DESIGN AND SIMULATION OF A MODULAR FPGA-BASED ELEVATOR

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Modular Elevator

Why

This project addresses these needs by implementing a modular elevator controller architecture that integrates key functionalities including floor request processing, door double-click handling, emergency logic, overweight detection with LED and alarm indicators, and movement optimization. With the support of a comprehensive testbench, the system successfully demonstrates realistic operational behavior while showcasing the practical application of digital design principles.

We extend our sincere appreciation to our lecturers, mentors, and peers who provided continuous support, constructive feedback, and valuable insights throughout the development of this project. All comments and suggestions received will serve as a foundation for future improvements and development within the field of digital control and FPGA-based system design.
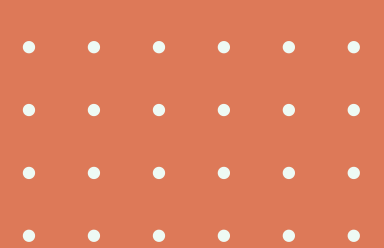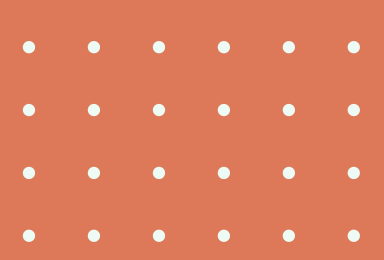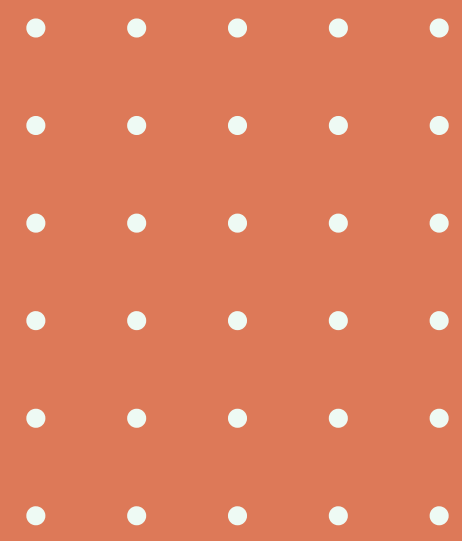
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Objectives

1. To implement an FPGA-based elevator control system capable of handling floor requests, door control, emergency responses, and overload detection.
2. To develop modular VHDL subsystems, each responsible for a specific aspect of system functionality, ensuring clarity, scalability, and ease of debugging.
3. To integrate safety-critical features such as the emergency stop mechanism and weight overload detection system with LED and alarm indicators.
4. To incorporate realistic user interaction, including the call system and door double-click functionality, to replicate real elevator behaviour.
5. To construct a comprehensive testbench simulating multiple passengers, floor requests, emergency events, and timing sequences over a long virtual simulation period.
6. To analyze system performance, focusing on metrics such as total energy consumption and average passenger waiting time, ensuring operational efficiency.
7. To demonstrate practical application of VHDL design, including state machine implementation, signal synchronization, and modular architecture construction.
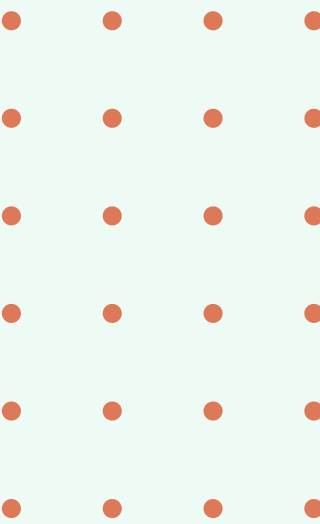
ROLES AND RESPONSIBILITIES

Roles	Responsibilities	Person
Making the VHDL code	Base Code, Floor System 1-8, Emergency Feature, Double click Feature	Evandra Rasya Fadhillah
Making the VHDL code	Weight System, Call System, LED and Alarm for Weight system	Muhammad Arfassya Setyadi
Making the Report	Making the whole report	Derryl Liandryo Putra
Making the Presentation	Making the whole presentation	Muhammad Risyad Ali

implementation

Floor Request Handling

- Floor buttons latch the user's request until the elevator arrives and the passenger exits.
- A cancel button clears the request once the passenger leaves the elevator.
- This module provides a user experience similar to a standard elevator call panel.

Safety Subsystems

- Emergency Button: Stops the elevator immediately, ignores all new requests, and keeps the doors open.
- Overweight Handler: Checks total passenger weight before entering; if the limit is exceeded, the elevator will not move and an alarm is activated.
- Door Control: Manages door open/close commands, including a familiar double-click feature to extend door-open time.

Passenger Generator (System-Level Test Dummy)

- Models human behavior with randomized arrival times, weights, and destination floors.
- Simulates user states: waiting → entering → traveling → exiting.
- Computes performance metrics such as energy consumption and average wait time to evaluate overall system efficiency.

Summary

Testing

- The elevator controller was tested using a VHDL testbench capable of simulating real elevator operation for 20 hours with an accurate 5-second clock.
- The testbench continuously generates randomized passengers (arrival time, destination floor, weight) through the passenger_generator module.
- When a new passenger arrives, the testbench activates the floor button inputs, records the request, and schedules the elevator to pick up the passenger.
- Special event scenarios were also included to verify whether safety features (emergency, overload, door logic) correctly override normal operation.
- All input and output signals were visualized in Vivado's waveform viewer, allowing analysis of timing, state transitions, and inter-module communication.

Result

- The simulation shows that the elevator controller operates properly, consistently, and as expected for all test cases.
- Under normal conditions, the system can:
- receive and process floor requests,
- transport passengers based on the optimization handler,
- open doors on arrival at the correct floor.
- The cancel_request function correctly removes requests once the last passenger exits.
- In emergency mode, the elevator stops immediately, opens the doors, and ignores all new requests until the emergency is cleared.
- The overweight subsystem reliably detects overload conditions and prevents the elevator from moving.
- The motion controller provides accurate real-time floor position and door status using an incremental counter and safety flags.

Analysis

- The modular architecture greatly enhances system stability, scalability, and error isolation.
- Testing confirms proper communication between modules:
- optimization handler → motion controller
- floor handler → request latch/clear
- safety modules → override operational commands when required
- The system always returns to a safe state before resuming normal operation.
- Waveform analysis shows that all synchronous signals remain correctly aligned throughout testing.
- Although movement logic and door timing could be improved for more realistic behavior, the implementation successfully models the essential functions of a real elevator system.

CONCLUSION

Summary

- The project successfully developed a digital elevator controller using VHDL and demonstrated strong hardware design principles.
- A modular architecture separates major functions: floor requests, motion control, door logic, emergency handling, overload detection, and passenger simulation.
- Integration of all modules enables the elevator to respond to requests, transport passengers, and maintain safety under abnormal conditions.

Simulation Findings

- Testbench results show deterministic and stable performance in normal operation, emergency stops, and overload scenarios.
- Performance metrics (energy use, average wait time) confirm the system's accuracy and reliability.

Opportunities for Improvement

- More refined door timing logic
- Advanced optimization and scheduling algorithms
- Improved behavioral realism

Project Value

- The project provided hands-on experience with:
- Synchronized digital system design
- Concurrent process coordination
- Full system validation using VHDL testbenches
- The knowledge gained supports future work in digital systems, embedded control, and FPGA development.

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the next lift

together.