

SIMULATION OF THE FLIGHT HEIGHT CHANGE OF A SMALL AIRCRAFT EFIS SYSTEM

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Abstract. The presented article briefly describes the creation of a functional stand device of the EFIS system intended for simulating height changes of small aircraft. The procedure for the preparation of the workplace, a description of the design, implementation, and program management of the simulation of the required input parameters, which can be monitored in real-time on the display unit of the device, is presented. The created user interface, which is in the Slovak language, turns the stand device into a study aid for students of the Faculty of Aeronautics, the Technical University of Košice, especially for students of the Department of Avionics.

Keywords: EFIS; interface; simulation; stand device; study aid

1. INTRODUCTION

Technologies that are almost invisible to the lay observer are behind the progress of avionics and aeronautical technology. For example, avionics instruments have a crucial role in flight safety, efficiency and reliability, as they maintain and control the aircraft's stable position and power control while also serving communication and navigation purposes.

The development of avionics devices went from the zero generation through the first generation, which mainly included the devices of combat aircraft of the Second World War, smoothly to the second, post-war generation, which united jet-powered aircraft. Until the 1960s, avionics were primarily in the form of electromechanical flight instruments, with each display element, dial, intended to display one piece of information – for example, airspeed indicator, attitude indicator, altimeter, radio altimeter, turn coordinator, heading indicator, and vertical speed indicator [1]. These instruments worked on basic physics principles, but for maintenance staff and pilots, it was a hazard to health because these dials emitted radiation spontaneously [2].

The second half of the seventies of the last century represented an imaginary border for the emergence of the third generation of devices, characterized by the use of the first digital technology - microprocessors and computers. It is the use of information technology that makes it much easier to capture, receive and process the information obtained. Instead of the separate management of data on quantities to special dials, the collection of multiple data from sensors on data buses is used, from where they are subsequently transmitted to multifunctional avionics devices.

Nowadays, Integrated Modular Avionics (IMA) is used in most modern transport aircraft. It created a new standard for connection and communication between onboard avionics systems. Its main goal is to incorporate most aircraft functions into standardized modular units working with each other in a network, thereby simplifying data transport and reducing possible failure rates and the weight of the necessary cabling [3].

These separate devices, dials, have been the subject of many studies and research dealing with reliability, functionality and the possibilities of improving and innovating individual aircraft instruments – dials (such as radio altimeter, which was the main object of many researches of our author's team [4, 5]), but also creating simulation models of individual aircraft instruments, or whole aircraft [6, 7, 8].

An ever-increasing number of monitored and displayed data, with which the pilot is constantly confronted during flight, a change in the method of their transmission and the modernization of their former electromechanical presentation to an electronic one paved the way for the creation of the Electronic Flight Instrument System (EFIS) [9, 10].

It is this combined system of electronic flight instruments, specifically its version for small light sports aircraft, that is dedicated to the presented article, especially the practical and experimental part, in which the electronic flight information system EFIS - D100 from the manufacturer Dynon Avionics will be used and transformed into a stand device for simulation purposes changes in altitude as it happens in the flight of an aircraft. The stand device created in this way, designed to simulate a change in flight height, will be programmed and controlled through a straightforward user interface.

2. PRINCIPLE OF OPERATION OF THE EFIS SYSTEM

Modern aircraft belonging to the category of small sports aircraft have implemented advanced instrumentation, which can also include the EFIS system. This system provides information about the position, flight speed or vertical speed, flight height, the aircraft's pitch or the way the turn is performed. It can also include a moving map - navigation with the ability to plot terrain and surrounding traffic, an offer to display weather information, engine data (if an additional ECAM system is available, connected to the EFIS system) and all this on one or two LCDs. As a result, EFIS has become a reliable and relatively cheap replacement for classic electromechanical and gyroscopic avionics devices. A significant advantage of this system is the relative lack of maintenance, especially compared to mechanical instrumentation [11].

2.1. Monitored parameters and displayed values of the EFIS system

The Electronic Flight Information System is a system used to display electronic flight instruments in the cockpit area. It is a modern system implemented in newer third-generation aircraft; information began to be transmitted digitally from the initial analogue form.

The EFIS system, implemented in modern aircraft, uses symbol generators connected to two independent displays (one for each pilot), usually located in the centre of the instrument panel. Symbol generators obtain data from the aircraft's position and navigation systems. Each pilot can individually select their own display mode or screen functions through the display controls. In case of failure of one of the two primary symbol generators, the third backup symbol generator is ready to replace the faulty generator fully automatically, without the need for pilot intervention.

In modern aircraft, it is most often possible to meet the EFIS system, consisting of two parts:

1. Primary flight display (PFD) – Electronic indicator of basic flight information + artificial horizon (EADI);
2. Navigation Display (ND) – Electronic Horizontal Position Indicator (EHSI) [12].

2.2. EFIS-D100 device

The Dynon Avionics EFIS-D100 system was chosen for the stand equipment. When describing the function of the device itself and displaying flight data, it is, therefore, desirable to focus on the type of Electronic Flight Information System chosen by us.

The source of information about the aircraft's position are three fixed gyroscopes and three fixed accelerometers supplemented with data from the dynamic pressure sensor. Three fixed magnetometers stored in the EDC-D10A devices are used to provide information about the direction of the aircraft's movement. The device also contains three separate pressure sensors used to determine height, speed and angle of attack. After processing in the symbol generator, this information is displayed on the Primary Flight Display (PFD) [13].

3. DESIGN OF THE STAND DEVICE WITH EFIS-D100 AND PREPARATION OF THE METHOD FOR SIMULATION OF THE REQUIRED INPUT PARAMETERS.

The idea of implementing the stand equipment of the EFIS system arose from the need to bring modern aviation instruments and their functions closer to students of aviation technical fields. In this case, it is not a bench device used for calibration purposes, for which very high accuracy, reliability and repeatability would be required, but it is a study aid, the task of which is to approximate the function of this avionics device, which is otherwise located on onboard the plane. The EFIS-D100, as mentioned earlier, was chosen for this purpose. The description of main components mounted on the printed circuit boards of a specific device is described in the following subsection.



