FINAL YEAR PROJECT REPORT

DEVELOPMENT OF T-37 CONTROL STICK TESTER

By

A/C MUHAMMAD USMAN

Pak/20095010, 95(B) EC

ADVISOR

SQUADRON LEADER FARRUKH PERVEZ

CO-ADVISOR

SQUADRON LEADER MOHSIN KHALIL

COLLEGE OF AERONAUTICAL

ENGINEERING

PAF Academy, Asghar Khan, Risalpur

May 17, 2024

DEVELOPMENT OF T-37 CONTROL STICK TESTER

By

A/C MUHAMMAD USMAN

Pak/20095010, 95(B) EC

ADVISOR

SQUADRON LEADER FARRUKH PERVEZ

CO-ADVISOR

SQUADRON LEADER MOHSIN KHALIL

Report submitted in partial fulfillment of the requirements for the degree of Bachelors of Engineering in Avionics, (BE Avionics)

In

COLLEGE OF AERONAUTICAL ENGINEERING

PAF Academy, Asghar Khan, Risalpur

May 17, 2024

Approval

It is certified that the contents and form of the project entitled “Development Of T-37 Control Stick Tester” submitted by Aviation Cadet Muhammad Usman have been found satisfactory for the requirement of the degree.

Advisor: Sqn Ldr Farrukh Pervez

Signature: ________________

Date: ________________

Co-Advisor: Sqn Ldr Mohsin Khalil

Signature: ________________

Date: ________________

Dedication

I want to take this opportunity to express my sincere gratitude to all those who have played a significant role in making this project possible. I would like to extend a special thanks to my loving family and my dedicated advisor, whose unwavering support and guidance have been instrumental in my academic success. Without their encouragement and support, I would not have been able to reach this point. To my parents, in particular, I owe a debt of gratitude for their selfless sacrifices, endless encouragement, and unwavering belief in me. This report is a tribute to them and all those who have contributed to my journey, and I am honored to share this achievement with them.

Acknowledgement

I express my sincere gratitude to Allah Almighty, who bestowed upon me the strength and determination to complete this project to the best of my abilities. My parents, whose unfailing love, unrelenting support, and steadfast prayers have been the compass in my life, deserve the utmost gratitude. Without their support, this accomplishment would not have been possible. I am immensely grateful to my advisor, Sqn Ldr Farrukh Pervez, for his constant guidance, invaluable feedback, and unwavering support. His encouragement and mentorship have been instrumental in shaping my research skills and intellectual growth. I also extend my heartfelt thanks to my co-advisor, Sqn Ldr Mohsin Khalil, for his valuable input and for sharing his expertise in the field. I am grateful to all my teachers and colleagues who have contributed to my academic and professional growth in various ways. Finally, I would like to acknowledge the support of my friends and family members, who have been there for me throughout my academic journey. Thank you all for your support, encouragement, and motivation.

Abstract

In the fast-paced world of aviation where safety is a top priority, the strength of aircraft control systems is crucial for passenger well-being. At the heart of these systems is the control stick—a collection of buttons and switches orchestrating commands for secure flights. This project delves into two key areas: creating testing circuits mimicking real aviation scenarios and developing a detailed method to evaluate control stick buttons. Using GUI interfacing, the study adds a dynamic layer by linking Arduino through a Python GUI, offering a clearer understanding of the control systems with accessible results. The testing phase ensures button reliability through continuity and load tests under various conditions. This multifaceted assessment, combined with the graphical user interface, offers a comprehensive view of control systems' performance. Additionally, the operational manual includes details on the web app, incorporating Bootstrap, CSS, Java, PHP and MySQL for the interface and data storage.

Contents

List of Figures

List of Tables

Chapter 1

1 Introduction to the Project

1.1 Project Title

The title of the project is ”Development Of T-37 Control Stick Tester”.

1.2 Project Description

This project, situated in the dynamic landscape of aviation, prioritizes safety by focusing on the resilience of aircraft control systems, particularly the intricate control stick—a nexus of buttons and switches orchestrating commands for secure flights. The venture unfolds across two pivotal domains: crafting testing circuits that faithfully emulate real aviation scenarios and formulating an intricate methodology to thoroughly scrutinize the performance of control stick buttons. The inclusion of GUI interfacing, featuring the linkage of Arduino through a Python GUI, introduces a dynamic layer to the evaluation process, facilitating a clearer understanding of control systems with accessible results. The testing phase encompasses continuity and load tests conducted under various conditions, ensuring the reliability of buttons. This multifaceted assessment, harmonized with the graphical user interface, provides a comprehensive insight into the performance of control systems. Furthermore, the operational manual sheds light on the incorporation of a web app, leveraging Bootstrap, CSS, Java, PHP, and MySQL for the interface and data storage, enhancing the overall functionality and accessibility of the project.

1.3 Scope of the Project

The scope of this project encompasses a thorough exploration of aircraft control systems, with a specific focus on the control stick—a pivotal component in ensuring flight safety. The project aims to contribute significantly to aviation technology by developing testing circuits that closely replicate real-world aviation scenarios. Through the meticulous crafting of a detailed methodology, the performance of control stick buttons undergoes comprehensive evaluation, addressing the critical need for reliability in aviation systems.

Chapter 2

2 Literature Review

Control stick systems has garnered attention to ensure the safety and reliability of aircraft. Researchers have delved into various aspects, encompassing both electronic and mechanical components. Notable studies have focused on simulating real-world conditions mirroring the complexities of aviation environments. Others have emphasized the importance of evaluating the reliability of control stick buttons under different conditions, considering the critical role they play in aircraft control as shown in Table. 1:

Kirkland explores the health management of avionics with the primary objective of finding prognostic parameters. The study looks at intermittent faults, degraded performance trends and test parameters as well as failure information through ATE (Automated Test Equipment). The aim of the study is to gain insight into the health & prognostic characteristics of avionics systems to improve diagnostic capabilities for better aircraft performance & safety(1).

Lucena's mission is to improve the troubleshooting process for fly by-wire actuators. The objective of this study is to reduce the troubleshooting time by introducing an innovative tester capable of accurately identifying defective systems. The proposed approach takes advantage of the fly by-wire aircraft computer's diagnostic capabilities to improve the diagnostic performance of EH actuators, resulting in better maintenance procedures and increased system reliability(2).

Coldsnow and team delved into the active feel control of stick systems. They particularly looked at how these systems perform during operational tasks and in the presence of pilot-in-the-loop oscillation. While the study provided valuable insights into active feel controls, its scope was somewhat limited(3).

The work by Hansen et al. focused on transforming an airplane into a self-tester, eliminating the need for ground support equipment. Their emphasis was on Maintenance Built-In Test (BIT) capabilities. The study demonstrated the feasibility of self-testing but was centered around digital flight control systems(4).

Yan and colleagues concentrated on the development of force sensors in control sticks. The study primarily explored the mechanical movements and force-sensing aspects of control sticks. While it contributed to the understanding of force sensing, the scope remained centered on sensor development(5).

Barnett and colleagues concentrated on a detailed assessment of aircraft flight control actuators. The research employs specialized tools such as an MTS hydraulic load frame dedicated to the analysis of control surface loads. To facilitate data collection during evaluations, the researchers rely on a National Instruments (NI) based Data Acquisition (DAQ) system. The objective is to gain insights into the functionality and effectiveness of electromechanical actuation systems in the realm of aircraft flight control(6).

