

Design and Implementation of Framework for Optimized Relay-Timed Electronic Security System (Fortress)

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Abstract

This study presents the design, development, and evaluation of FORTRESS (Framework for Optimized Relay Time-Relay Electronic Security System). Focused on affordability and practicality, FORTRESS utilizes readily available components for a cost-effective security solution. The prototype leverages relay logic and solenoid locks to manage access control in rooms I-208 and I-206 at Bldg. I, Pablo Umali Hall, University of Batangas.

A functional prototype was constructed using locally sourced components at an estimated cost of ₱21,350. To assess the system's effectiveness, a 22-day evaluation period focused on reliability, efficiency, and durability. The results were promising: reliability testing yielded consistently high performance, core component efficiency reached 96%, and the system functioned correctly for over 87% of a 220-hour durability test.

Based on these findings, the researchers recommend further exploration to understand minor variations observed in reliability testing. Additionally, they propose investigating the integration of advanced access control technologies like RFID and fingerprint sensors for enhanced security. Furthermore, the study suggests the potential for expanding the use of FORTRESS to secure other university laboratories housing valuable equipment.

Keywords: Framework for Optimized Relay-Timed Electronics Security System (FORTRESS), Door lock, Security, Electromagnetic Relay, Electromagnetic Timer Relay, mini relays, electro-mechanical lock, push buttons, power supply, UPS, LDR, Transistor, efficiency, reliability, durability

1.0 INTRODUCTION

The College of Industrial Technology of the University of Batangas recognizes the growing need for innovative and effective security solutions in various settings. In response to this critical demand, the researchers developed a prototype electronic system named “FORTRESS” (Framework for Optimized Relay and Timing-based Residential Electronic Security System). FORTRESS aims to enhance security through a novel approach that utilizes relay logic and solenoids to control door-locking and unlocking mechanisms. This project prioritizes efficiency and effectiveness in its design, making it suitable for implementation in a wide range of environments, including homes, offices, and public or private spaces. The significance of this project is multifaceted. Firstly, it seeks to provide a cost-effective and reliable security solution for various settings. This holds particular relevance for the University where securing valuable laboratory equipment is a constant priority. Secondly, by leveraging advancements in relay logic and solenoid technology, FORTRESS aligns with institutional policies and plans that promote security, technology adoption, and innovation. Finally, the project acknowledges the evolving landscape of security threats and technological advancements. By exploring innovative solutions that utilize readily available technology, FORTRESS aims to address increasingly complex security challenges.

Several studies in the Philippines have explored using relay logic and solenoid locks in security systems (Gesundo, 2015; Belaong, 2016; Alimuddin & Palar, 2019). These studies demonstrate the effectiveness of this approach in enhancing security, preventing false alarms, and restricting unauthorized access. Beyond the Philippines, research has also investigated the integration of relay logic and solenoid locks with advanced technologies like ARM processors (Zhu & Shun, 2017) for enhanced control algorithms, and with the Internet of Things (IoT) for creating smart home security systems (Charturvedi & Sahu, 2017). Studies conducted by Almeida Freitas & Castro (2020) have focused on specific applications, such as access control systems using biometric authentication. A study conducted by Ravelo & Navea (2019) focused on RFID Technology and Goel (2019) concentrated on automated door lock systems. These studies highlight the versatility of relay logic and solenoid locks in various security contexts.

Saeed & Khan (2015) supports the proposition that FORTRESS can offer significant benefits. Existing studies have demonstrated the effectiveness of solenoid locks and relay logic in access control and security systems. FORTRESS builds upon this foundation by

designing a comprehensive system that utilizes these strengths and evaluates its performance in real-world settings, including the University of Batangas laboratories.

To guide future researchers and respondents, the following definitions of terms were identified:

FORTRESS – an acronym that stands for “Framework for Optimized Relay- Timed Electronic Security System”, a prototype security system that uses relay logic-solenoid locks to enhance security in various settings

Relay Logic - a type of digital logic that uses electromechanical relays to implement logical functions. It is often used in control systems and automation applications.

