receiver are connected to pins of the controller to record servo control signals. Sensors and ADC cooperation resulted in total sensitivity 2,4 mg/LSB for accelerometer and 0,4 ^{o}/s/LSB for angular rate sensor.

As measurements storage device microSD card is used. Processor STM32F103 includes Secure Digital Input Output interface controller. It provides an opportunity to use microSD card at high record speed.

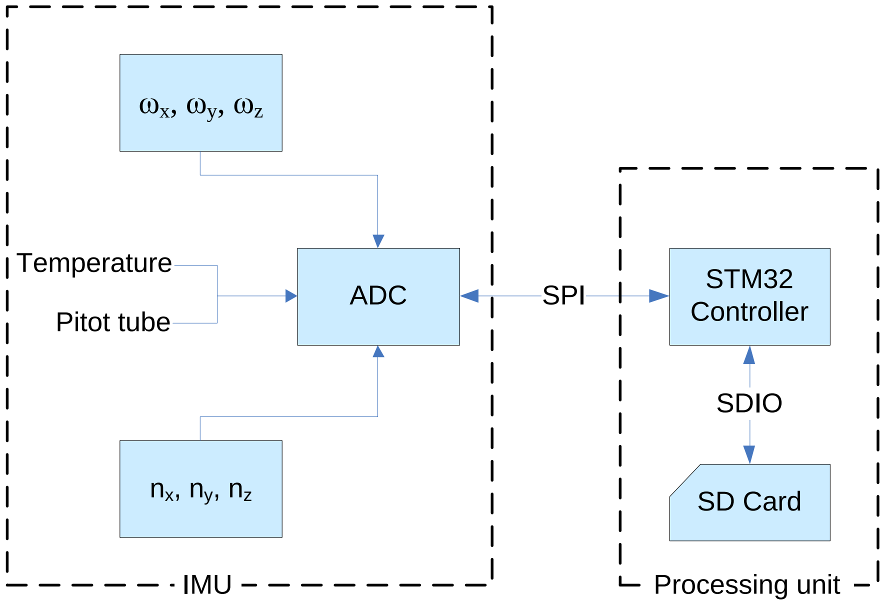

Figure 1. Hardware scheme.

Principal scheme of hardware connections is depicted at Fig.1. Microcontroller directs information stream from sensors to the microSD memory card.

The software part of the registration system involved was written with the C programming language via Keil μVision V4. The latest version of the compiled hex-file has the size of approximately 200 kByte, while the microcontroller flash capacity is 512 kByte. The software developed has the next main features:

- Configured SPI channel to send and receive data to/from the sensors board;
- Configured UART channel to communicate with the PC-station via RS-232 – USB bridge;
- Convenient terminal with the command line for real-time monitoring and operating the registration system;
- Configured interface to communicate with the SD card;

At the next figure you can see the main function flowchart:

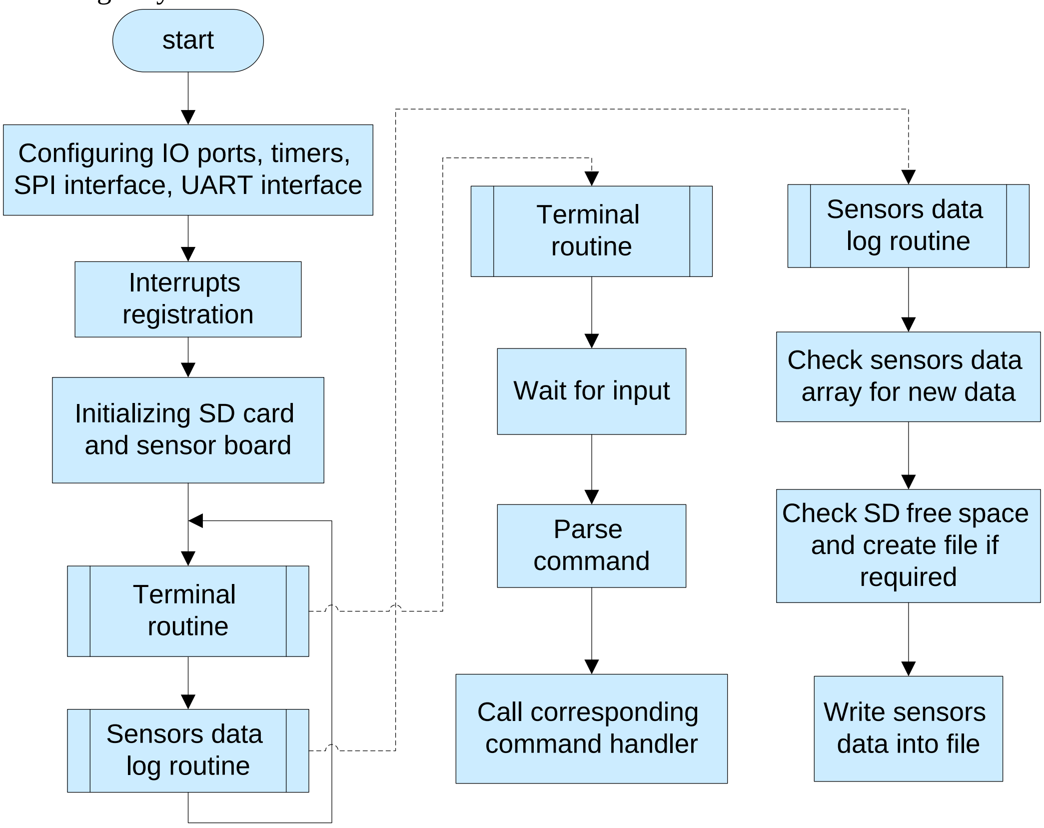

Figure 2. Software main function flowchart.

Software structure is consisted of the first order functions (interruptions handlers) and ordinary consecutive functions (those which called one-by-one in a main function cycle). The need of the first order functions is appeared due to the number of purposes: to generate PWM signal, to read input PWM signal parameters, to receive readings from the sensors board. The first order functions were realized via interruptions mechanism of STM 32.

To perform the output PWM signal embedded timer was used. Having 1 timer with 4 channels 4 PWM signals with equal periods, but free value of duty cycles can be generated. The data collected by sensors board may be written on SD card into files of FAT32 file system. Also a sort of a terminal with a command line allows developer to control STM32 board by the means of the text commands via PC.

3. Calibration procedure

Sensitivity calibration of the sensors used was performed with the help of the etalon inertial measurement unit. This system was a least three times more sensitive and well calibrated. Our IMU board was mounted onto etalon align its axis and simultaneous data achieving was performed. Data obtained gave information about IMU sensitivity.

Datasheets of the inertial sensors used include information about sensitivity and “zero” output voltages corresponding to the zero projections of acceleration vector or angular rate vector to the specified axis. However measurements have shown that “zero” readings differ from that written in documentation. In case of angular rate sensor calibration zero basic level measurements is not a big problem, if there is no aim to measure small angular rates up to the Earth’s rotation speed. In case of accelerometers basic levels measurements are not such easy because gravity affects sensor readings. For the gravity effects to be separated inertial sensor were tossed up in the air several times and during it’s free fall acceleration data were achieved. As shown in fig. 3 regions of free fall are easily seen. As a result zero voltage levels deviation from zero voltage level (1,5 V) is about 10%. Tossing turned out to be efficient way in accelerometers calibration.