Figure 1 EFIS-D100 front and back view of the device [Author]

The selected device is delivered in a duralumin box, which can be quickly built into the aircraft instrument panel. On the back of the box, there is a hole for the power connector and a trio of holes for the static pressure (STA), pressure obtained from the pitot tube (PITOT) and pressure data from the angle of attack (AOA) sensor.

After dismantling the duralumin box itself (Fig. 1), which is attached around the perimeter and sides with fifteen screws, the internal structure of the device is visible, which consists of two bare printed circuit boards (upper and lower), the connecting printed circuit board on the right side and the LCD, which is located in a frame with built-in buttons

3.1.1. EFIS-D100 device - top printed circuit board

The top printed circuit board (Fig. 2) primarily powers and controls the LCD unit. The essential components located on this printed circuit board are marked with numbers. This includes the connecting connector for the LCD (1), RAM and symbol generator for the LCD (2) and high-voltage semiconductor transformers for powering the backlight - CCFL tubes (3). Symbol generation for the display unit is provided by the System on Chip (SoC) LH79520 [14].

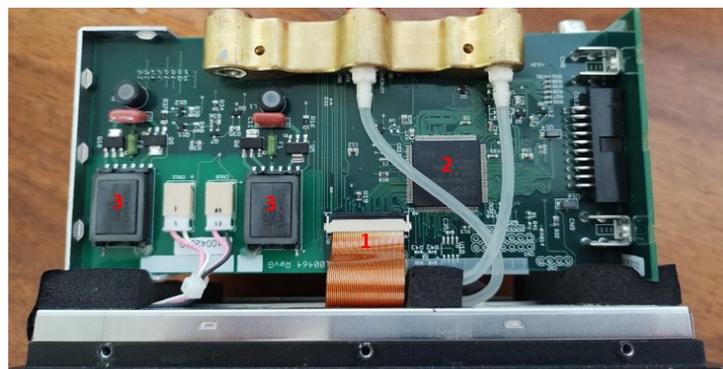


Figure 2 View on the top printed circuit board of the EFIS-D100 device [Author]

3.1.2. EFIS-D100 device - lower printed circuit board

The bottom printed circuit board (Fig. 3) is equipped with components for receiving and processing data from sensors, such as three fixed MEMS gyroscopes and three fixed MEMS accelerometers - located together (4) or pressure sensors (5). In addition, a source (6) is also located at this location, which transforms the voltage from 12 V to the partial voltage needed to power specific sensors.



Figure 3 View on the lower printed circuit board of the EFIS-D100 device [Author]

In the previous figure, it can be seen that three fixed MEMS gyroscopes and three fixed MEMS accelerometers (4) are placed on a common position sensing platform orthogonally in three axes – one pair for each axis (X, Y, Z).

The SM5470 and SM5430 pressure sensors used by Silicon Microstructures are designed for direct surface mounting and offer a wide range of pressure measurement ranges. The low-pressure series (sensor model SM5470) uses the unique Silicon Microstructures technology – the low-pressure die enables high resolution in the pressure range from 0.15 PSI (equivalent to 1.03421 kPa) to 3.0 PSI (equivalent to 20.68427).

The SM5430 pressure transmitter model is supplied as a differential and absolute pressure gauge for pressures ranging from 5 PSI (equivalent to 34.47379 kPa) to 60 PSI (equivalent to 413.68544 kPa) over the entire range. For comparison, the pressure value determined according to the International Standard Atmosphere at sea level and a temperature of 15°C reaches a value of 101.32500 kPa [15].

The printed circuit boards used in this device have passed the UL 94 flammability test. This is an independent plastic flammability test in which a plastic rod of prescribed dimensions is burned according to UL test procedures. Circuits built on printed circuit boards that comply with UL 94 V-0 standards are ideal for the manufacture of rugged electronic equipment and equipment that will be exposed to significant changes in ambient pressure during operation - as is the case in aerospace applications [16].

4. SIMULATION OF THE INPUT PARAMETERS – HEIGHT CHANGE, ALTIMETER

The chosen parameter for the simulation is the simulation of the flight height by the method of changing the static pressure. Since the change in height does not occur in real life, the required change is controlled by the program described in the following subchapter, based on the change in the voltage value, which is measured by a potentiometer firmly connected to the adjusted piston of the syringe, performing a simulated change in static pressure [17,18,19].

The movement of the piston in the syringe is provided by the EPSON EM-178 stepper motor, controlled by the A4988 stepper motor control module (Fig. 4).

We consider a stepper motor to be a commutator-less DC motor, consisting of a rotor and a stator, in which the whole shaft revolution is divided by 360° into a fixed number of steps - these results from the design of the motor in question. For example, if the number of steps determined for one full revolution equals 200 steps, one step corresponds to 1.8° of shaft rotation since $200 \times 1.8^\circ = 360^\circ$ [20, 21].



Figure 4 EPSON EM-178 stepper motor and stepper control module engine A4988 [Author] [22] [23]

The stationary part of the stepper motor - the stator and the movable rotor, located on the shaft in bearings, rotates in the magnetic field that is created around the stator. The stator, which is often made of steel but often of another metal, forms the framework for the electromagnets - coils mounted in precisely determined places around the rotor. If the current flows through the stator coils, a magnetic field is created in their vicinity; the magnetic flux's direction and intensity depend on the current flowing through the given coil [20, 21].

In simple terms, stepper motors use a gear wheel and electromagnets to turn the wheel step by step. Each high pulse energizes the coil, pulling the nearest gear teeth to itself and rotating the motor one step. The way in which the pulses are generated for the coils significantly affects the operation of the motor as follows:

- The sequence of transmitted pulses determines the direction of rotation of the motor,
- The frequency of the pulses determines the speed of rotation of the motor,
- The number of pulses determines how many revolutions the motor turns [20, 21].