Solenoid Lock - a type of lock that uses a solenoid, an electromechanical device that converts electrical energy into linear motion, to control the locking mechanism. It is often used in security systems due to its fast response time and ease of integration.

Security System - a system designed to detect, prevent, and respond to security threats. It typically consists of various components, such as sensors, alarms, locks, and surveillance systems, that work together to provide enhanced security.

Efficiency - the ability to achieve a desired outcome with the minimum amount of resources, such as time, energy, or cost. This study defines efficiency as the testing phase of major functioning parts of the FORTRESS spanned 22 working days to evaluate the prototype’s capacity to deliver consistent performance over an extended period.

Reliability - the ability of a system to consistently perform its intended function under various conditions and over a certain period. This study defines reliability as the prototype’s internal consistency in five distinct time points throughout a 22-day testing period.

Durability - the ability to last over time, resisting wear, breakage, deterioration, etc. In this study, durability is defined as the ability to work correctly within the 220 operating hours without malfunction due to defective components cost by over usage.

Innovation - the introduction of new ideas, methods, or technologies that offer significant improvements over existing solutions. In the context of this study, innovation refers to the use of relay logic and solenoid locks to enhance security in various settings.

This project represents the College of Industrial Technology’s commitment to fostering practical solutions that enhance security while remaining cost-effective and efficient. The development and testing of this prototype will contribute valuable knowledge to the field of security technology, paving the way for potential future applications.

This study is focused on designing and developing a prototype using relay logic- solenoid locks. Specifically, this study aims to:

1. To develop a prototype of Framework for Optimized Relay and Timing-based Residential Electronic Security System using locally available materials.
2. To evaluate the performance of the FORTRESS prototype in terms of:
 - 2.1 Reliability
 - 2.2 Efficiency
 - 2.3 Durability
3. To identify potential areas for further improvement and development of the FORTRESS prototype based on the evaluation results and feedback from users

2.0 METHODOLOGY

This study will be conducted at the University of Batangas in laboratory settings, computer laboratories, classrooms, faculty rooms, and other school areas. The researchers will conduct a series of tests to validate the objectives of the study. In line with this, there will be no participants needed to test the project. FORTRESS is expected to yield several outputs and derivations that encompass products/processes, people, policy, utilization, and partnership aspects.