Kish and team investigated the stall characteristics and trim changes in six general aviation aircraft. The study examined factors such as trim force changes, loss of control in traffic patterns, and un-augmented stall characteristics. This

Table 1: Comparison with Existing Surveys regarding Integration of Control Stick Tester

Scope of Survey / Review	**Year**	**Details / Remarks**
Avionics health management: searching for the prognostics grail	2004	Occurrence of intermittent fault, Degraded performance trends, Automated test equipment (ATE)
Electro-Hydraulic Actuator Tester for Fly-By-Wire Aircrafts	2007	Troubleshooting time reduction of the actuators, Detection of faulty system
Limited Investigation of Active Feel Control Stick System	2009	Handling qualities during operational tasks, Pilot-in-the-loop oscillation
Testing a digital flight control system without the use of ground support equipment	2012	Elaboration of transforming the airplane into its own self-tester, Maintenance BIT
Development of Control Stick Force sensor	2014	Mechanical movement and Force sensing
Evaluate Electromechanical Actuation System for Aircraft Flight Control	2015	MTS hydraulic frame for control surface load analysis, NI based DAQ system for data collection
Stall Characteristics and Trim Changes of Six General Aviation Aircraft	2018	Trim Force changes, Un-augumented stall characteristics
Next-generation more electric aircraft control system	2021	Diminishing energy consumption by the aircraft's automatic flight control, Electrical trim system
Design of control stick by Laser powder bed fusion	2022	Structure optimization, reduction of weight and improvement in portability
Electronic Testing of Aircraft Control Stick: Application and Analysis	**2024**	**Continuity and Load testing methodologies, User-friendly interface, Efficient Back-end system for data storage**

comprehensive approach provided insights into various dynamics of control sticks(7).

Zajdel et al. explored the next generation of more electric aircraft control systems. The study focused on diminishing energy consumption by the aircraft's automatic flight control and the integration of an electrical trim system. The research addressed energy efficiency aspects but with a specific focus(8).

In Wang et al.'s work, the emphasis was on the design of control sticks using laser powder bed fusion. The study aimed at optimizing the structure, reducing weight, and enhancing portability. While providing insights into physical design aspects, it may have a more specific focus on certain elements of control system dynamics(9).

However, existing literature often falls short in providing a holistic approach that combines both electronic testing and mechanical movement evaluations. The integration of GUI interfacing has been limited in its exploration, leaving a gap in understanding how control systems perform under dynamic conditions and user interfaces.

The limitations of previous works underscore the need for a comprehensive methodology that bridges the gap between electronic and mechanical evaluations of control stick systems. While some studies focus on one aspect or the other, the combination of in-depth electronic testing, GUI interfacing, and consideration of mechanical movements is a unique and crucial contribution that this research seeks to address.

Chapter 3

3 Continuity Testing

Continuity testing is the process of making sure that electrical connections stay intact. It is a meticulous process that ensures that the electricity flows through all the paths that it is supposed to run through. It is used to double-check the communication lines between pilot and aircraft. This testing mechanism keeps an eye out for any problems, such as broken paths, too short paths, or not connected correctly, making sure that every step of the way is perfect. Every test is a conductor making sure that the buttons on the control stick are reliable and strong enough to make flying safer for everyone.(10).

3.1 Tester Architecture for Continuity Testing

Continuity testing takes on a new role as a choreographer, making sure that aircraft control systems run as smoothly as possible. It is the moment when this circuit comes to an end. At that moment, the light bulb glows like a beacon, indicating the continuous flow of electricity. As shown in the Fig. 1:

In such moments, the tester which runs on its 28V DC power supply and a luminous LED indicating continuous flow of current contribute to the symphony of security in aviation ensuring that all buttons and switches perform their roles with uninterrupted accuracy.(11).

3.2 Performance Parameters for Continuity Testing

Electrical Conductivity determines the effectiveness of the control stick buttons in transmitting electrical signals without significant resistance. The smooth communication between the buttons and the aircraft's control system is ensured by a high level of electrical conductivity.

The signal integrity is essential to ensure that the signals transmitted through the control stick buttons are maintained, without interruption. The ability of buttons to maintain the integrity of electric signals, which are reflected in accurate and precise data transmission into aircraft's electronic systems shall be evaluated by this parameter.

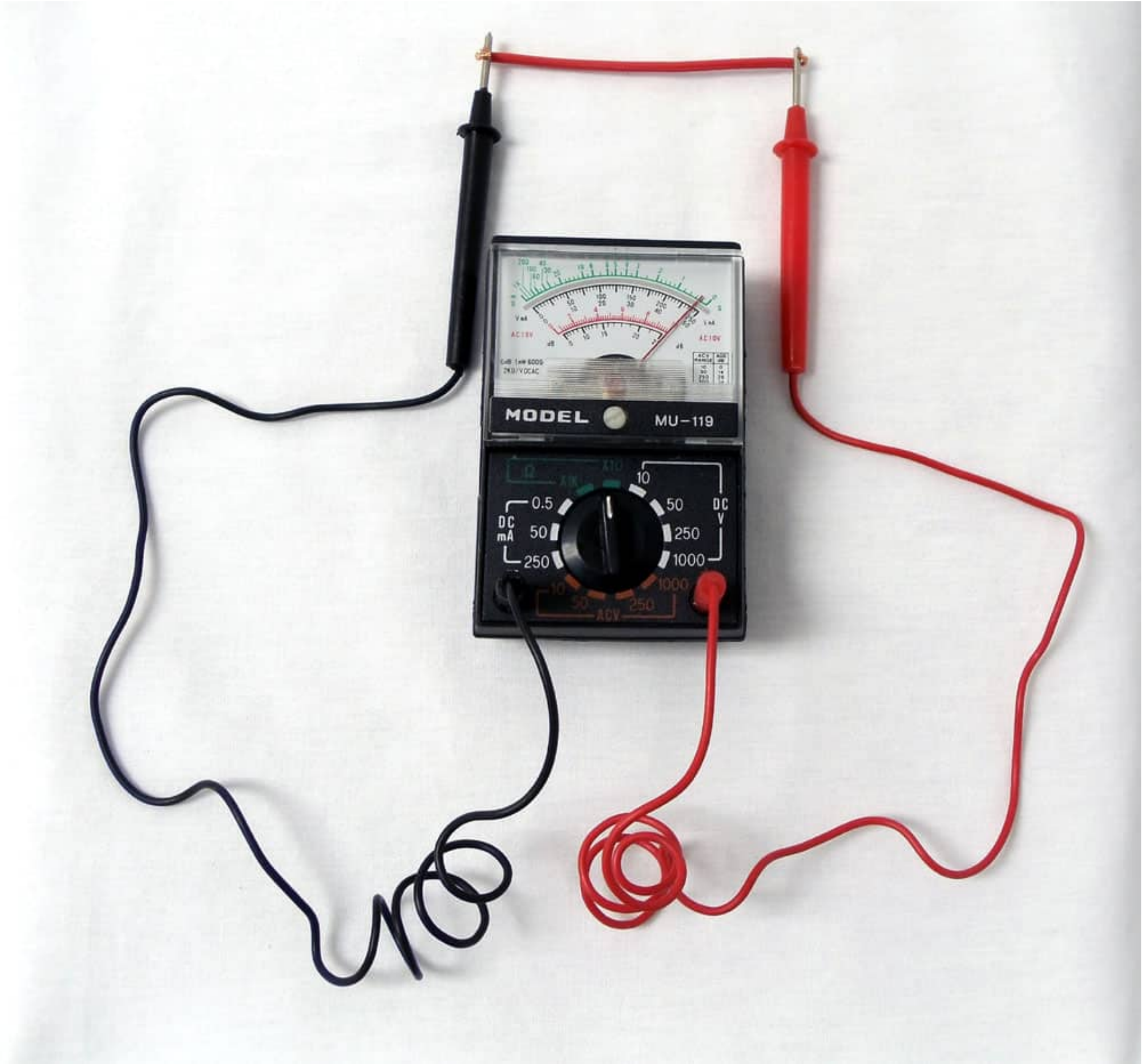

Figure 1: Continuity Testing

Chapter 4

4 Load Analysis

Load analysis assesses how a component or circuit performs under specified loads. For aircraft control stick buttons, it's essential to check their performance under load conditions to guarantee proper functionality, especially under high-stress situations during flight.