The A4988 module, as mentioned earlier, shown in the previous picture (Fig. 51), represents a simple interface that allows controlling the motor's steps and direction of rotation. It works in the voltage range from 8 V to 35 V, and without additional cooling, it can supply a current of 1.2 A per phase; with sufficient cooling, it can be up to 2 A per phase. The control module offers five different step resolutions – full step, half step, quarter step, eighth step and sixteenth step. It also has built-in protection against overheating or under-voltage [21].

The use of a stepper motor, in combination with a control module, was a clear choice in the case of the required simulation, as it was necessary to determine the position of the shaft accurately and at the same time it was necessary to carry out a precise control of the movement of the piston.

The creation of a 3D design and a process of 3D printing of the piston itself, meeting the requirements for the exact shape and size, the style of attaching the threaded rod to the shaft of the stepper motor and connecting it with the piston itself, or the method of rectilinearly guiding the movement of the piston in the designed holder and simultaneously acting on the linear potential, which could not be solved in one step. This is demonstrated by the attached image (Fig. 5), which records a piston's development and manufacturing process that meets all our criteria.

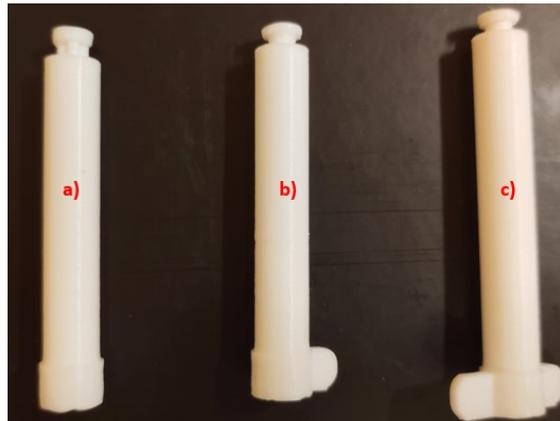


Figure 5 The process of development and production of a syringe piston used to simulate a change in flight height - without side guide a), with one side guide b) and with double guide c) [Author]

The piston shown in the previous picture (Fig. 5), marked with the letter a), was an initial design used to test the size, shape, method of fixing the threaded rod to the piston, and, last but not least, the possibility of testing the fluidity of movement and sufficient sealing in the syringe itself, used for simulation pressure.

The piston marked with the letter b) represented the idea of guiding the movement of the piston in the designed holder in only one direction, without simultaneous movement, which would represent the input for the linear potentiometer. The design of the stepper motor holder and piston syringe with one-way guidance in Autodesk Fusion 360 and its real version, which is the result of 3D printing, is shown in the following figure (Fig. 6).

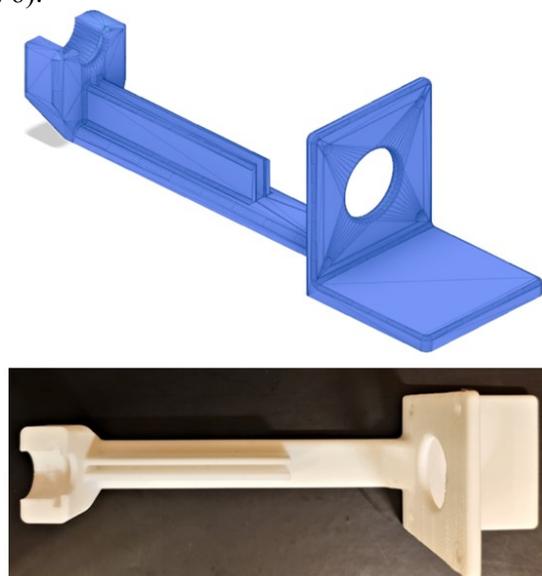


Figure 6 Design and realization of a stepper motor holder and a syringe with a piston with a guide in one direction [Author]

Guiding the piston in one direction was sufficient in terms of straightness of movement, but when performing a strength analysis, simulated in the Autodesk Fusion 360 program (shown in Fig. 7) and in real conditions - measurement with a load cell (the measured force value was equal to 6.5 N), it was found, that when such a force is applied to the syringe, during the simulation of a change in height, the frame in which it is fixed bends. There was also a need to sense the current voltage level with a linear sliding potentiometer, which required the improvement of the design of the piston as shown in the figure (Fig. 5) in point c) and thus the modification of the holder of the simulation device itself – fixing the syringe on both the bottom and the top handle (Fig. 9).

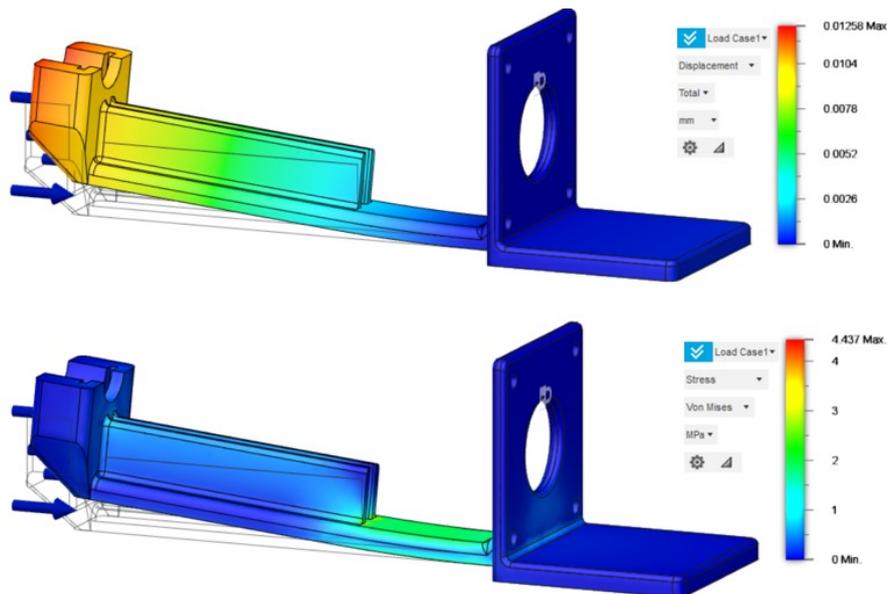


Figure 7 Strength analysis of the holder under the action of the force (pull) of the rotary motor on the piston of the attached syringe [Author]

A comparison of the design of the syringe piston used to simulate the change of static pressure, with the piston with the designed guide in two directions in the Autodesk Fusion 360 program and its real version, which is the result of 3D printing, is shown in the upcoming figure (Fig. 8).