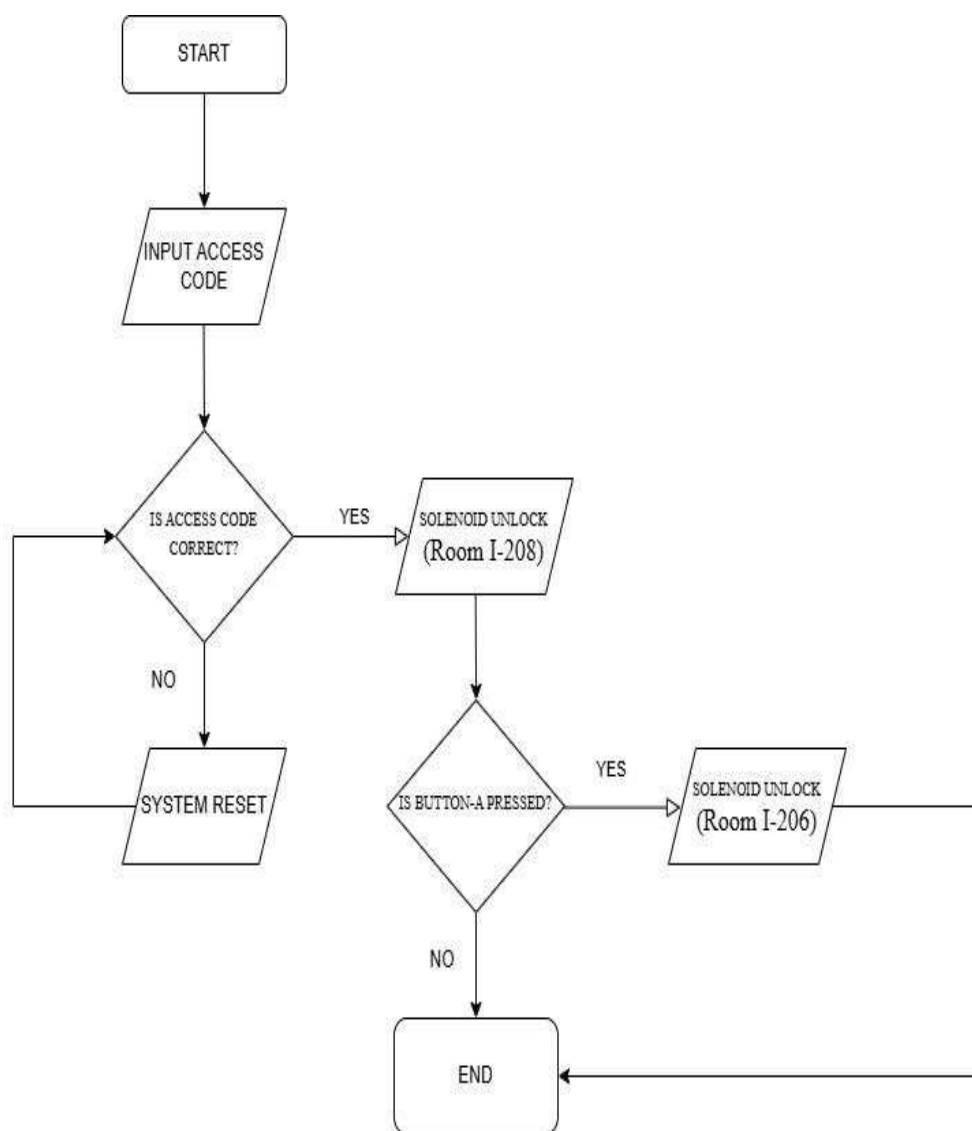
The output of this research is a prototype and a paper that presents the practical applications and its benefits. The successful implementation of the F.O.R.T.R.E.S.S. will enable its utilization in various settings. Specifically, within the University of Batangas (UB), the research project can be installed in laboratories, rooms, and other designated areas, enhancing the security measures within the institution at a minimum cost. Moreover, the research project's adoption by other interested parties, such as government

agencies, private organizations, hospitals, banks, research facilities, and commercial establishments, has the potential to greatly enhance their security systems. This broad utilization can contribute to increased safety and protection in various sectors. The research project aims to foster collaboration and partnership with science and technology agencies, such as the Department of Science and Technology (DOST). These collaborations will facilitate the exchange of research findings, potential funding support, and access to additional resources and expertise, thus promoting the further development and promotion of the F.O.R.T.R.E.S.S. Additionally, partnerships with industry stakeholders, including security companies and manufacturers of security equipment, will be pursued. Such collaborations will ensure the practical implementation and deployment of the F.O.R.T.R.E.S.S., aligning it with industry standards and requirements.

Developing the prototype has three stages: Planning and Design, Installation and Testing, and Commissioning. The methodology of each stage is presented below.