Load analysis is like a thorough check to see how strong and durable the buttons in the plane's control system are. It's like giving these buttons a set of challenges to ensure they can handle anything that might happen during a real flight. Load analysis is like a careful observer making sure the buttons hold up well under pressure. It's not just about checking if the buttons work but making sure they're strong enough for important tasks. The buttons need to prove they can handle the responsibilities of flying. The tester ensures each button is reliable and tough enough to face the challenges of the sky(12).

4.1 Tester Architecture for Load Analysis

Each button shall be tested to see how much load it is capable of. It's about three amps of load, in the majority of buttons. This is a test to see if the buttons can do their job, which is to help you communicate and fly the plane.

There's also a trimming button. They have to carry a load that's about 12.5 amps. That's because they're connected to trim motors and they need a lot of current to drive them.

When load testing is carried out, each button is individually selected and tested to see how well it can handle the loads that may occur during the flight.For example, Here in Fig. 2, we have placed several light bulbs stacked on top of one another to act as a load in the flow path.

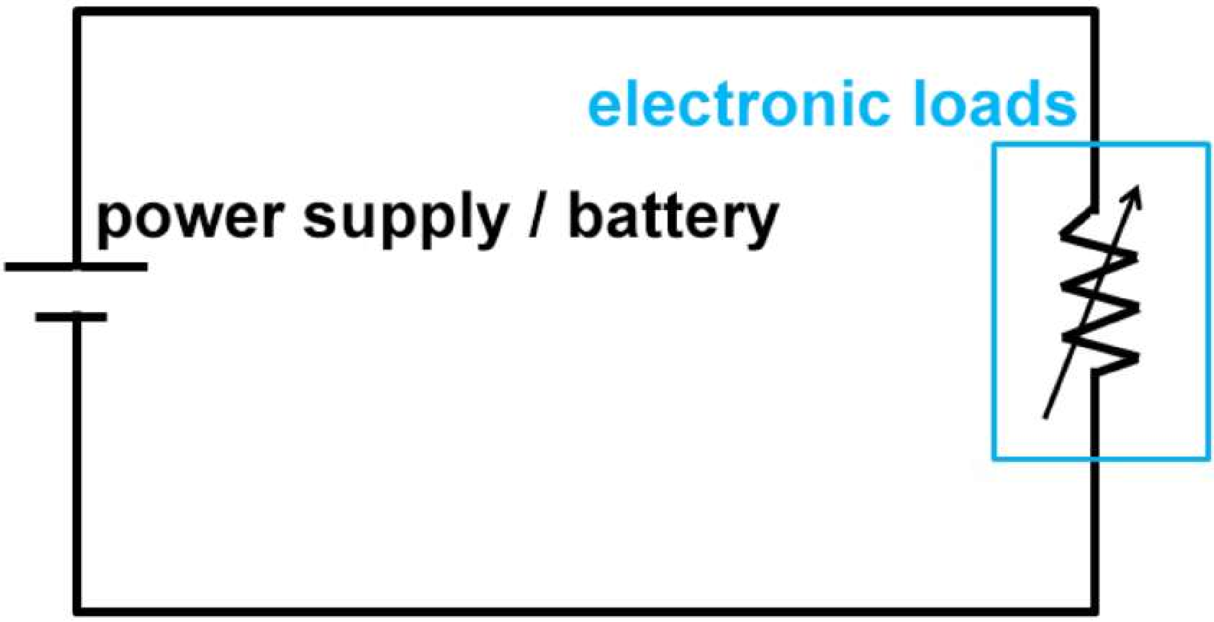

Figure 2: Load Testing

4.2 Performance Parameters for Load Analysis

Current Handling Capacity evaluates the current handling capacity of control stick buttons. It guarantees that the buttons are able to cope with the electrical load that is applied to them during different flight conditions.

Dynamic load variations are a common part of aircraft operations, particularly during maneuvers or changes in flight environment. Assessing how the control stick buttons respond to dynamic load variations provides insight into their performance during various stages of flight.

A critical parameter that emerges from these component choices is the intrinsic time constant of the inductive load, determined by the equation

$$\tau = \frac{L}{R} \tag{1}$$

The time constant indicates how quickly the inductor's stored energy is discharged. As the control stick button circuit is subjected to changes in voltage or current, the inductor's time constant plays a crucial role in determining how voltage and current evolve over time. It signifies the time it takes for these parameters to reach approximately 63.2% of their final or steady-state values.

When inductive load circuits are energized, an inductor accumulates inductive magnetic energy over time. This inductive energy accumulates in proportion to the flow through the circuit. When the circuit experiences a change, such as when an electrical power source is turned off, the stored inductive energy is discharged. The rate of discharge of this inductive energy, as measured by a time constant, affects the way voltage and current accumulate over time.

Chapter 5

5 Methodology

As we have two different testing modes, we will start with the first mode, Continuity Testing, by undertaking the following steps:

In this method we have actually verify the electrical continuity of the control stick buttons. Each button's electrical contacts are tested to ensure that they maintain proper connectivity, even under extreme conditions.

The Toggle Switch SW2 switches between the Continuity and Load test circuits. When SW2 connects to bottom circuitry, continuity operation takes place. We have 5 Switches in which 3 are simple push bottom switch, 1 is trim button switch, which works in 2 phases, pressing once will trigger one circuit, pressing again will trigger another, and the last is trim button which works in 4 directions.

In this simulation, Trigger button is represented by 2 button switches, trim button is represented by 4 switches, so finally we have 9 Switches. The LED's are connected to each switch via resistors. By pressing switches one by one, the LED turns ON to display the electrical continuity of control stick buttons. If there is an error, the LED stays OFF.

The schematics of the entire circuit, including both testing methods, can be seen in Figure. 3.

