

**DEVELOPMENT MONITORING AND PID CONTROL OF AN
ENVIRONMENTAL TESTING CHAMBER USING NODE RED**

By

SUHARTINAH
21952059

MASTER'S DEGREE
in

MECHANICAL ENGINEERING (MECHATRONICS)
FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY



SWISS GERMAN UNIVERSITY
The Prominence Tower
Jalan Jalur Sutera Barat No. 15, Alam Sutera
Tangerang, Banten 15143 - Indonesia

January 2021
Revised after Thesis Defence on January, 27th 2021

STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.

Suhartinah

Student

Date

Approved by:

Dr. Ir. Hanny J Berchman, M.T.,

Thesis Advisor

Date

Dr. Ir. Henry Nasution, M.T.

Thesis Co-Advisor

Date

Dr. Maulahikmah Galinium S.Kom., M.Sc.

Dean

Date

Suhartinah

ABSTRACT

DEVELOPMENT MONITORING AND PID CONTROL OF AN ENVIRONMENTAL TESTING CHAMBER USING NODE RED

By

Suhartinah

Dr. Ir. Hanny J Berchman, M.T., Advisor

Dr. Ir. Henry Nasution, M.T., Co-Advisor

SWISS GERMAN UNIVERSITY

The market potential for testing machines for environmental conditions in Indonesia is very large, from the food industry, the cosmetic industry, the pharmaceutical industry, etc. These industries in their product development often experience problems in testing environmental condition test machines, because almost 100% are imported products and there are no locally made environmental conditions testing machines. This condition resulted in the author and the team taking the initiative to try to develop a test machine control system for environmental conditions that controls temperature and monitoring humidity, air pressure and CO gas in an environment as the main parameters in food testing. The test machine is designed using Raspberry pi zero w as a control device, and Node Red as an application for display control and monitoring that can be accessed remotely. The research conducted resulted in an environmental test machine that controls temperature using the PID method with an error rate of 0.375% with a value of $K_p = 2.73$, $K_i = 0.1$ and $K_d = 1$. with the concept of IoT control and monitoring chamber can be done remotely using the Node Red Software.

Keywords: Environment Test Chamber, PID, Node Red, Monitoring, DHT22

COPYRIGHT

© Copyright 2021
by Suhartinah
All rights reserved

DEDICATION

I dedicate this work for my beloved husband and beautiful daughters who constantly encourage and inspire me, patiently wait as well as give the best prayers for my struggle.

Allah is the One Who created seven heavens 'in layers', and likewise for the earth. The 'divine' command descends between them so you may know that Allah is Most Capable of everything and that Allah certainly encompasses all things in 'His' knowledge. (Q.S. At-Talaq : 12)

ACKNOWLEDGEMENTS

Praise and gratitude to Allah Subhanahu wa ta'ala for all blessings and guidance, so that until now they are still given the opportunity and health. By His will the writer is also able to complete the preparation of a thesis and complete study assignments in this beloved campus.

The author's gratitude goes to Mr. Dr. Ir. Henry Nasution, M.T. and Dr. Ir. Hanny J Berchman, M.T. for his patience and sincerity in guiding authors and always give advice like parents themselves. The author is very proud to study at this campus with the support of lecturers, employees and colleagues in the Master of Mechanical Engineering (Mechatronics) study program.

The author also expresses his gratitude to Mr. Ir. Tony Harley Silalahi, M.A.B., E.M.B.A., Mr. Tonny Pongoh, S.H., LL.M, Mr. Budi Hartono, S.T., M.T., and all colleagues at Astra Manufacturing Polytechnic who have provided opportunities and support so that this study assignment can be carried out and completed.

The author realizes that this thesis is still far from perfect, so the writer is open to constructive criticism and suggestions. Hopefully this thesis can be useful for Swiss German University students in general and Mechanical Engineering (Mechatronics) students in particular.