Figure 8 Realization and design of a piston with double-sided guidance [Author]

The third version of the piston, visualized in one previous image (Fig. 8) and the image comparing the development and manufacturing process of the syringe piston (Fig. 5), marked with the letter c), is the final product used in the syringe used to simulate pressure change d), controlled by the stepper motor e) and its position is evaluated by sensing the voltage by the potentiometer f) as shown in the attached picture (Fig. 9).

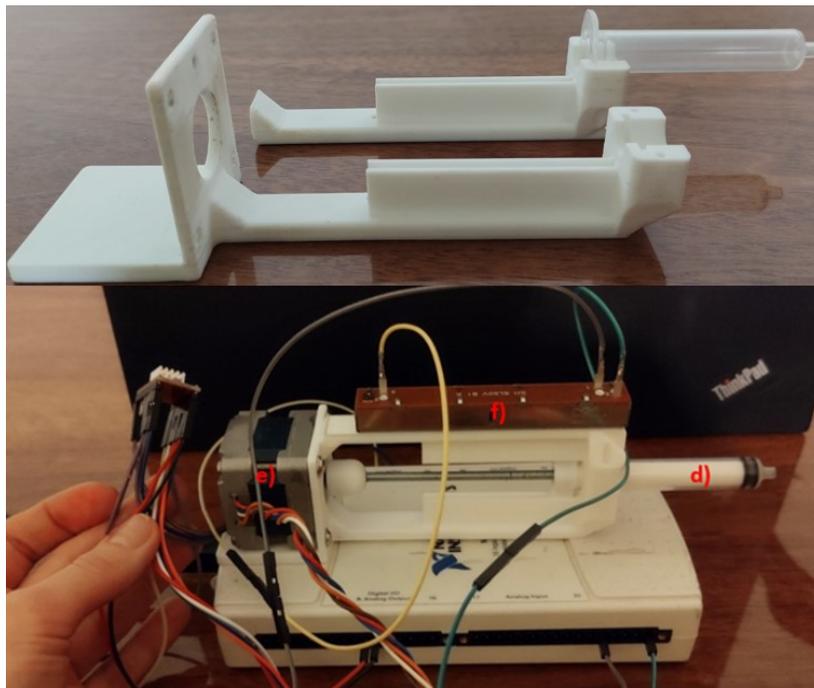


Figure 9 The final version of syringe holder with dual lead piston d), stepper motor e) and potentiometer f) [Author]

The resulting form of the simulation part of the workplace for controlling the change in flight height is shown in the following figure (Fig. 10). The workstation consists of the already mentioned components, namely the EPSON stepper motor EM-178 linked and controlled by the A4988 stepper motor control module. This linear potentiometer voltage sensor is controlled by the side guide of the syringe piston, which causes a change in the applied pressure. The output from the syringe is led through a rubber tube to the SM5470/SM5430 pressure sensor of the EFIS output device, on the screen of which the change in static pressure is made for the change in flight height. In order to control the simulation through an interface designed for intuitive use by students, all components are connected to a DAQ bus multifunction signal processing device NI USB-6216, which is connected via a USB cable to a computer running the control program simulating the change in height flight [17, 18, 19].

The primary source of electrical energy for powering the simulation workplace is a SmartLine SL 700 uninterruptible power supply (UPS). This intermediate element was chosen mainly because of the need to obtain a stabilized output voltage value (230 V and 50 Hz \pm 1 Hz) with protection against overvoltage and also because of the possibility of power supply workplace in the event of power outages or drops, which often occurred during the creation of the workplace.

A DC voltage of 12 V / current of 1.5 A is supplied to the non-soldering field via a power source that draws electrical energy from the UPS, which powers the EFIS-D100 device as well as the EPSON EM-178 stepper motor.

A laptop, a Lenovo Thinkpad 7663 - CTO, running the simulation program and connected to the DAQ, also draws electricity from the UPS.



Figure 10 A simulation workplace controlling the change in flight height [Author]

4.1 Program part of simulating flight height - altimeter

For the reliable functionality of the simulation program, in addition to the correct setting of the sequence of commands and conditions executed by it, it is necessary to work with high-quality obtained and processed input data.

In the case of a simulation of a change in flight height, in order to obtain such data, it was necessary to perform several series of measurements used to determine the interval of voltage values corresponding to a specific value of the flight height during the ascent and descent of an imaginary aircraft. The obtained values are subsequently implemented as decision variables in a program designed to control the change in imaginary flight height.

Since the EFIS-D100 device works with a static pressure value, the current pressure value at a given location is not negligible, nor is the height at which the device is currently located. Measurements used to obtain the necessary input data for the simulation program were carried out in Košice. During the measurement, the air pressure corresponded to a value of 102 300 Pa (1 013 hPa), altitude 206 m (rounded 676 ft). During the measurement, the device was located in a high-rise building, specifically on the 12th floor, corresponding to a height of 35 m (rounded 114 ft) above ground level. The static pressure value was entered directly into the EFIS instrument - D100 (1023 hPa), which made the display show the current altitude at which the device is located - 790 ft, which corresponds to the sum of the altitude of the given location and the altitude of the location of the device. During the test measurements, this height was considered the zero (reference) height from which the imaginary climb of the aircraft was possible.

The imaginary reach of the aircraft was limited to a height of 17 000 ft (5 181.6 m) for the simulation, taking into account the real use of the EFIS - D100 device mainly in small sports aircraft, which do not reach such a flight height during their standard operation. By limiting the maximum access, the range needed for simulation measurements was determined and used to determine the voltage value corresponding to the given height - from 790 ft to 17 000 ft, with a step of 100 ft. A total

of 163 height changes were made in one series of measurements with a recorded voltage value when climbing from a height of 790 ft and the same number of height change measurements, i.e., 163 when descending from a height of 17 000 ft.