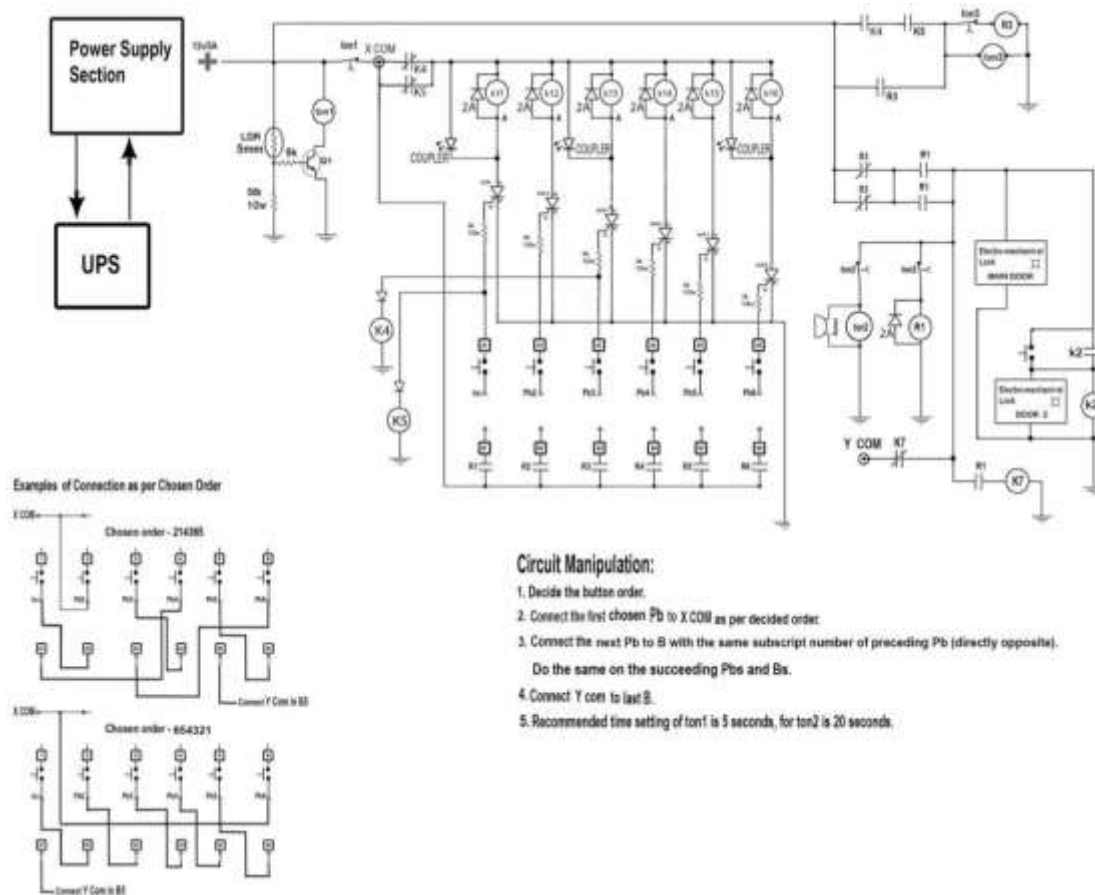
PLANNING & DESIGNING

Figure 1 FORTRESS Flow Chart



The flowchart shows the FORTRESS' access control system which utilizes a two- stage process to secure Rooms I-208 and I-206 at Bldg. I, Pablo Umali Hall at the University of Batangas. The initial stage requires a valid access code to grant entry to Room I-208. To access Room I-206, an optional button is pressed and the system resets after an incorrect code is entered.

Figure 2 Schematic Diagram of FORTRESS



The circuit above shows some simple electronic components which functions are specifically defined as follows:

- Power Supply - provides electrical power to the entire control system.
- UPS - Uninterrupted Power Supply) unit that supports power to the entire control system in case of utility power supply failures.
- LDR - Oversees intentional simultaneous press of keys (buttons)
- Transistor, Mini-relays, Magnetic Relays, Magnetic Timer relay, Push Buttons - act as signal switching components.

By utilizing each component logic functions, the objectives of the project are accomplished. This also eliminates the possibilities of accessing the control system other than the assigned codes.

Testing & Commissioning

To assess the consistency of the installed FORTRESS' performance, a test-retest reliability approach was implemented. This method as outlined by Middleton (2019), evaluates the stability of results by administering identical tests to the prototype at two distinct time points.

The testing phase spanned 22 working days, commenced on April 15, 2024, and concluded on May 4, 2024. This rigorous testing regime aimed to evaluate the prototype's capacity to deliver consistent performance over an extended period. The gathered data provides information on the integrity of the FORTRESS' installation.

3.0 RESULTS AND DISCUSSION

This section discusses the results of the testing and commissioning of the FORTRESS prototype. These results are tangible evidence of the objectives met throughout the conduct of the research study.