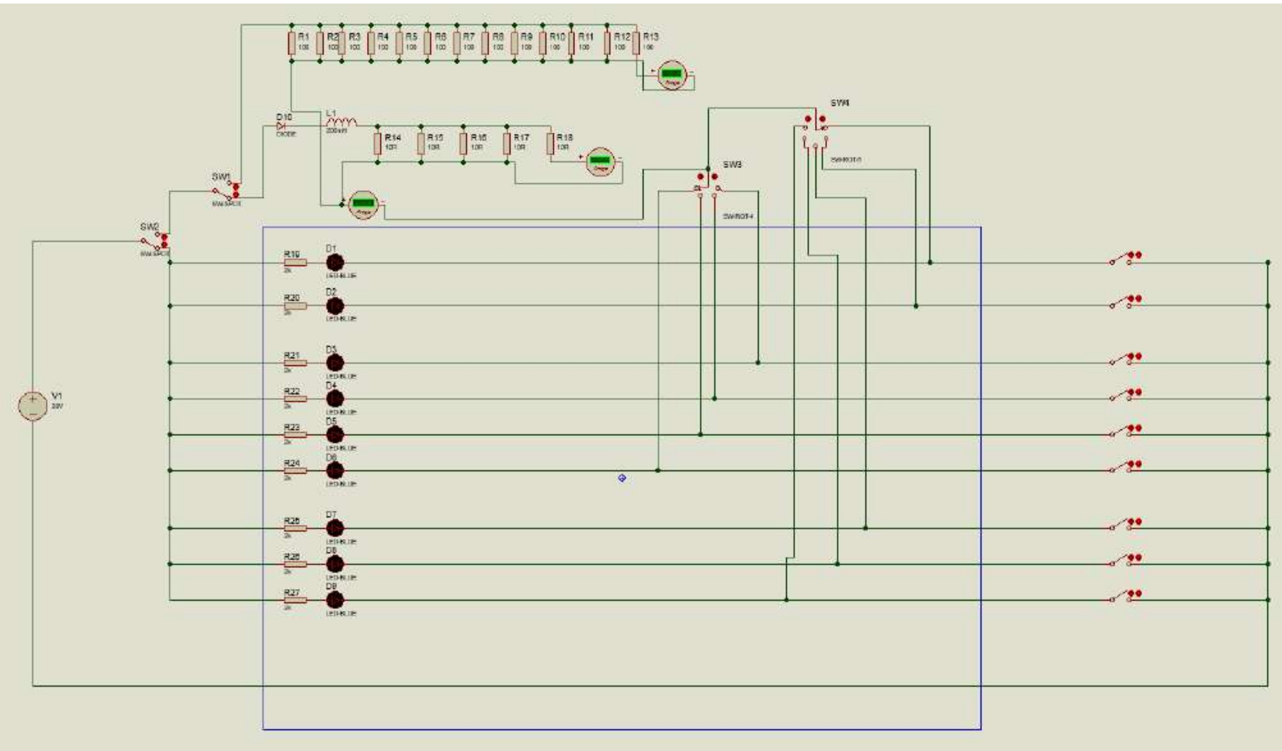

Figure 3: Continuity and Load Testing

We are now on the second phase of Load Testing with the following steps: There are basic two types of load testing:

- **Resistive Load Testing:** When an entirely resistive load is applied to the device to check its performance, usually using resistors or heaters.
- **Inductive Load Testing:** When an inductive load is applied to a device to test its operation, typically inductors or motor loads.

Once the top circuitry is connected to the SW2, Load testing is functional. Loads are available in two types: Pure resistive and inductive+ resistive. For 3 push buttons i.e. top, side, bottom and trigger switch, resistive load is required. However, the trim button requires inductive load as it adjusts trim tabs where motors are connected. The trim button requires a large amount of current (at least 12.5 Amp) to operate, so the Power Supply has to be able to maintain it.

Pure resistive load consists of wire wound resistors. These resistors have to have power handling capacity or else they will heat up and burn. 3A is the minimum current required by these switches except trim. So 5-Positon rotary switch is used to connect circuits to 5 switches top, sides, bottom and trigger switch. So when one of these switches turns on and rotary switch is connected to that particular switch circuit then current will flow and we can visualize it.

Inductive + resistive load consists of inductors & wire wound resistors. The minimum current required for Trim Switch is 12.5 Amp. Trim button switch has 4 ways of operation i.e. top, bottom, left and right and is replicated through 4 different switches. Inductive load is connected to Inductive + resistive switch by 4-Position Rotary switch which is connected to the switch of our choice. When Switches are closed one by one, current starts to flow.

Chapter 6

6 GUI Implementation

When it comes to GUI interfacing, this study adds a new layer to the evaluation by seamlessly connecting the Arduino to the Python GUI interface. This interface allows you to gain a better understanding and interact with the control systems by displaying results in an easy-to-understand format.

ACS712 functions as a current sensor, discreetly monitoring the changes in electric currents. This specialized device has the capability to detect variations in electrical activity, distinguishing between heightened or optimal behaviour. The data gathered by ACS712 is then processed through a sophisticated graphical user interface (GUI), which serves as a comprehensive display for status monitoring, further troubleshooting and analysis (13; 14).

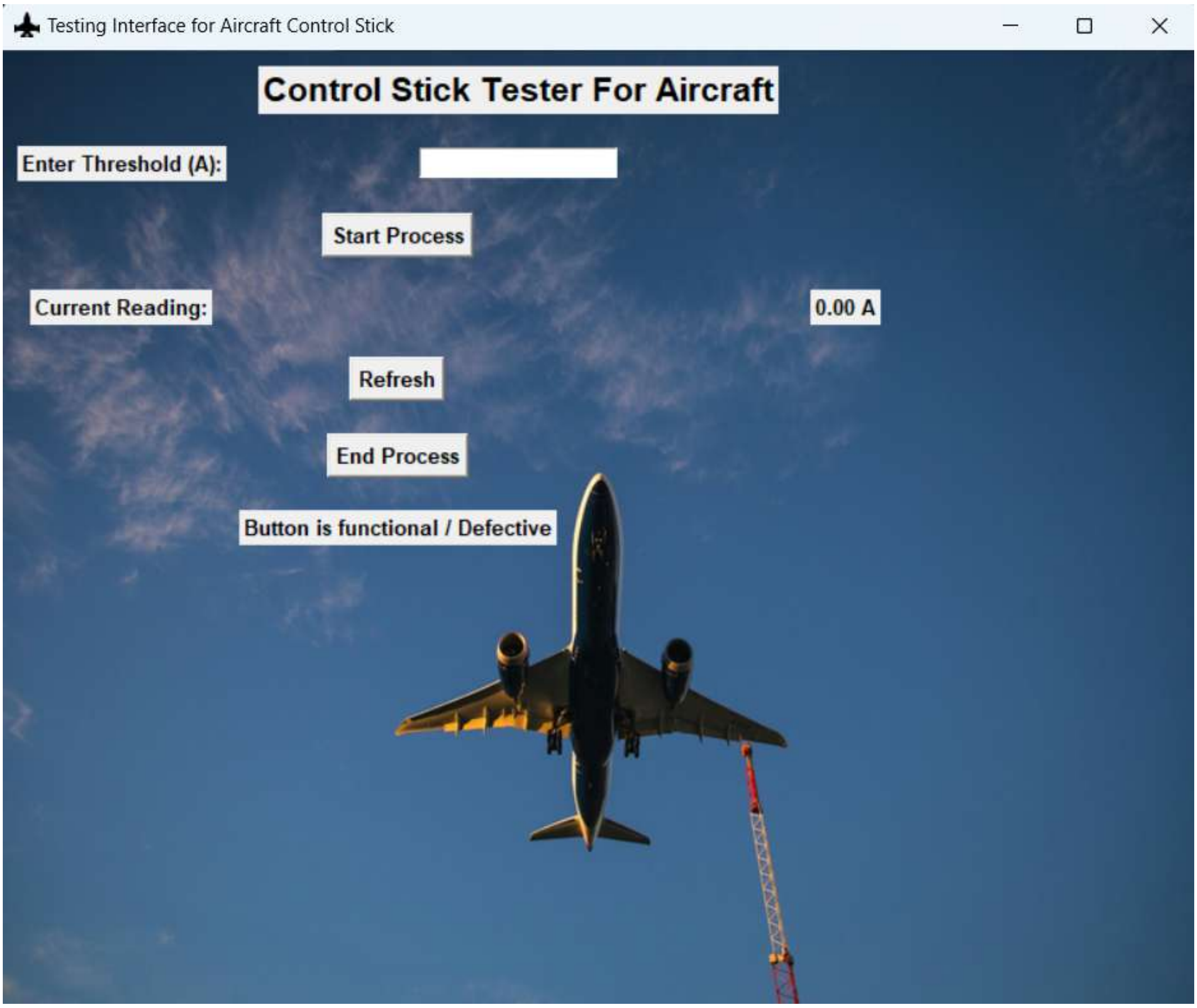

Figure 4: Testing Interface for Aircraft Control Stick

In Fig. 4, the graphical user interface (GUI) has been depicted which is the visual interface to a complete data acquisition and data processing system. The intuitive GUI is designed to interact with a circuit in order to acquire data in an easy-to-use way.