The measurement environment was designed and implemented through a control program in the LabView environment (Fig. 11), the task of which was to extend the piston of the syringe as it rises and retract it as it descends, which causes a change in pressure, which simulates a change in height on the display of the EFIS device. As indicated, the measurement was made in 100 ft increments (equivalent to 30.48 m) and the corresponding voltage value, measured by a sliding potentiometer, and converted to a numerical value displayed on a computer display via an NI USB-6216 bus multifunction device, was recorded only after complete stabilization to the required amount.

Were made 326 changes in height, ascent and subsequent descent were made in one series of measurements. Altogether, three series of measurements were made, which means 978 changes in the height with step 100 ft, with a total duration of all height measurements and their corresponding voltage values, of more than 20 hours.

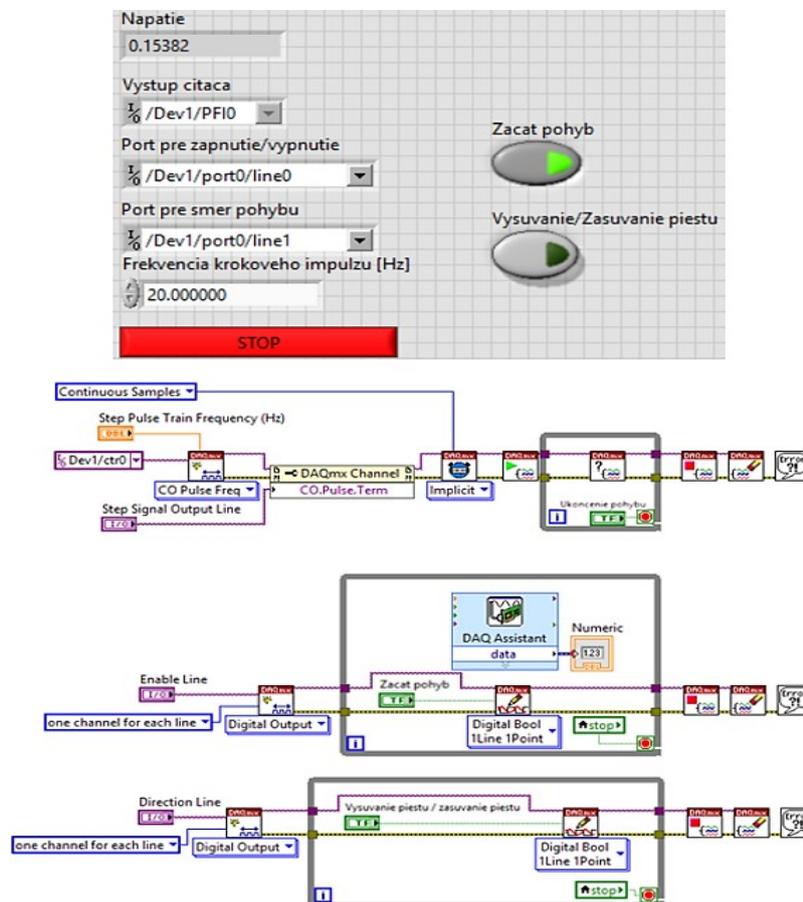


Figure 11 Interface and block solution of the program used for simulating the change in height step by step and recording the resulting voltage [Author]

The obtained data were recorded in several tables and averaged, and then hysteresis was calculated from them. A graphical course (Fig. 12) of voltage changes during rise (blue curve) and descent (red curve) was drawn with the use of a shorter - 25 cm tube intended for conducting pressure to the device.

The voltage values obtained in this way form an essential part of the program part for the simulation of the height change controlled by the voltage change, controlled by the student by selecting the request on the interface, as shown, and described in the following part of the presented article.

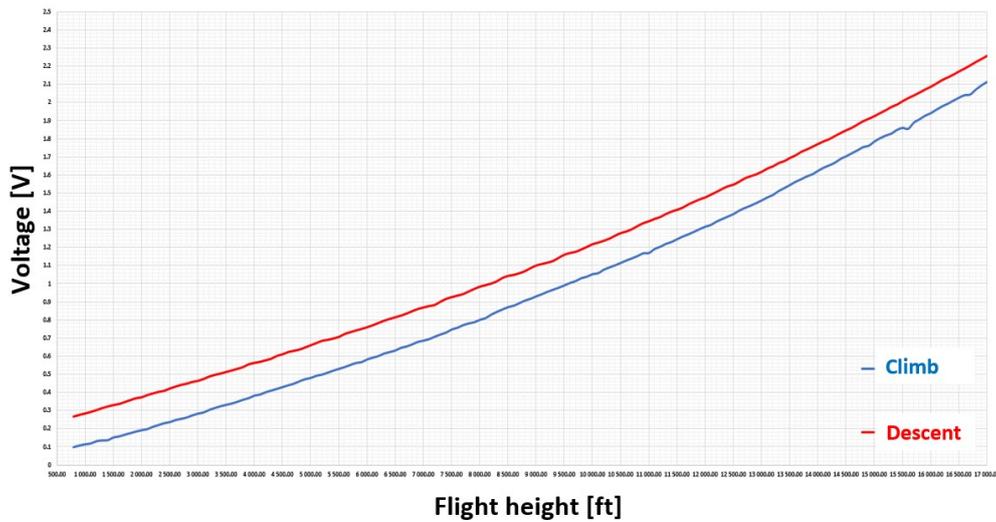


Figure 12 The graphical course of voltage change during rise and descend [Author]

From the measured data, the combinations of height ranges that will be reached during the simulation and their corresponding voltage values were determined (Tab. 1), taking into account the need to use a longer tube for conducting pressure into the device - 55 cm, which affected the resulting voltage values for the simulation.