Local Materials for the Prototype

Through an iterative design process involving multiple prototyping cycles, the FORTRESS project has identified optimal component selection to meet its system requirements. Materials were procured from local vendors to ensure efficient logistics and support project timeline. A detailed bill of materials is presented below.

Table 1 Bill of Materials

Qty./Unit	Description	Unit Cost	Cost
2 unit	Power supply, 1 amp	750	1500
2 units	Battery, 12v, 7Ah	1000	2000
5 pc	Power Transistor, NPN C1061	70	350
30 pcs	Diode, rectifier 50v, 2 A	20	600
12 pcs	SCR, 5A, 50 v	50	600
7 m	Flat cord, #16	50	3500
16 pcs	Push button, 12mm, NO	100	1600
8 units	Mini-relay, 5 pins, 12 v	150	1200
4 units	Electromagnetic relay, 14 pins 12v with socket	300	1200
3 units	Electromagnetic Timer relay, 14 pins 12v with socket	750	2250
8 pc	Rubber Grommet	12	96
5 m	Wire, Stranded, # 24	10	50
6 m	Wire, Flat cord, Stranded, # 16	24	144
5 pc	LDR, 5mm	50	250
4 pc	Terminal Block, twin, mini	50	200
2 pc	Fuse Holder, line connected	100	200
6 pc	Glass fuse, 5 A, 1 inch	10	60
4 pc	PCV, 2" x 4"	50	200
2 ounces	Ferric chloride	150	300
10 m	Soldering lead	20	200
15 pc	LED, 3mm	10	150
2 units	Electro-mechanical lock	300	600
2 units	Electro-mechanical lock Bracket	300	600
2 units	Lock Support mechanism	1000	2000
1 pair	Enclosure Chassi	500	500
	Assorted Roughing-in materials	500	500
	Assorted bolts and screws	500	500
Total			P 21350

The bill of materials provides detailed breakdown of the components required to build a prototype of the FORTRESS. The focus revolves around creating a low cost, locally sourced supply of components. The development utilized a test-retest procedure that allowed the researcher to maximize the compatibility of components available in the local market. This means using trial and error approach to identify and validate which component fits the specific requirement of the system.

Performance Evaluation

After installing and commissioning the prototype, the performance was evaluated using the test instruments. The summary of the results is presented below.

Reliability

A test-retest reliability procedure was employed to assess the prototype's internal consistency. Data were collected at five distinct time points throughout a 22-day testing period. The results of the reliability analysis are presented in Table 2.

Table 2 Reliability Testing Results

Trial Day No.	Number testing	Number of passed tests	Number of failed tests	Reliability index
1	5	5	0	100%
2	5	4	1	80%
3	5	4	1	80%
4	5	4	1	80%
5	5	5	0	100%
6	5	3	2	60%
7	5	4	1	80%
8	5	4	1	80%
9	5	5	0	100%
10	5	4	1	80%
11	5	4	1	80%
12	5	4	1	80%
13	5	4	1	80%
14	5	4	1	80%
15	5	4	1	80%
16	5	4	1	80%
17	5	4	1	80%
18	5	4	1	80%
19	5	5	0	100%
20	5	5	0	100%
21	5	5	0	100%
22	5	5	0	100%

The reliability index presented above reflects the proportion of test administrations that yielded consistent results. As shown, 7 out of 22 days achieved a 100% reliability index, indicating perfect consistency between test and retest measurements. Fourteen days achieved an 80% reliability index, and only one day fell below this threshold, registering a 60% reliability index. Considering the test-retest reliability method employed in this study, Chiang et al. (2015) suggest that a correlation coefficient of 0.080 or higher indicates good reliability.

Efficiency

To measure the efficiency of the functionality of the prototype, different parts of the model were assessed at five distinct time points throughout a 22-day testing period giving a total of 110 total number of trials. The data collected to measure the efficiency is shown in Table 3.