The circuit, which is intricately integrated with the GUI, is the main source of information. The GUI acts as the middleman that takes care of the whole data acquisition process, starting the process of extracting information from your circuit. Once you have the raw data, the GUI performs a complex processing operation, using algorithms and calculations to extract valuable insights and trends from your collected data. Not only does this interface help you understand the processed data better, but it also enables you to analyze and make decisions based on the results in real-time.

Chapter 7

7 Control Stick Tester Prototype

The Control Stick Tester Prototype is designed to evaluate the electronic aspects of control stick buttons, focusing on their mechanical robustness and functional reliability within the aircraft's control system e-g. When pressing the trim buttons, for instance the prototype examines not only the mechanical motions but also the activation of circuitry controlling servo motors for adjusting elevator and rudder tabs(15; 16).

It is essential to clarify that the prototype's scope does not extend to assessing the mechanical movements of the control stick itself, such as pitching up, down, or directional adjustments. Rather, the primary emphasis is on scrutinizing the electronic components, ensuring that each button's operation triggers the intended circuitry and functions seamlessly. This targeted approach allows for a more precise evaluation of the electronic reliability and performance of the control stick buttons, addressing the specific electronic intricacies relevant to aviation safety and control system efficiency(17; 18).

Now let's look at the types of test we're using to check whether all buttons on a control stick function properly and handle electricity. The first type of test we use is continuity testing. Continuity testing ensures that the electricity flows in a smooth manner. Wire Wound Power Resistors are used because they have a high degree of tolerance for the flow of current through them.

The next step is the load test. We use the same resistors but this time they have to be able to withstand at least 3 amp's of power for the top, side, bottom and trigger buttons. However, there are some buttons (like trim buttons) which require more power – 12.5 amp's. Because the trim buttons are attached to servo motors, we're adding a few inductors that will give us an induction effect. When the power supply is turned off, a reverse polarity occurs. Due to the inductive effect, current builds up on the strips of the button. As the strips of the button deteriorate over time, this test can be used to determine whether the button is able to withstand such a high level of current.

To supply the 3amp current, 100R 25W resistors have been used and 13 resistors are connected in parallel to supply a minimum of 3amp through the circuit.

$$R_{eq} = 7.6923\ \Omega \tag{2}$$

This means that the current flowing through the circuit will cross the limit of our 3amp.

$$I = 3.64\ A \tag{3}$$

In the same way, inductors and resistive load are used for 12.5 amp inductive+ resistive load. For inductive load, Ten inductors are used together with 50W 20R Wire Wound resistors.

$$R_{eq} = 2\ \Omega \tag{4}$$

The current will now exceed our 12.5 amp threshold.

$$I = 14\ A \tag{5}$$

At NI Multisim, we have implemented our Load simulation with the correct safety measures taken. As shown in the Fig. 5:

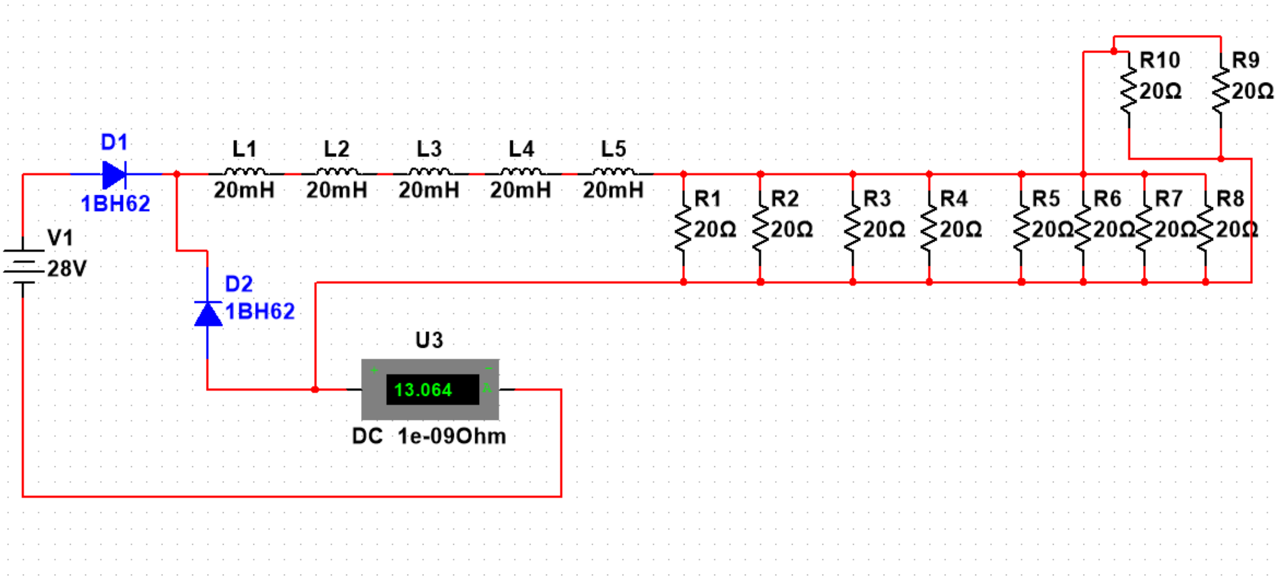

Figure 5: 100R 25W Resistor

To ensure utmost safety, our prototype incorporates a vigilant diode, acting as a robust shield against potent electrical currents. This protective feature safeguards the tester from potential hazards. Monitoring and controlling the entire process is a user-friendly Graphical User Interface (GUI), portrayed on a smart screen. This GUI serves as a supervisory entity, overseeing and facilitating seamless operation, ensuring every element is in optimal condition. The integration of Python, with the assistance of Tkinter, contributes to the creation of this sophisticated screen, offering a user-friendly interface that simplifies control(19; 20).

The synergy between Python, Tkinter, and Arduino elevates our prototype to a dynamic level. This powerful trio collaborates seamlessly, translating the on-screen commands into real-world actions. When a button is pressed on the GUI, Arduino responds promptly, orchestrating the corresponding actions in the physical realm(21).

Our control stick tester is turned into an easy-to-use and intuitive device thanks to the synergy between Python, Tkinter, and Arduino. This combination not only improves usability but also guarantees accuracy and efficiency in testing as we can see our GUI in Fig. 4:(22; 23).

Chapter 8

8 Web Application Integration: Elevating Tester Functionality

Control Stick Tester expands its functionality to a fully-featured web application that integrates Bootstrap, CSS and Java for an easy-to-use and responsive interface. The web application functions as the central control stick button test manual, enabling operators to visualize and analyse the test process(24).

The user interface, crafted with Bootstrap and CSS, ensures a visually appealing and interactive experience. The incorporation of Java enhances the application's functionality, enabling dynamic responses and efficient data handling. Through the web app, operators can see the manual of the continuity and load testing process for the buttons of the control stick (25; 26).

Furthermore, the web app goes beyond mere interface design. It incorporates a robust backend system powered by PHP and MySQL, allowing for secure and organized storage of testing results in a relational database. This integration ensures that testing data is systematically recorded and easily retrievable, facilitating comprehensive analysis and reporting(27; 28).

