MSc Trong Son Phan, 2026, 14:3
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

Design and Fabrication of a Simulator for the Fire Detection and Fire Extinguishing System on the MI-8 Helicopter

[1]MSc Trong Son Phan, [2]MSc Van Huong Ngo, [3]MSc Le Phan
[1]MSc Trong Son Phan, Air Force Officer's College, Khanh Hoa, Viet Nam, trongson21@gmail.com
[2]MSc Van Huong Ngo, Air Force Officer's College, Khanh Hoa, Viet Nam, Vanhuongkq@gmail.com
[3]MSc Le Phan, Air Force Officer's College, Khanh Hoa, Viet Nam, lephan1093@gmail.com

Abstract- The fire detection and extinguishing system on the Mi-8 helicopter is tasked with detecting, alerting, and extinguishing fires when they occur. The extinguishing process is carried out by discharging extinguishing bottles to the localized fire zones automatically, or manually by pressing the control buttons. To improve the quality of education and training, strengthen theoretical foundations, and enhance the practical operating and troubleshooting skills of trainees, the authors utilized hardware design and microcontroller applications to successfully design and fabricate a training simulator for the fire detection and extinguishing system on the Mi-8 helicopter.

Keywords— Mi-8 Helicopter, Fire Protection System, Embedded Trainer, Hardware-in-the-Loop Simulation, Atmel 89C51, Automated Control Sequence.

I. INTRODUCTION

This paper presents the design and fabrication of an interactive training simulator for the Mi-8 helicopter's fire detection and extinguishing system. Traditional training on genuine aircraft hardware faces constraints due to high costs, component wear, and limited equipment availability. To bridge the gap between theory and practice, an embedded hardware-in-the-loop (HIL) solution was developed using an Atmel 89C51 microcontroller, digital shift registers, and dynamic LED matrices. Mounted on a mobile chassis, this high-fidelity simulator successfully replicates automatic and manual suppression sequences across four critical zones, providing an effective, cost-efficient pedagogical tool for aviation technical training.

II. SYSTEM FABRICATION METHOD

The research and fabrication process was conducted through two main steps: developing the algorithm and system flowcharts, followed by designing the hardware circuits and programming the control software.

1. Developing the Algorithm and System Flowcharts

The simulation software flowcharts were developed based on the actual operating principles and functional modes of the fire detection and extinguishing system on the Mi-8 helicopter. These flowcharts serve as the foundational basis for programming the microcontroller's firmware. The system's program architecture includes a main program and several subroutines.

Main Program

The main program coordinates the operational sequence of the system in a closed loop, encompassing all functional states: System Test, Fire Detection, Automatic Extinguishing, and Manual Extinguishing. The main algorithm performs continuous polling to monitor system statuses (fire detected, normal status, test mode active) and executes the corresponding logic for each state. The main flowchart is illustrated in Figure 1.

2. Subroutines

The subroutines are executed within step 3 of the main program loop. They define the sequential steps for fire suppression corresponding to specific hazard zones: Left Engine, Right Engine, Main Gearbox and Hydraulics (GTC), and the KO-50 Heater Compartment.

Consequently, four independent subroutines were developed. Each subroutine supports both automatic and manual actuation modes. These subroutines can execute independently or concurrently, depending on whether a fire breaks out in a single zone or multiple zones simultaneously.