Table 3 Efficiency of Parts' Functionality

Parts of the Prototype	Power Supply	Solenoid Lock	Relay	Correct Lock Key	Wrong Lock Key	Bypass Feature
Total number of tests	110	110	110	110	110	110
Tests Failed	3	4	4	4	4	4
Tests Passed	107	106	106	106	106	106
Efficiency Rating	97%	96%	96%	96%	96%	96%
Verbal Interpretation	Efficient	Efficient	Efficient	Efficient	Efficient	Efficient

As shown in the table above, the initial testing of the solenoid lock prototype yielded promising results. Lai & Locatelli (2021) used the same measurement process. Table 2 demonstrated that all the core components, including the power supply, solenoid relay, lock key, and bypass feature, achieved an efficiency rating of 96%, successfully functioning in 106 out of 110 trials. Even the power supply surpassed others with a 97% efficiency rating. While a small number of failures occurred across these components, further analysis is required to pinpoint the cause and determine if design modifications are necessary for the next development stage.

Durability

The measure of durability was done using a sturdiness testing of 110 trials. According to Boulos et. al., (2015), durability is the ability of a product to perform its function at the anticipated performance level over a given operation hours or the number of cycle-hours in use under expected conditions of use and foreseeable actions. The data collected throughout the 110 trials are presented in Table 4.

Table 4 Durability Testing Results

Operating Hours	1 st Cycle-hours 7am-9am	2 nd Cycle-hours 9am-11am	3 rd Cycle-hours 11am-1pm	4 th Cycle-hours 1pm-3pm	5 th Cycle-hours 3pm-5pm
Total number testing days	22	22	22	22	22
Number of Days Working Correctly	19	21	19	19	18
<i>Prototype Working Correctly for the whole 10 operating hours for 22 days: 192hrs out of 220 hrs</i>					
Verbal Interpretation: Durability Rating 87% - Durable					

The prototype underwent a rigorous durability test lasting a total of 220 hours over 22 working days. The test yielded a positive outcome, with the lock functioning correctly for 192 hours or 87% of the total duration. This extended period of successful operation demonstrates the prototype's durability. Furthermore, the findings align with the established concept of durability as defined by Hollander et. al, (2017) where a product is considered durable when the product's resistance to degradation surpasses that of comparable products. This extended lifespan aligns with the performance characteristics observed in similar studies, such as the one conducted by Sing et al. (2019).

4.0 CONCLUSION AND DIRECTION FOR FUTURE USE

1. The prototype Framework for Optimized Relay and Timing-based Residential Electronic Security System has been developed using locally available materials and equipment. The developed prototype has been installed and commissioned in Room No. 208 and 206 of Umali Building, which is the Instrumentation and Control Servicing NC II and Mechatronics Servicing NC II Laboratory of the University, respectively. The said laboratories house the state of the art equipment and laboratory set-up for students' performance tasks. The local material costing was computed to be a total of more or less 21,000 pesos giving an investment of 10,000 pesos per laboratory room.
2. The Reliability Evaluation of the developed prototype revealed a promising level of consistency within the system. Over a testing period spanning 22 dyas, a significant portion achieved a high reliability index. This suggests the system exhibits good overall reliability in replicating performance across repeated trials.
3. The efficiency testing of the prototype yielded highly promising results showing all the core components achieved a remarkable 96% efficiency resting which is 106 out of 110 trials. The findings demonstrate the overall effectiveness of the current design and pave the way for further optimization in the next stage.
4. In terms of the prototype's durability, the 220 cycle-hours over 22 days have demonstrated the prototype's durable performance. With a remarkable 87% uptime, the lock exhibited superior resistance to degradation.

Areas for Further Improvement and Development

From the given conclusions that were based on the results of the study, the researchers recommended that:

1. While a limited number of failures were observed across the components, further investigation is crucial to identify the root cause and determine if design adjustments are necessary for the next development phase. Further investigation is necessary to explore the factors contributing to the single day

with a lower reliability score and to optimize the system for even greater consistency.

2. Other technologies, such as RFID, fingerprint sensors, and IoT can be employed in the future design and development to integrate automation technology in the system.
3. Further expansion and utilization of the prototype should be explored by applying the prototype design into laboratories of the University housing high cost equipment.

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APPENDIX A

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