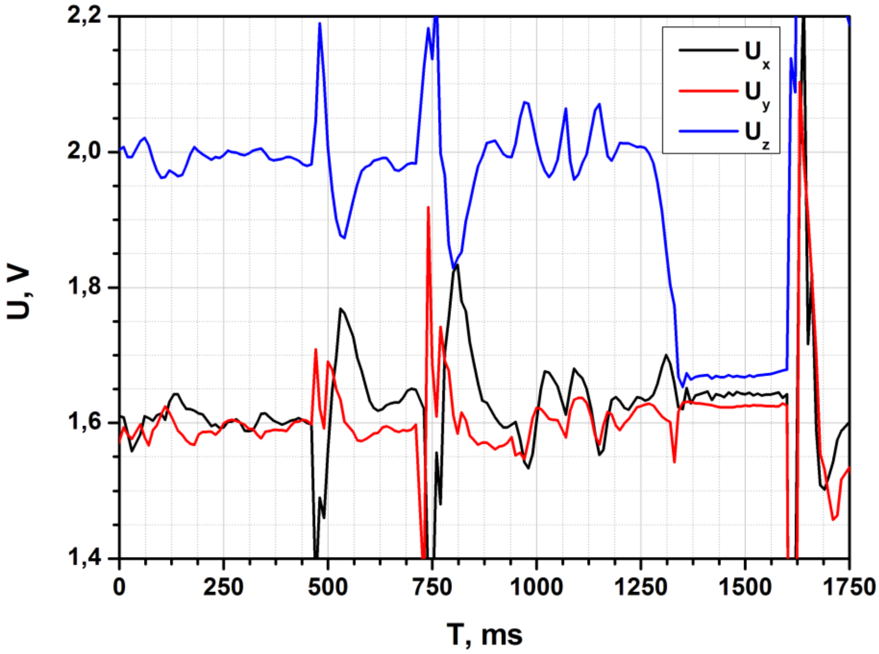

Figure. 3. Accelerometers output voltage.

4. System application

System developed was applied to measure “ground effect” phenomena in small helicopter dynamics. Flight experiments were carried out in a large room, so atmospheric disturbances were removed. 35 cm span coaxial propeller small radio controlled helicopter had total weight of 315 g. Measurement process consisted of successive hovering actions followed by manual flat solid plate placing under the helicopter at a distance about 5 cm. These actions introduced “ground effect” conditions.

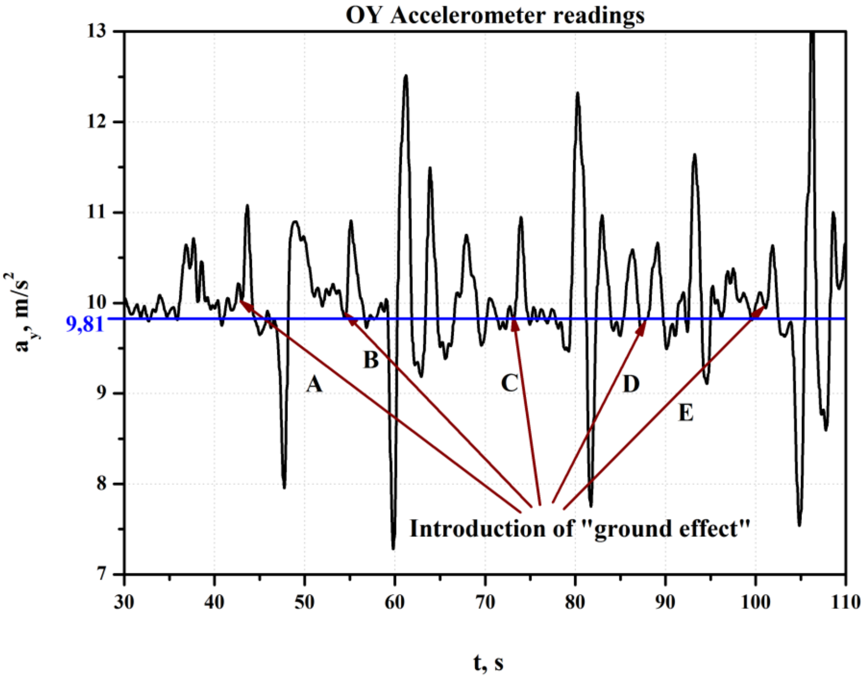

Figure 4. Vertical axis accelerometer readings.

Figure 4 represents typical experimental data. Each flight cycle was about two minutes long and it included 4-6 “ground effect” introductions. Before the analysis experimental data were FFT filtered with 10Hz cutoff frequency.