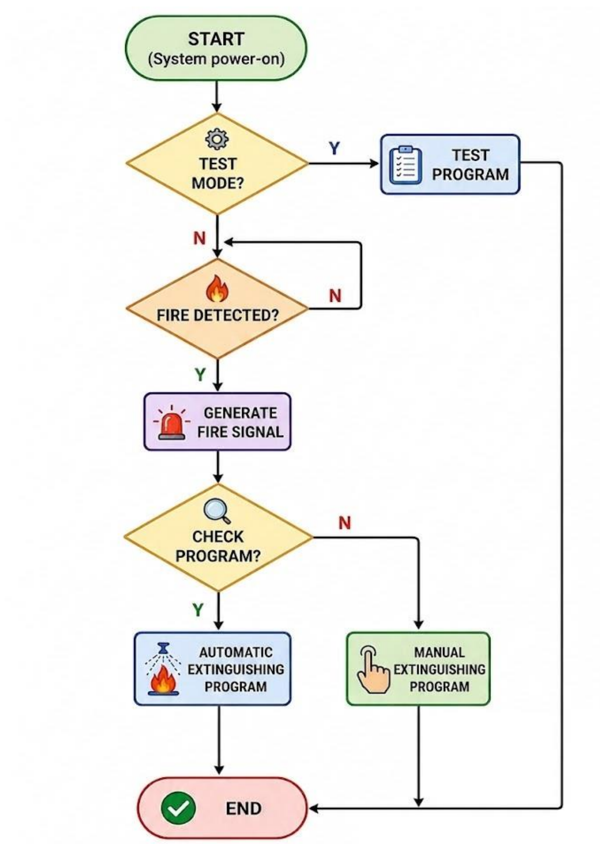

Figure 1. Flowchart of the main program algorithm

As a specific example, the operational sequence for a Left Engine Compartment fire consists of the following primary steps:

- Step 1: Receive the fire detection signal.
- Step 2: Output electrical control signals to actuate the fire isolation valves and illuminate the warning indicator: "Пожар в отсеке левого двигат." (Fire in Left Engine Compartment).
- Step 3: Verify the operational integrity of the left engine compartment's solenoid valve.
- Step 4: Upon successful fire suppression, clear the "Пожар в отсеке левого двигат." warning indicator.
- Step 5: Terminate the subroutine execution loop.
- The algorithmic subroutines for the Right Engine, Main Gearbox, and KO-50 Heater Compartment follow an identical logic sequence.

3. Hardware Circuit Design and Control Programming

Following the theoretical analysis, operational logic mapping, and flowchart construction for the Mi-8 helicopter's fire protection system, the next phase involved hardware circuit design and firmware development. The schematic design, verification, and electronic simulation were conducted on a computer using Proteus VSM software. This phase was completed in four steps:

Step 1: Schematic Circuit Design

Since the helicopter's fire suppression system operates according to a pre-defined automated sequence or via direct user intervention (manual override), a microcontroller-based architecture combined with digital integrated circuits (ICs) was chosen as the optimal solution to dynamically and accurately simulate the system.

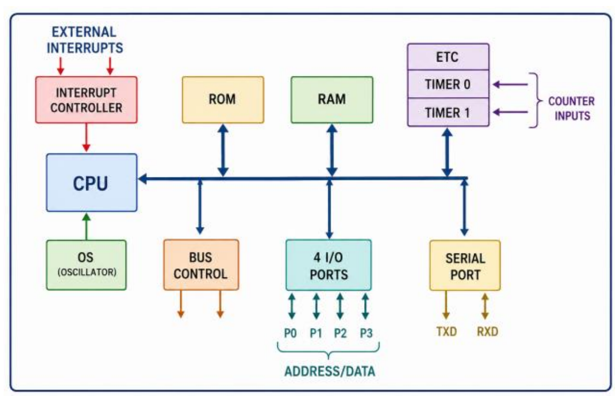

Figure 2. Structural diagram of the Atmel 89C51 microcontroller

Microcontroller Unit (MCU): The system utilizes an Atmel 89C51 microcontroller (Figure 2). This MCU features 4 Kbytes of Flash ROM, 128 bytes of RAM, high-speed processing capabilities, and supports multiple re-programming cycles, making it ideal for simulation applications.

Signal Line Indicator Matrix: The activation of fire sensors and control signal paths are visually represented by multi-colored LED arrays driven directly by the MCU logic.

Display Driver Circuit: The LED control and driving network utilizes 4015 shift registers and 74HC573 data latches to ensure high reliability and operational stability.

Control Buttons: Crystal-stabilized pulse generation circuits are implemented for the control buttons to ensure rapid response times and excellent hardware debouncing/noise immunity.

Switches and Selectors: Industrial-grade rotary switches and toggle switches are integrated into the panel.