We can now feed our data that has been validated and tested for CI and Load both, and comments can be provided at

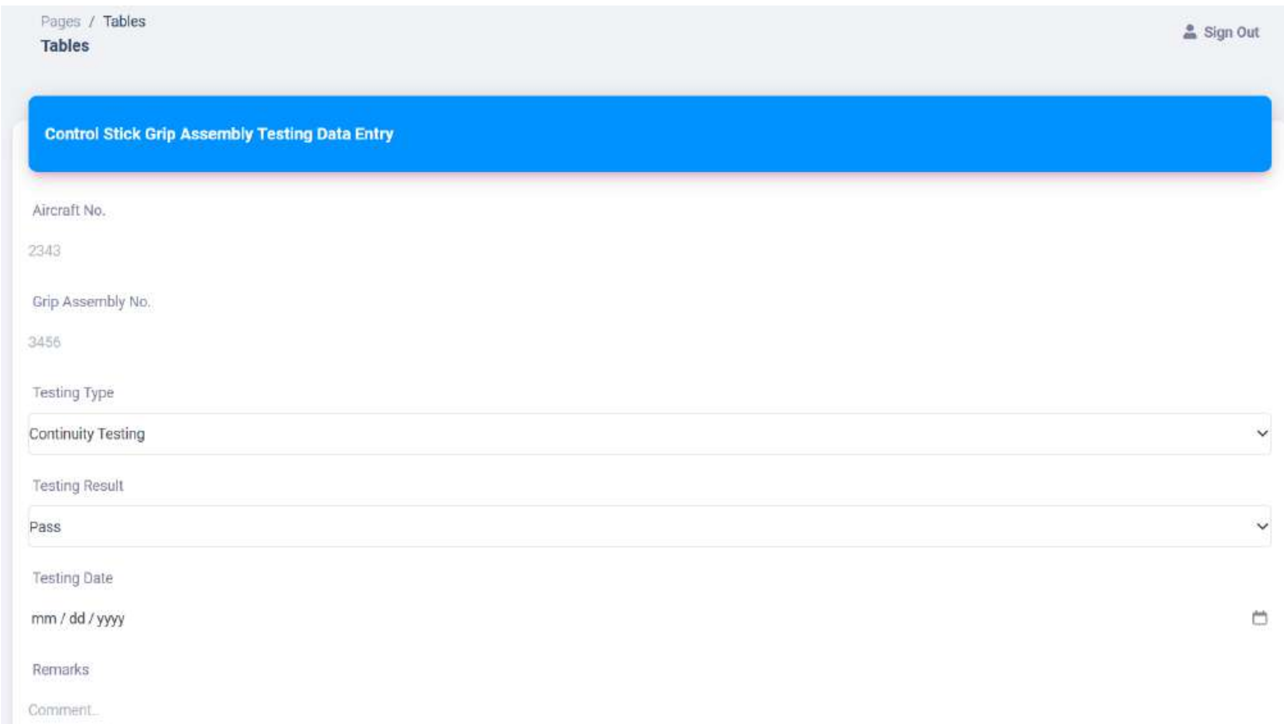

Figure 6: Data Entry In Web App

the end. As shown in the Fig. 6.

In essence, our web application not only elevates the user experience with its sleek design and functionality but also establishes a reliable infrastructure for storing and managing the valuable data generated during control stick button testing(29; 30).

We can see our test process data saved after entering data in data entry page, and it will also be saved in i-ePHPmyAdmin database. As shown in the Fig. 7.

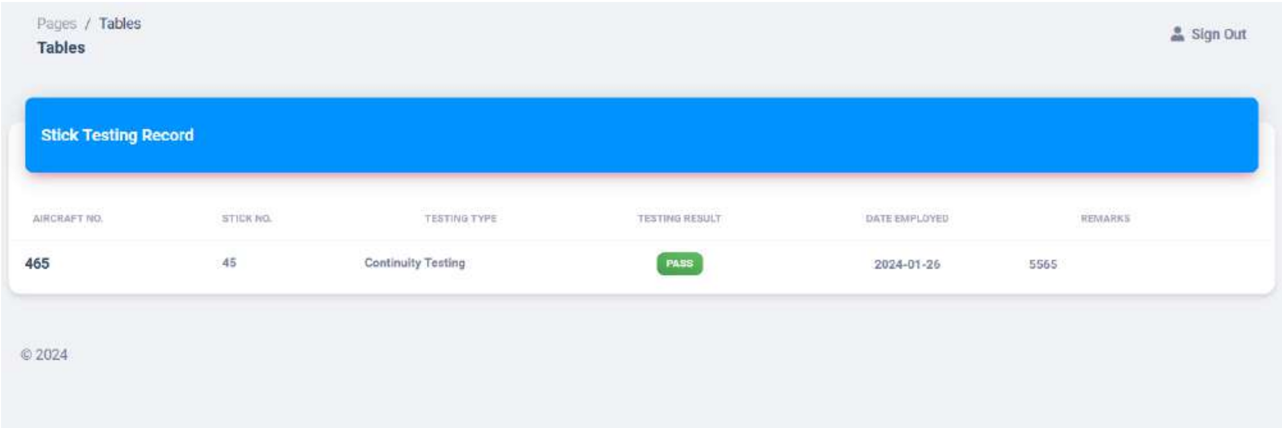

Figure 7: Record for Testing Process

Bootstrap CSS-based Operational Manual website with the Test procedure compiled in Java as shown in the Fig. 8.

Chapter 9

9 Challenges and Open Issues

While the integration of cutting-edge technology into the aviation testing domain brings about significant advancements, it also presents a set of open challenges and issues that merit attention. One notable concern lies in the complexity of the control stick tester setup, particularly in the integration of various components such as Arduino, Python GUI, and the ACS712 sensor. Ensuring seamless communication and synchronization among these elements requires meticulous calibration and can be susceptible to unforeseen compatibility issues.

Moreover, the reliance on simulation tools, including Proteus and NI Multisim, while beneficial for design and testing phases, introduces a potential gap between simulated and real-world conditions. The translation of results from simulation environments to physical setups may encounter discrepancies, highlighting the need for continuous refinement to align these two realms accurately.

In the realm of GUI interfacing, the challenge lies in optimizing the user interface to accommodate varying user skill levels. Striking a balance between a user-friendly design and providing in-depth control and analysis capabilities poses a