Table 1 Table caption [Author]

Height step [ft]	Voltage [V] ↑	Voltage [V] ↓
1 000 – 2 000	0.198	0.284
2 500 – 3 500	0.491	0.583
4 000 – 5 000	0.805	0.902
5 500 – 6 500	1.143	1.219
7 000 – 8 000	1.508	1.586
8 500 – 9 500	1.897	1.971
10 000 – 11 000	2.318	2.369
11 500 – 12 500	2.766	2.806
13 000 – 14 000	3.219	3.265
14 500 – 15 500	3.720	3.754
16 000 – 17 000	4.209	4.132

The subsequent step, implemented after determining the limit values of altitudes and voltages, was the creation of a final fully automated control program, enabling the simulation of a change in the flight height of an imaginary aircraft. The simulation is controlled through a simple interface (Fig. 13) in the LabView program. After starting the simulation, the required flight height is selected by pressing the button, to which the imaginary plane climbs - the very progress of the climb and stabilization at the desired height value from the selected interval can be watched directly on the display of the EFIS device - D100. Similarly, the descent of an imaginary plane can be simulated under the condition that a climb above the required height was previously carried out, ideally to a height in the range of 16 000 – 17 000 ft. The user interface was made in the Slovak language because it's primarily for Slovak students at the Faculty of Aeronautics, Department of Avionics.

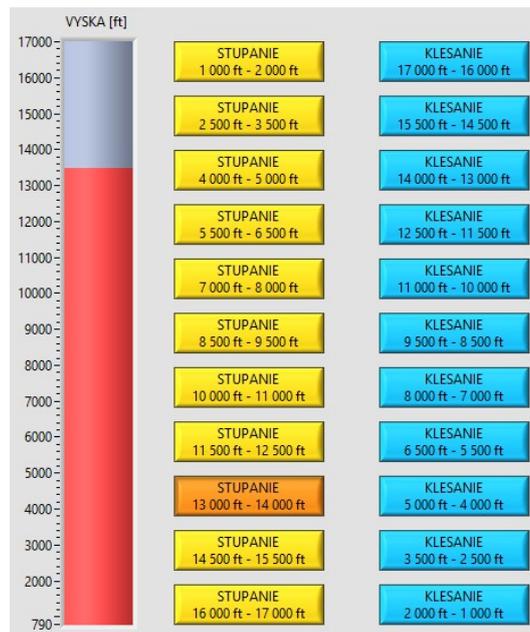


Figure 13 Interface for controlling the simulation of the change in a flight height of an imaginary aircraft [Author]

An example of a part of the control program simulating a change in flight height is shown as a block diagram in the LabView environment in the following figure (Fig. 14).

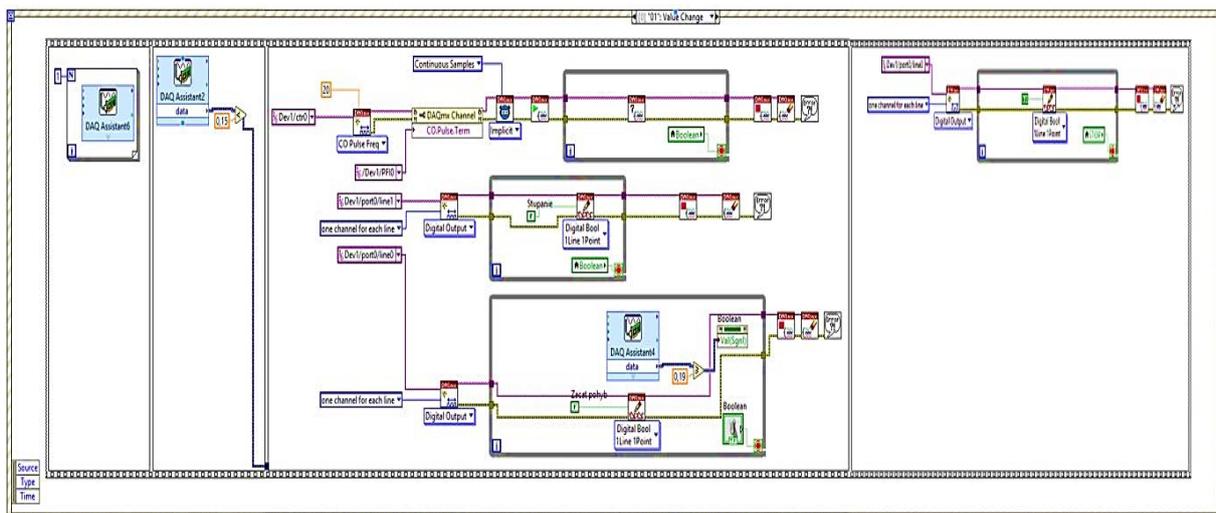


Figure 14 Part of the control program for simulating the change in altitude of an imaginary aircraft [Author]

The flight altitude change simulation control program, implemented by the LabView system engineering software designed for measuring, testing, and checking hardware equipment, consists of twenty-two possible events, which correspond to twenty-two options for selecting the flight altitude change of a hypothetical aircraft. In the presented case, a separate event structure (Event Structure) is created for each button, which is assigned a sequence (Flat Sequence) consisting of four frames. Subprograms located in individual frames are executed as a sequence of steps - from left to right [24, 25].

After pressing the button with the selected value of the height range for ascent or descent, the corresponding structure is activated, which includes the mentioned frames and the subprograms contained in them.

The content of the first frame is the steps needed to verify the connection of the correct functionality of the device simulating the change in height - a system consisting of a stepper motor connected by means of a coupling to a threaded rod that drives the syringe piston. The verification is implemented by sending a control pulse, the result of which is a rotation of the threaded rod by one turn, which does not negatively affect the simulation itself; on the contrary, it allows the provision of feedback on possible incorrect connections.

Suppose the first frame is successfully executed, and the program smoothly transitions to the second frame. In that case, this is used to measure the current value of the voltage using a potentiometer connected to the syringe piston and then compare it with a fixed reference value, a constant that was determined separately for each button and its corresponding structure according to the voltage range for the selected height range. If the condition (in the case of a rise, the current value of the voltage is less than the reference, and in the case of a fall, the current value of the voltage is greater than the reference) is fulfilled, it smoothly transitions to the third frame.