Status Indicators & Lighting: High-efficiency LEDs are used for system status indicators and backlighting to emphasize active signal lines on the control panel.

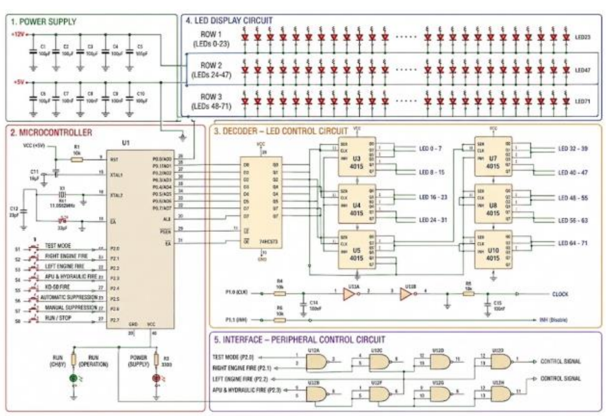

Figure 3. Electrical circuit design of the simulator

Step 2: Firmware Development
The control software was developed in Assembly language, compiled, and flashed into the internal ROM of the AT89C51 microcontroller using a dedicated hardware programmer.

Step 3: Simulator Bench Fabrication
The simulation trainer board is designed with structural dimensions of 2200mm × 1200mm. The board is mounted on a mobile chassis constructed from 40x40mm square steel tubing with overall dimensions of 1900mm × 2200mm × 700mm. The chassis is equipped with 4 heavy-duty caster wheels to ensure mobility, stability, and ease of arrangement in classrooms or lecture halls.

The control panel layout is divided into three functional sections: System Simulation Diagram; Helicopter Cockpit Control Panel Replica; Simulation Master Control Unit.

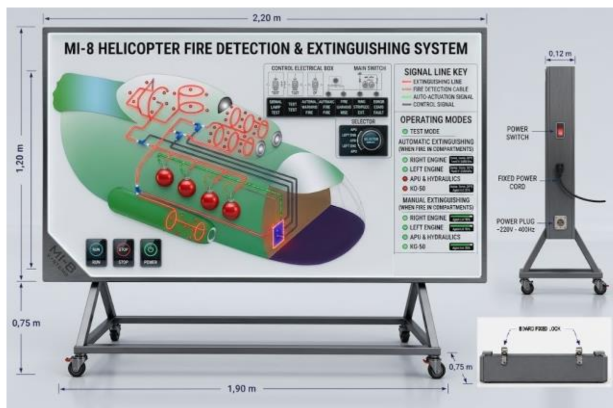

Figure 4. Simulator equipment

Step 4: Testing, Calibration, and Optimization
Following the integration of the electronic circuits into the chassis enclosure, debugging and parametric calibrations were performed. Initial test runs met the core design requirements. Minor adjustments were made to calibrate the physical positioning of the rotary mode switches and optimize the display refresh rate of the LED panel to match user inputs. Post-calibration tests confirmed that the simulator operates smoothly and complies fully with the technical specifications.

IV. RESULTS AND CONCLUSION

The developed simulator successfully reproduces the operating principles of the Mi-8 helicopter fire detection and fire extinguishing system. The hardware implementation accurately simulates four automatic fire suppression channels and four manual fire suppression channels corresponding to the left engine, right engine, main gearbox, and KO-50 heater compartments.

The simulator provides a compact, portable, and reliable training platform that enables trainees to perform operational procedures, observe real-time system responses, and understand the operating logic of both automatic and manual fire suppression modes. Compared with conventional classroom instruction, the developed equipment offers a more intuitive and interactive learning environment while eliminating the safety risks and operational costs associated with training on operational aircraft.

The proposed design demonstrates that embedded control technology can effectively reproduce complex aircraft systems for educational purposes. The developed simulator serves as an effective teaching aid for aviation maintenance training by bridging theoretical instruction and practical operation, thereby improving trainees' technical competence and troubleshooting skills, particularly in institutions where access to operational aircraft is limited.

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