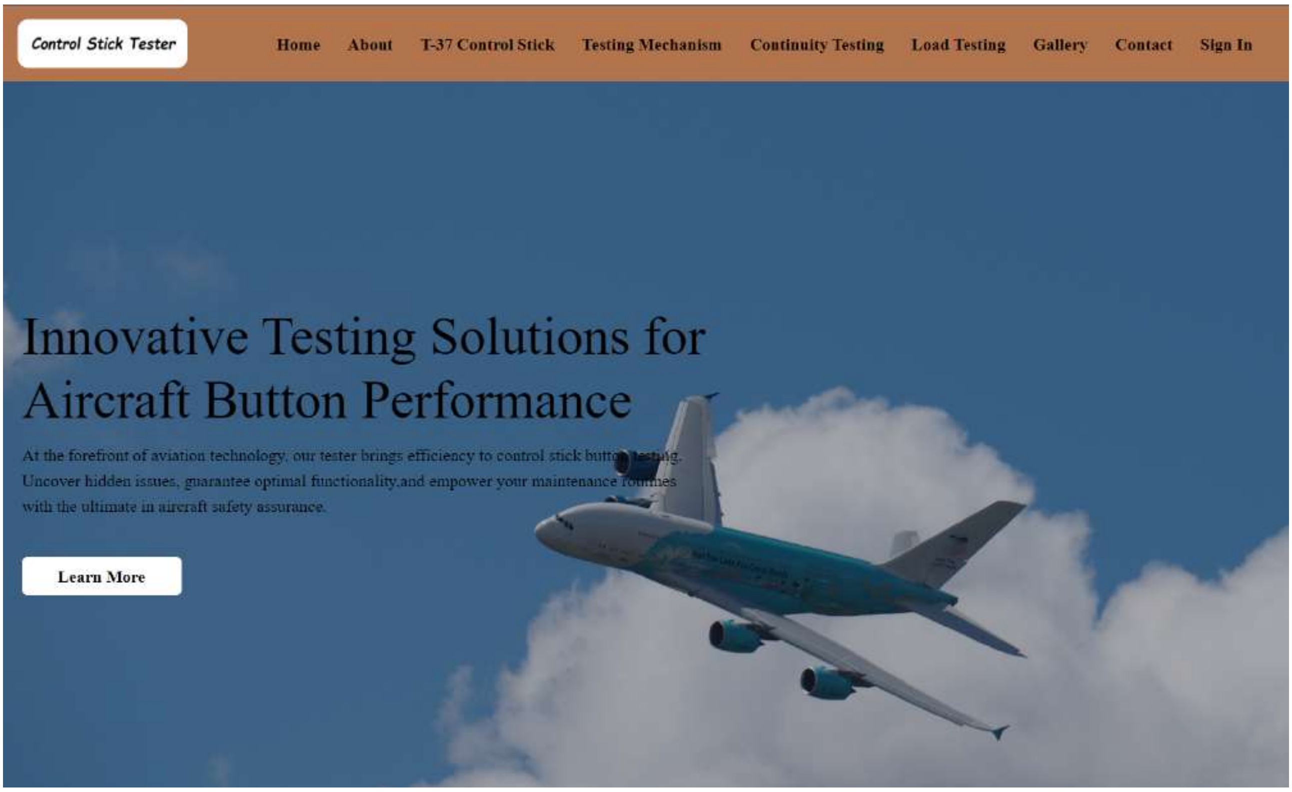

Figure 8: Web App for Operational Manual

design challenge. Additionally, the security of the web application and database system requires stringent measures to safeguard sensitive testing data from potential breaches.

Furthermore, the transition from a simulated environment to a physical prototype demands meticulous consideration of real-world constraints, such as electrical noise, interference, and environmental conditions. Addressing these challenges will be paramount to ensuring the reliability and accuracy of the control stick tester in diverse operational scenarios.

Chapter 10

10 Conclusion

In this work, we have reviewed world of aircraft control systems, emphasizing safety and reliability. By exploring and developing a meticulous evaluation method for control stick buttons, the study aims to elevate aviation standards. The integration of GUI interfacing, connecting Arduino through a Python GUI, enhances our understanding of control systems. Through rigorous testing, including continuity and load tests, we ensure the resilience of control stick buttons under diverse conditions. The graphical user interface provides a user-friendly overview, and the operational manual introduces a web app for streamlined accessibility. Overall, this work contributes to the ongoing efforts to enhance the precision and safety of aviation systems.

Chapter 11

11 Applications

The applications of this project are widespread and contribute significantly to enhancing the safety and reliability of aircraft control systems. Key applications include:

11.1 Aviation Safety Enhancement

The project focuses on ensuring the reliability and robustness of control stick buttons, directly contributing to the safety of aviation operations. By conducting comprehensive continuity and load tests, potential issues are identified and addressed, minimizing the risk of malfunctions during flights.

11.2 Aircraft Control System Optimization

The detailed methodology developed for evaluating control stick buttons aids in optimizing the performance of aircraft control systems. Understanding the behavior of buttons under different conditions allows for targeted improvements, contributing to the overall efficiency of control mechanisms.

11.3 Technology Integration with GUI

The integration of GUI interfacing, linking Arduino through a Python GUI, brings modern technology into the evaluation process. This not only provides a clearer understanding of control systems but also enhances the user experience, making it more accessible for operators and maintenance personnel.

11.4 Web Application for Centralized Testing

The development of a web app, utilizing Bootstrap, CSS, Java, PHP, and MySQL, serves as a centralized hub for testing processes. This application facilitates easy initiation, monitoring, and analysis of control stick button tests, streamlining the overall testing workflow.

11.5 Operational Manual and Documentation

The project includes the creation of an operational manual, providing comprehensive guidance on the testing procedures. This documentation ensures that operators and maintenance teams can effectively utilize the developed methodologies and technologies, contributing to standardized practices.

11.6 Research and Development in Aviation Technology

The project's multifaceted exploration of inductive load circuits, testing methodologies, and GUI interfacing contributes valuable insights to the broader field of aviation technology. It stands as a research and development effort with the potential to inspire further innovations in the domain of aircraft control systems.

Chapter 12

Bibliography

[1] L. V. Kirkland, T. Pombo, K. Nelson, and F. Berghout, "Avionics health management: Searching for the prognostics grail," in *2004 IEEE Aerospace Conference Proceedings (IEEE Cat. No. 04TH8720)*, vol. 5. IEEE, 2004, pp. 3448–3454.

[2] S. E. De Lucena and E. Y. Suzuki, "Electro-hydraulic actuator tester for fly-by-wire aircrafts," in *2007 IEEE Instrumentation & Measurement Technology Conference IMTC 2007*. IEEE, 2007, pp. 1–3.

[3] M. Coldsnow, A. Driver, P. Uybarreta, C. Kirkland, and D. Rippy, "Limited investigation of active feel control stick system (active stick)," AFFTC-TIM-09-04, Edwards AFB, CA, Tech. Rep., 2009.

[4] H. HANSEN, "A method for testing a digital flight control system without the useof ground support equipment," in *Digital Avionics Systems Conference*, 1984, p. 2664.

[5] G. M. Yan, D. C. Zhao, and A. Y. Yang, "In situ tester research and development of control stick force sensor," *Applied Mechanics and Materials*, vol. 599, pp. 970–973, 2014.

[6] S. Barnett, "Laboratory test set-up to evaluate electromechanical actuation system for aircraft flight control," Ph.D. dissertation, University of Dayton, 2015.

[7] B. A. Kish, M. Wilde, R. Kimberlin, I. Silver, E. Kolano, R. Schaller, D. Sizoo, and D. Webber, "Stall characteristics and trim changes of six general aviation aircraft," in *2018 Flight Testing Conference*, 2018, p. 2922.

[8] A. Zajdel, M. Krawczyk, and C. Szczepański, "Next-generation more electric aircraft control system."

[9] D. Wang, X. Wei, J. Liu, Y. Xiao, Y. Yang, L. Liu, C. Tan, X. Yang, and C. Han, "Lightweight design of an alsi10mg aviation control stick additively manufactured by laser powder bed fusion," *Rapid Prototyping Journal*, vol. 28, no. 10, pp. 1869–1881, 2022.

[10] A. Kunaraj, J. Joy Mathavan, and K. Jayasekara, "Portable multifunction tester design to check the continuity of wires and to measure the electrical parameters," in *Proceedings of International Conference on Intelligent Computing, Information and Control Systems: ICICCS 2020*. Springer, 2021, pp. 863–878.

[11] P. Roy, S. Karmakar, P. Basak, S. Das, and S. Khatua, "Designing of a device for checking the polarity and continuity of any electrical and electronics circuit," *IRJET*, vol. 3, no. 7, pp. 170–172, 2016.