The third frame is the most complex part of the simulation program. It controls the switching on of the motor and the permission to move it, and it determines the direction of rotation of the motor and the threaded rods connected to it - by which the simulation of ascent or descent is selected. At the same time, the movement of the motor is controlled with a defined frequency of 20 Hz in a loop until the required voltage is reached for the selected height range as indicated in the corresponding table (Tab. 1). If the desired voltage is reached, the subroutine stops executing the control commands in the appropriate loops. The fourth frame will disconnect the stepper motor, preventing unwanted overheating.

The described program works similarly for each altitude selection button of an imaginary aircraft with variations that ensure the correct comparison of voltages in the second frame and, at the same time, adjust the voltage values corresponding to the required heights in the third frame.

4.2 User interface and description of the simulation of the change in a flight height of an imaginary aircraft in space

After performing actions leading to the creation of simulation workstations for changing the flight height and position of an imaginary aircraft in space, subsequent measurement and testing of the correctness of functionality during repeated use and the creation of a fully automated simulation program in the LabView environment, the creation of an acceptable user interface followed (Fig. 15).

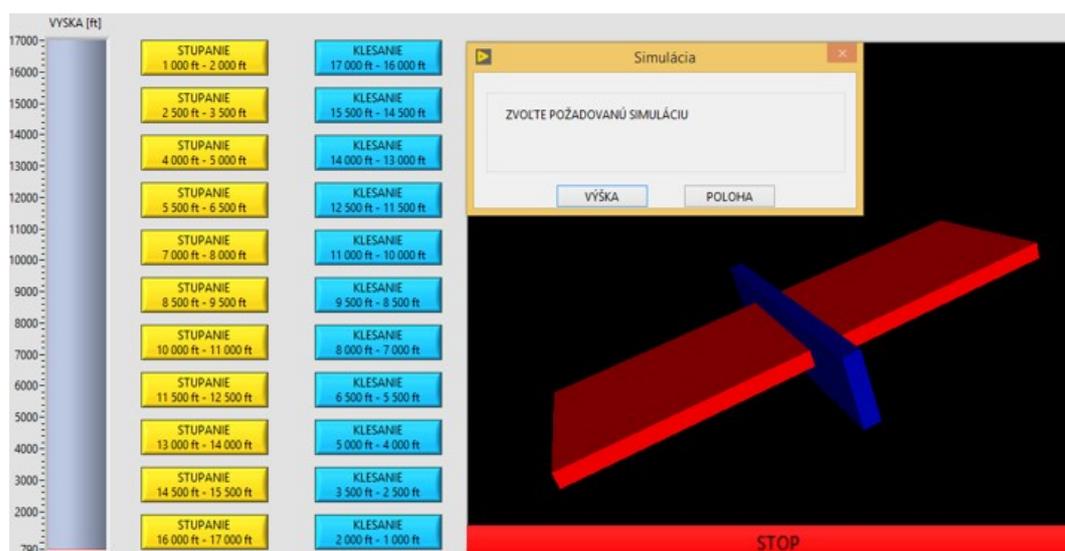


Figure 15 An interface for simulating the change in height and position of an imaginary aircraft in space [Author]

The user interface consists of two parts - the left part is dedicated to simulating the change in flight height, and the right side controls the simulation of the change in the aircraft's position in space.

After starting the program, the user is asked via a pop-up window which part of the simulation he wants to perform - HEIGHT or POSITION.

If "HEIGHT" is selected as the first simulation, the program for simulating the change in height is started. The user first checks the set pressure value on the EFIS device, which should correspond to the current pressure value at the given location – the correctness of the displayed height value can be verified based on the current pressure information if we know the height of the location where the simulation is taking place. If the pressure and height values correspond, the user selects the climb as the first option - yellow selection option buttons. While the program performs the simulation, it is possible to monitor the change in the height value together with its trend, i.e., the prediction, directly on the display of the EFIS device. This change is also displayed in the interface environment in the form of an incremental slider, the value of which changes continuously with the changing value of the height shown on the display of the EFIS device - starting from the value of 790 ft, which is considered zero at the point of measurement - the reference value, to the altitude value of 17 000 ft, which was chosen as the maximum access value.

After reaching the required height value, selected by pressing the button with the selected height interval, the program stops. The user is again offered the option of choosing a simulation – HEIGHT or POSITION.

If the altitude simulation option is selected again, it can either climb to a higher altitude or descend to a lower one. If descent simulation is selected, a value that is lower than the currently reached altitude value is selected. After selecting and pressing the button to descend to the required height - the blue selection button, the program is started again, and in this case, the descent to the given value is performed. As in the case of climbing, the progress can be monitored on the display of the EFIS device or on the display of the computer on which the program is running, and the user interface is open.

The height simulation process can be repeated over and over; it is always important to pay attention to the current height and the desired height. If it is chosen to descend to a height that is above the current height, the program will not start the simulation because the requirements stated in the program part of the simulation are not met.

Upon reaching the desired height, the simulation is terminated again, and the user is asked again and chooses the desired simulation.

By selecting and pressing the POSITION button, the simulation of the change in the position of the imaginary plane in space is started. On the monitor, which is part of the interface, it is possible to observe the change in the position of the 3D object, the aircraft, depending on how the EFIS device physically moves it.

The same changes can also be observed directly on the display of the EFIS device as the movement of the pointer along the artificial horizon. In order to simulate and monitor the change in position in space, the user needs to physically move the EFIS device in three axes (X, Y and Z) by means of a suitable stand.

The position simulation can be terminated by pressing the STOP button – after pressing which, the user is again offered the option of selecting a height or position simulation, but it is also possible to terminate the entire simulation program.

5. CONCLUSION

As the air force developed, so did the instruments used in aircraft. From primitive, very simple devices used primarily to monitor engine parameters, speed and direction of flight, the aviation industry has reached the point of the war. In this period, the most remarkable progress was recorded in the field of combat aircraft, where individual quantities were monitored in analogue form. However, development continued even in the post-war period; digital microprocessor technology came to the fore, thanks to which the first bus systems began to be used, initially based on an elementary principle,

later more complex and connecting a more significant number of devices, which led the development to today when integrated modular avionics is widely used.

