International Scientific Journal of Engineering and Management (ISJEM)
Volume: 04 Issue: 03 | March – 2025
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata
ISSN: 2583-6129
DOI: 10.55041/ISJEM020301

Advanced Engine Control : A Review of Full Authority Digital Engine Control in Aviation

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1.ABSTRACT

The advancement of aviation technology necessitates improved engine control systems for performance, safety, and efficiency. This review paper explores the design and implementation of a Full Authority Digital Engine Control (FADEC) system with an auto-thrust mechanism. The project integrates hardware components such as Arduino Uno R3, servo motors, tachometers, thermal sensors, and potentiometers to develop a comprehensive FADEC prototype. The system's inputs are managed via a laptop, with outputs and feedback displayed on-screen. This approach highlights the integration of automation with digital control, aiming to enhance engine reliability and optimize thrust performance.

2. INTRODUCTION

Modern aviation demands sophisticated control systems that enhance engine performance, fuel efficiency, and operational safety. FADEC systems provide complete control over aircraft engines, replacing traditional mechanical linkages. In contrast to conventional systems, FADEC optimizes parameters like fuel flow and thrust in real-time, significantly reducing pilot workload. This paper outlines the design and development of a FADEC prototype using readily available components, offering a cost-effective approach to simulating real-world applications.

3. METHODOLOGY

This review paper adopts a systematic approach that begins with identifying and sourcing necessary components, such as the Arduino Uno R3, servo motors, tachometers, thermal sensors, potentiometers, and other critical elements. Circuit diagrams and system flowcharts were created to visualize and plan interactions between hardware and software. Following this, the selected components were assembled on a testing platform to ensure compatibility and proper communication. Custom algorithms were written, focusing on Proportional-Integral-Derivative (PID) control techniques to regulate engine parameters like thrust and temperature. Rigorous testing of the prototype in controlled environments ensured functionality and reliability, while validation against predefined benchmarks confirmed that the system met safety and operational requirements.

3.1 Design

The FADEC prototype simulates a real-world engine control system, integrating a range of components to achieve precise control. The Arduino Uno R3 serves as the central processing unit, managing inputs and executing control algorithms. The system includes sensors such as tachometers, which measure real-time engine speed, and thermal sensors that monitor engine temperature to prevent overheating. Actuators, including servo motors, adjust throttle positions to regulate thrust effectively. A potentiometer is incorporated for manual input during testing and calibration. Additionally, safety-critical components such as the weight-on-wheels switch and angle of attack sensor provide data essential for operational scenarios. The feedback mechanism displays system parameters like engine speed, temperature, and thrust levels on a laptop interface, enabling real-time monitoring and troubleshooting.

4. IMPLEMENTATION PLAN

The implementation of the FADEC system is divided into seven detailed phases. In the first phase, project

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planning and feasibility analysis involve defining the project's scope and goals while conducting feasibility studies to determine hardware and software requirements. A detailed project timeline and resource allocation plan are developed during this phase. The second phase focuses on system design, where the architecture was established, control algorithms are created using PID techniques, and hardware-software interactions are specified.

The third phase, prototyping and development, involves assembling the hardware, writing and testing software algorithms, and simulating engine operations under controlled conditions. This is followed by the fourth phase of testing and validation, where the system undergoes component-level and system-level testing under simulated flight conditions to ensure reliability, fault tolerance, and adherence to safety standards. The fifth phase, integration with the aircraft engine, entails installing the FADEC system on a test engine, evaluating performance, and monitoring real-time data during test runs.

In the sixth phase, final testing and certification, the system is subjected to comprehensive ground and flight tests to ensure compliance with aviation standards. Certification data is collected and documented for regulatory approval. The final phase involves deployment and maintenance, where the system is implemented in operational settings, personnel are trained on diagnostics and maintenance, and a maintenance schedule is developed to ensure long-term reliability.

5. WORKING

5.1 WORKING OF COMPONENTS

The FADEC system relies on several interconnected components to function effectively.

- **The Arduino Uno R3** serves as the system's brain, processing inputs from sensors and issuing commands to actuators. In this project this chip executes the code necessary for the project.
- **Servo motors** simulate real-time throttle adjustments, controlling thrust levels with precision. It is used to rotate the potentiometer to control the RMP of the motor in this project.
- **Tachometer** provides accurate measurements of engine speed, while thermal sensors monitor temperature variations to maintain safe operating conditions. In this case, it senses the motor RPM and displays it on the respective screen.
- **Potentiometer** varies the voltage in a circuit by regulating resistance. It is used to vary the RPM of the respective motor used.
- **DC motor** converts electrical energy into mechanical motion. When 9V is applied, it creates a magnetic field that interacts with the armature, causing it to rotate, producing torque for driving wheels or other mechanical loads. It is , in this case , used to run the engine prototype.
- **Thermal Sensor** detects temperature changes by measuring the resistance change in thermistors or using infrared technology. It converts thermal energy into electrical signals, which are processed to determine the object's temperature or detect temperature variations in an environment. This signal will be interpreted as over heating or fire in the engine, in reference to this project.
- **Weight on Wheels Switch** is triggered by the application of weight, usually through a mechanical lever or pressure-sensitive element. When weight is applied to the wheels, it closes or opens a circuit, signalling presence or absence of load for automation purposes. It serves as a mock-up to indicate whether the aircraft is on ground or airborne.
- **Angle of Attack Sensor** measures the angle between an aircraft's wing and the oncoming airflow. It typically uses a vane or sensor to detect airflow direction, providing data to help control lift and stability in flight. It is used to indicate the condition of the aircraft while or on approaching stall.