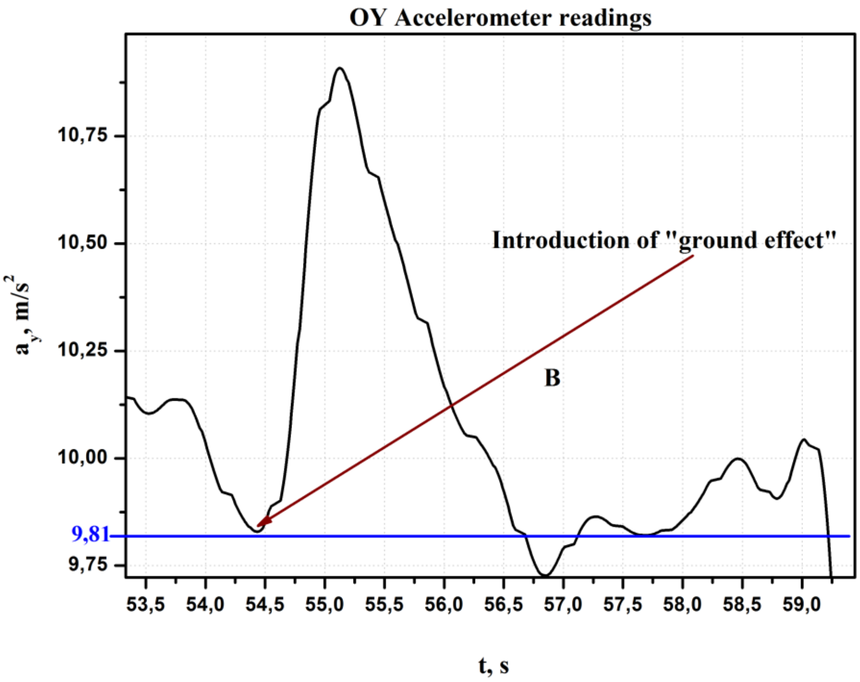

Figure 5. Detailed readings of “ground effect” introduction.

Figure 5 shows detailed picture of accelerometers readings during the “ground effect” introduction. Front edge slope edge is a very steep due to immediate flat plane placing. Trailing edge is proportional to the ΔT – the difference between thrust at hovering regime (T_{inf}) and the effective thrust influence by the “ground effect”. Double integration of this signal gives an information about the distance of the helicopter above the surface.

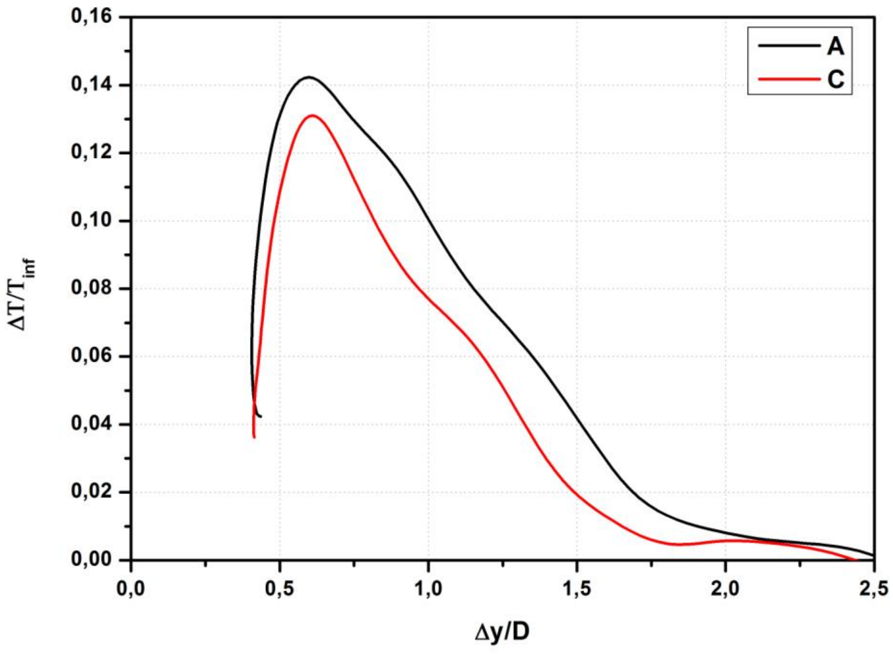

Figure 6. The dependence of thrust ratio to the distance from the surface (Δy) vs. airscrew diameter (D).

This information provides the ability to derive the curves presented at Figure 6. There are two best matching experimental curves of the ground effect introduction. These curves are of the same order and slope with the theoretical analysis based on vortex airscrew model given at [5].

5. Conclusion

Basic principles of the sensors usage and flight experiment were practiced during the work.The system developed has shown the ability to measure correctly small UAV unsteady movement as “ground effect” interaction. It can be used for flight parameters registration at the helicopters and small planes. The system involved may be used for numerous research purposes such as control system synthesis, dynamic and aerodynamic characteristics analysis. All of these tasks are interested for research and development of MAV[6,7].

The system can be improved in further directions: weight decrease for micro UAV, precision increase for long endurance MAV and reliable measurements, performance increase for high maneuverable systems.

Acknowledgment

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Reference

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