[12] Y. Kuai and S. Yuvarajan, "An electronic load for testing photovoltaic panels," *Journal of Power Sources*, vol. 154, no. 1, pp. 308–313, 2006.

[13] S. Kumar, M. R. Das, R. Kushalkar, N. Venkat, C. Gourshete, and K. M. Moudgalya, "Microcontroller programming with arduino and python." 2022.

[14] A. Khattak, M. M. Ahmad, and F. U. Khan, "Arduino based control and data acquisition system using python graphical user interface (gui)."

[15] M. N. Callender, "A conceptual design of a general aviation hands-on-throttle and stick (hotas) system." 2003.

[16] E. T. Jones, "Flight testing methods," *The Journal of the Royal Aeronautical Society*, vol. 48, no. 401, p. 99–158, 1944.

[17] R. F. G. B. G. Andreas, A. A. Gerall and D. P. Murphy, "Performance in following tracking as a function of the sensitivity of the airplane-type control stick," *The Journal of Psychology*, vol. 43, no. 2, pp. 169–179, 1957.

[18] Y. Gao, G. An, and C. Zhi, "Chapter 10 - development and expectations on test techniques of the flight control system," in *Test Techniques for Flight Control Systems of Large Transport Aircraft*, Y. Gao, G. An, and C. Zhi, Eds. Academic Press, 2021, pp. 673–680. [Online]. Available: https://www.sciencedirect.com/science/article/pii/B9780128229903000103

[19] A. D. Moore, *Python GUI Programming with Tkinter: Develop responsive and powerful GUI applications with Tkinter*. Packt Publishing Ltd, 2018.

[20] D. Amos, "Python gui programming with tkinter," *Real Python*, 2020.

[21] A. D. Moore, *Python GUI Programming with Tkinter: Design and build functional and user-friendly GUI applications*. Packt Publishing Ltd, 2021.

[22] B. A. Meier, *Python GUI programming cookbook*. Packt Publishing Ltd, 2015.

[23] A. D. Moore and B. Harwani, *Python GUI Programming-A Complete Reference Guide: Develop responsive and powerful GUI applications with PyQt and Tkinter*. Packt Publishing Ltd, 2019.

[24] J. Anttonen, "Building a responsive web application with the mvc php framework," 2018.

[25] J. Mawansyah, L. Mulyadi, S. Hidayat, and W. Maranatha, "Build a construction management application based on php, javascript, css, mysql, and bootstrap," *International Journal of Sci-entific Engineering and Science*, vol. 4, no. 12, pp. 34–38, 2020.

[26] B. Bulger, J. Greenspan, and D. Wall, *MySQL/PHP database applications*. John Wiley & Sons, 2003.

[27] I. Bello, "Front end programming in designing responsive web application for imagine cup," 2015.

[28] M. K. Glass, Y. Le Scouarnec, E. Naramore, G. Mailer, J. Stolz, and J. Gerner, *Beginning PHP, Apache, MySQL Web Development*. John Wiley & Sons, 2004.

[29] T. Firdaus, *Responsive Web Design by Example: Beginner's Guide*. Packt Publishing Ltd, 2014.

[30] J. C. Meloni, *Sams teach yourself PHP, MySQL and Apache all in one*. Pearson Education India, 2008.

Advisor

(SQUADRON LEADER FARRUKH PERVEZ)

Date:

Co-Advisor

(SQUADRON LEADER MOHSIN KHALIL)

Date:

Appendices

12 Appendix A

12.1 Program Code For Python GUI

from tkinter import *

from PIL import Image,ImageTk

from tkinter import font

import serial

import time

import os

root = Tk()

root.title('Testing Interface for Aircraft Control Stick')

root.iconbitmap('jet.ico')

root.geometry("750x650") Add this line to set the geometry of the window

class Application:

def init(self,S1):

self.S1 = S1

self.serialport = serial.Serial('COM5', 9600, timeout=1) Update 'COM5' with your Arduino port

self.b1= Button(S1, text="Click !", command=self.click)

self.b1.pack(pady=10)

custom$_{font} ont = font.Font(family = "Helvetica", size = 16, weight = "bold")$

$customfont1 = font.Font(family = "Helvetica", size = 10, weight = "bold")$

$customfont2 = font.Font(family = "Helvetica", size = 10, weight = "bold")$

$customfont3 = font.Font(family = "Helvetica", size = 10, weight = "bold")$

$customfont4 = font.Font(family = "Helvetica", size = 10, weight = "bold")$

$customfont5 = font.Font(family = "Helvetica", size = 10, weight = "bold")$

$customfont6 = font.Font(family = "Helvetica", size = 10, weight = "bold")$

$customfont7 = font.Font(family = "Helvetica", size = 10, weight = "bold")$

Resize and convert the image

image$_p ath = os.path.join("C :$

$", "Users", "MUHAMMADUSMAN", "Documents", "ac4.jpg")$

image = Image.open(image$_p ath)$

image = image.resize((750, 650), Image.LANCZOS) self.bg image = ImageTk.PhotoImage(image)

background label = Label(S1, image=self.bg image)

background label.place(relwidth=1, relheight=1)

self.current label = Label(self.S1, text=”Control Stick Tester For Aircraft”, font=custom font)

self.current label.grid(row=0, column=1,padx=10, pady=10)

Current Reading Label

self.current label = Label(self.S1, text=”Current Reading:”, font=custom font1)

self.current label.grid(row=3, column=0, padx=10, pady=10)

Current Value Display

self.current value = Label(S1, text=”0.00 A”, font=custom font2)

self.current value.grid(row=3, column=2, padx=10, pady=10)

Current Threshold Label

self.threshold label = Label(S1, text=”Enter Threshold (A):”, font=custom font3)

self.threshold label.grid(row=1, column=0, padx=10, pady=10)

Current Threshold Entry

self.threshold entry = Entry(S1)

self.threshold entry.grid(row=1, column=1, padx=10, pady=10)

Refresh Button

self.refresh button = Button(S1, text=”Refresh”, command=self.refresh current, font=custom font4)

self.refresh button.grid(row=4, column=0, columnspan=2, pady=10)

Start Process Button

self.start button = Button(S1, text=”Start Process”, command=self.start process, font=custom font5)

self.start button.grid(row=2, column=0, columnspan=2, pady=10)

End Process Button

self.end button = Button(S1, text=”End Process”, command=self.end process, font=custom font6)

self.end button.grid(row=5, column=0, columnspan=2, pady=10)

Button Functionality Label

self.functionality label = Label(S1, text=”Button is functional / Defective”, font=custom font7)

self.functionality label.grid(row=6, column=0, columnspan=2, pady=10)

def refresh current(self):

self.serial port.write(b’REFRESH CURRENT’)

time.sleep(0.1)

current reading = self.serial port.readline().decode().strip()

current value = float(current reading.split()[1])

self.current value.config(text=current reading)

self.received data = current value

if float(self.received data) ¿

float(self.threshold entry.get()):

self.functionality label.config(text=”Button is functional”)

Turn off the LED

self.serial port.write(b’TURN OFF LED’)

else:

self.functionality label.config(text=”Button is not Functional or defective”)

Turn on the LED

self.serial port.write(b’TURN ON LED’)

def start process(self):

threshold = self.threshold entry.get()

if threshold:

command = f’START PROCESS threshold’.encode()

self.serial port.write(command) Send

command to Arduino to start monitoring

def end process(self):

print(”Sending END PROCESS command”)

self.serial port.write(b’END PROCESS’)

time.sleep(0.001)

def click(self):

print(”You have clicked”)

obj1= Application(root)

root.mainloop()