6. WORKING OF COMPONENTS RELATED TO THE PROJECT

The integration of these components creates a realistic simulation of a FADEC system in operation. Commands from the laptop interface are processed by the Arduino, which adjusts the servo motor to regulate throttle settings. Simultaneously, sensors provide real-time feedback on engine parameters, which is displayed on the laptop for monitoring. This seamless interaction between hardware and software ensures accurate performance and quick troubleshooting during testing.

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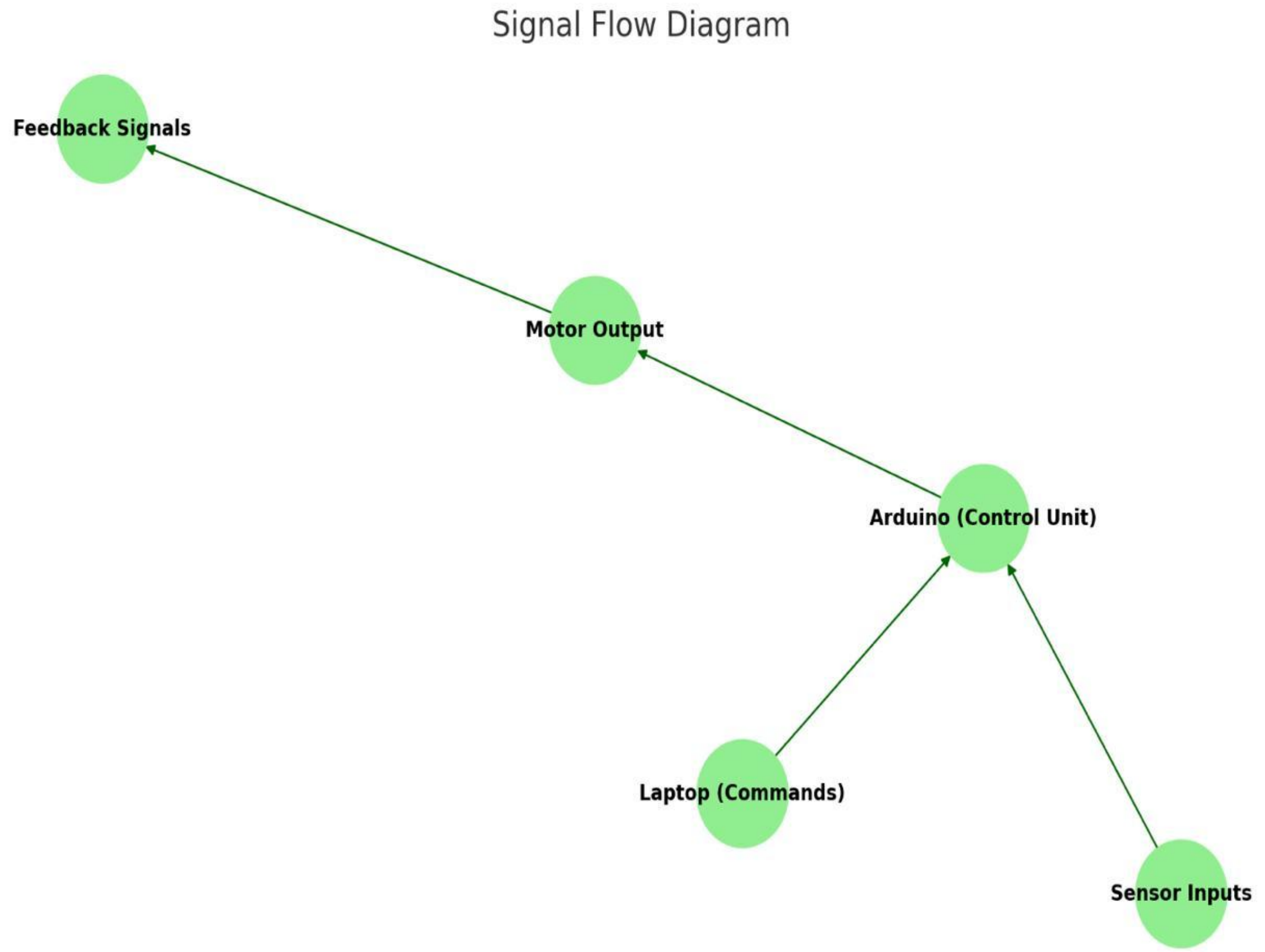

7. BASIC WORKING OF FULL SYSTEM IN STEPS

The FADEC system operates through a series of well-coordinated steps. First, an input command is sent from the laptop to the Arduino. The Arduino processes the command and activates the servo motor to adjust the throttle. Sensors then monitor critical engine parameters such as speed and temperature, providing feedback to the Arduino. Finally, this data is transmitted back to the laptop for real-time display, enabling continuous monitoring and adjustment.