The experimental part of the research, described in the presented article, includes a description of the creation and improvement of individual simulation workplaces, outputs from preliminary measurements, the resulting forms of the created simulation programs and workplaces, and last but not least, the display of the final user interface and the procedure for simulating the selected parameter - imaginary changes aircraft flight altitude. The bench simulation workplace for changing the aircraft's altitude was created to expand the practical teaching of students of aviation technical fields. For them, a user-friendly interface was created, controlling a fully functional simulation of the change in the flight height of an imaginary aircraft and the simulation of the change in the position of the aircraft in space.

References

- [1] Olamilekan, A. F. *The history of avionics*. Malaysia: UPM. 2018. 1-10 p. Available at: https://www.academia.edu/34766804/THE_HISTORY_OF_AVIONICS
- [2] Norquest, S. - Kile, A. - Peters, D. *Working with a collection of radioactive aircraft instruments*. USA: The American Institute for Conservation of Historic & Artistic Works. 2015. 169-180 p. Available at: <https://resources.culturalheritage.org/osg-postprints/wp-content/uploads/sites/8/2015/05/osg022-11.pdf>
- [3] Gaska, T. - Watkins, Ch. - Chen, Y. *Integrated Modular Avionics — Past, present, and future*. USA: IEEE. 2018. 12-23 p. Available at: <https://doi.org/10.1109/MAES.2015.150014>
- [4] Češkovič, M. - Kurdel, P. - Gecejová, N. - Labun J. - Laššák, M. *Evaluation of Doppler Effect Error Affecting the Radio Altimeter Altitude Measurements*. Switzerland: MDPI. 2023. 1-24 p. Available at: <https://doi.org/10.3390/s23010177>
- [5] Kurdel, P. - Češkovič, M. - Gecejová, N. - Labun J. - Gamec, J. *The Method of Evaluation of Radio Altimeter Methodological Error in Laboratory Environment*. Switzerland: MDPI. 2022. 1-21 p. Available at: <https://doi.org/10.3390/s22145394>
- [6] Li, H. *Design and Implementation of Mechanical Instrument for Flight Simulator*. France: EDP Sciences. 2019. 1-5 p. Available at: <https://doi.org/10.1051/mateconf/201929101007>
- [7] Li, F-w. - Shen, X-k. *A component-based aircraft instrument rapid modeling tool*. Germany: Springer. 2010. 911-918 p. Available at: <https://doi.org/10.1631/jzus.C1001010>
- [8] Khan, W. - Ansell, D. - Kuru, K. - Amina, M. *Automated aircraft instrument reading using real time video analysis*. USA: IEEE. 2018. 416-420 p. Available at: <https://doi.org/10.1109/IS.2016.7737454>
- [9] Brezonakova, A. - Skvarekova, I. - Pecho, P. - Davies, R. - Bugaj, M. - Kandra, B. *The Effects of back lit Aircraft Instrument Displays on Pilots Fatigue and Performance*. Netherlands: Elsevier. 2019. 1273-1280 p. Available at: <https://doi.org/10.1016/j.trpro.2019.07.177>
- [10] Hosman, R.J.A.V. - Mulder, M. - Theunissen, E. *Perception of Flight Information from EFIS Displays*. Netherlands: Elsevier. 1995. 247-252 p. Available at: [https://doi.org/10.1016/S1474-6670\(17\)45240-2](https://doi.org/10.1016/S1474-6670(17)45240-2)
- [11] U.S. Department of Transportation FAA. *Advanced Avionics Handbook*. Washington: Federal Aviation Administration. 2013. 114 p.
- [12] *Electronic Flight Instrument System*. Skybrary. 2023. Available at: https://www.skybrary.aero/index.php/Electronic_Flight_Instrument_System
- [13] *EFIS-D100 Electronic Flight Information System - Pilot's User Guide*. Dynon Avionics. 2010. Available at: https://www.dynonavionics.com/includes/guides/EFIS-D100_Pilot's_User_Guide_Rev_H.pdf
- [14] *Preliminary data sheet LH79520*. NXP. 2007. Available at: <https://pdf1.alldatasheet.com/datasheet-pdf/view/198765/NXP/LH79520.html>
- [15] *Surface mount and dip pressure sensors low-cost packaged die*. Silicon Microstructures. 2006. Available at: https://www.amsys.info/sheets/amsys.en.sm5430_e.pdf

- [16] *UL 94 Classification and Flame-Retardant Thermoplastics*. Protolabs. 2019. Available at: <https://www.protolabs.com/resources/blog/flame-retardant-thermoplastics-and-ul-classifications/>
- [17] Harris, S. L. - Harris, D.M. *Digital Design and Computer Architecture*. Amsterdam: Elsevier. 2016. 559 p.
- [18] *Specifications USB-6216*. National Instruments Corporation. 2023. Available at: <https://www.ni.com/docs/en-US/bundle/usb-6216-specs/page/specs.html>
- [19] *NI USB-621x User Manual*. National Instruments Corporation. 2023. Available at: <https://www.ni.com/pdf/manuals/375198d.pdf>
- [20] *Stepper Motors (Stepping Motors) – Types and Applications*. Transfer Multisort Elektronik. 2020. Available at: <https://www.tme.eu/sk/en/news/library-articles/page/41861/stepper-motors-stepping-motors-types-and-applications/>
- [21] *Control Stepper Motor with A4988 Driver Module & Arduino*. Last Minute Engineers. 2020. Available at: <https://lastminuteengineers.com/a4988-stepper-motor-driver-arduino-tutorial/>
- [22] *Stepper Motor EM-178 EPSON*. BB Elmix. 2020. Available at: <http://bbelmix.is-best.net/detail/show/8090011>
- [23] *Stepper Motor EPSON EM-178*. BB Elmix. 2020. Available at: <https://www.flickr.com/photos/103790135@N07/33128826465>
- [24] *LabVIEW Fundamentals*. National Instruments Corporation. 2005. Available at: https://neurophysics.ucsd.edu/Manuals/National%20Instruments/LV_Fundamentals.pdf
- [25] Halvorsen, H-P. *Introduction to LabVIEW*. Porsgrunn: Postboks. 2014. 122 p.

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