PROJET ARCHITECHTURE

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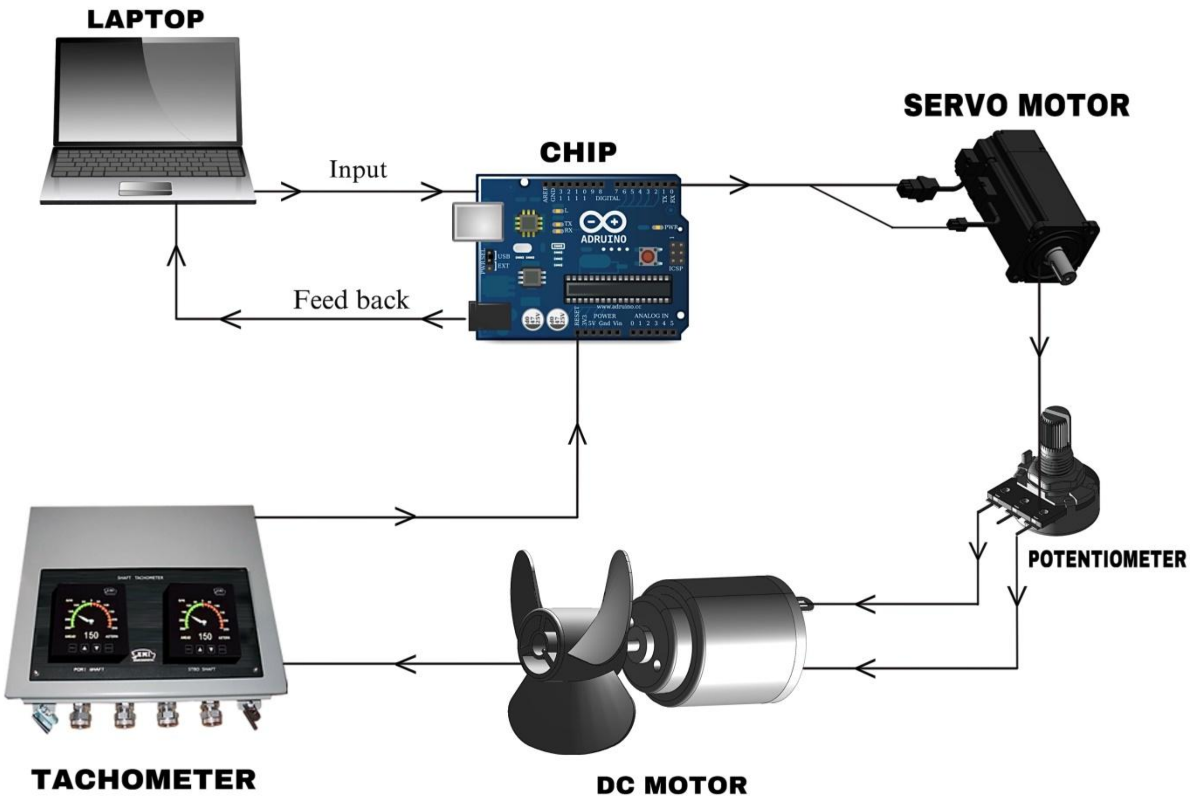

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6.EFFECTIVENESS

The FADEC system enhances engine control by providing accurate, real-time adjustments to engine parameters. This reduces pilot workload and improves overall safety by automating critical processes. The modular and scalable design ensures adaptability to various engine types, making it a versatile solution for modern aviation. Additionally, the system improves fuel efficiency and reduces maintenance requirements by optimizing engine performance.

7. LIMITATIONS

While the FADEC prototype demonstrates significant potential, it is constrained by its reliance on simulation and a limited-scale model. Real-world variables may not be fully captured, and long-term reliability and fault tolerance require additional validation. Resource limitations also restrict the scope of testing and evaluation.

8. EXPECTED RESULTS

The project aims to showcase efficient control of thrust levels, with precise real-time feedback from sensors and actuators. It highlights the potential of digital automation to enhance safety, efficiency, and performance in aviation. The results are expected to validate the feasibility of implementing a FADEC system in real-world applications.

9. FUTURE SCOPE

The FADEC system offers numerous opportunities for future development. Advanced sensors could be integrated to improve precision, while AI-driven algorithms could enable predictive analytics and maintenance. Full-scale testing in operational aircraft would provide valuable data for further refinement. Integration with other advanced aviation systems could create a seamless, fully automated engine management solution, advancing the field of aviation technology.

10. CONCLUSION

This review paper demonstrates the potential of a FADEC system with an auto-thrust mechanism to revolutionize engine control in aviation. By integrating digital automation and modular hardware, the project lays a strong foundation for future advancements in safety, efficiency, and performance optimization.

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