Tangerang, January 2021

Suhartinah

Suhartinah

TABLE OF CONTENT

STATEMENT BY THE AUTHOR.....	2
ABSTRACT.....	3
COPYRIGHT.....	4
DEDICATION.....	5
ACKNOWLEDGEMENTS.....	6
TABLE OF CONTENT.....	7
LIST OF FIGURES.....	9
LIST OF TABLES.....	11
CHAPTER 1 - INTRODUCTION.....	12
1.1 Background.....	12
1.2 Research Problems.....	14
1.3. Research Objectives.....	15
1.4 Significance of study.....	15
1.5 Research Questions.....	15
1.6 Hypothesis.....	15
CHAPTER 2 - LITERATURE REVIEW.....	17
2.1 Theoretical Perspective.....	17
2.1.1 Environmental testing chamber.....	17
2.1.2 Parameter control of environmental testing chamber.....	18
2.1.3 Development system control of environmental food chamber.....	19
2.1.4 PID Control.....	21
2.1.5 PID Tuning Method.....	26
2.1.6 Node Red programming.....	31
2.2 Previous Study.....	33
2.3 Gap of the Study.....	37
CHAPTER 3 – RESEARCH METHODS.....	38
3.1 Research Framework.....	38
3.2 Scope of Work.....	39
3.3 Materials and Equipment.....	39
3.3.1 DHT22 sensor module.....	39
3.3.2 Pressure sensor BMP180.....	41
3.3.3 Carbon monoxide sensor MQ-9.....	43
3.3.4 AC Light dimmer module.....	44
3.3.5 Heating elements.....	46
3.3.6 Raspberry Pi Zero W.....	47
3.4 Block Diagram.....	49

3.5 Flow Diagram	50
3.6 Wiring Diagram	51
3.7 Mechanical Design.....	51
3.8 Software Development.....	54
3.9 Testing of Components	57
3.9.1 Testing of temperature sensor DHT22	57
3.9.2 Testing raspberry pi zero w board	58
CHAPTER 4 – RESULTS AND DISCUSSIONS.....	62
4.1 Initial Evaluation.....	62
4.1.1 Hardware design changes	62
4.1.2 GPIO port user changes	63
4.2 Data Analysis	64
4.2.1 Implementation system control and monitoring environmental chamber .	67
4.2.2 Implementation flow program	69
4.2.3 Tuning PID and Testing of Chamber	74
4.3 Cost Analysis	78
CHAPTER 5 – CONCLUSIONS AND RECCOMENDATIONS	80
5.1 Conclusions.....	80
5.2 Recommendations.....	80
GLOSSARY	81
REFERENCES	82
APPENDIX.....	85
CURRICULUM VITAE	87

LIST OF FIGURES

Figures	Page
Figure 1. 1 RIPIN 2015-2035 according to PP 14 of 2015.....	12
Figure 1. 2 Market share machine environmental chamber data 2018-2023, with the potency of 21 trillion rupiah (http://www.digitaljournal.com/pr/3865370).....	13
Figure 2. 1 Environmental testing categories with some examples (Mensah and Choi, 2017)	17
Figure 2. 2 ArC One™	20
Figure 2. 3 Arduino Mega 2560.....	20
Figure 2.4 Proportional control block diagram	22
Figure 2.5 Integral control block diagram	23
Figure 2.6 Derivative control block diagram	24
Figure 2.7 PID control system block diagram	25
Figure 2.8 kp, ki and kd response	26
Figure 2.9 Tuning ZN with step response.....	28
Figure 2.10 ZN tuning with frequency response.....	28
Figure 2.11 Flow in the Node-RED development environment	32
Figure 2.12 Gap study system control and monitoring environmental test chamber	37
Figure 3.1 Research flow	38
Figure 3. 2 DHT22 sensor module.....	40
Figure 3.3 Pressure sensor BMP180 type	41
Figure 3.4 Schematic diagram BMP180 (Sensortec, 2013).....	42
Figure 3.5 MQ-9 sensor module (bottom view)	43
Figure 3.6 MQ-9 sensor module (upper view).....	43
Figure 3.7 AC light dimmer module.....	44
Figure 3.8 Heating elements	46
Figure 3. 9 Raspberry pi zero w	47
Figure 3. 10 Parts of the raspberry pi zero w	48
Figure 3. 11 Schematic diagram environmental testing chamber	49
Figure 3. 12 Flow diagram environmental testing chamber	50
Figure 3. 13 Wiring diagram environmental testing chamber	51
Figure 3. 14 CFD simulation of heat dispersion in the existing chamber design	52
Figure 3. 15 CFD simulation of heat dispersion in the existing chamber design.	53
Figure 3. 16 Modification of environmental chamber heater (before)	53
Figure 3. 17 Modification of environmental chamber heater (after)	54
Figure 3. 18 New heater design for environmental chamber.....	54
Figure 3. 19 Design programming PID for temperature environment chamber in Node Red	55
Figure 3. 20 Dashboard of environmental chamber in webserver	56
Figure 3. 21 Flowchart system PID	56
Figure 3. 22 Testing of temperature sensor DHT22	57
Figure 3. 23 Comparison of reading temperature chamber sensors of DHT22 and digital thermometer	58
Figure 3. 24 Position power led of raspberry pi zero w.....	59

Figure 3. 25 The power indicator (green LED) lights on the raspberry pi zero w board.59

Figure 3. 26 IP scanner application for find out ip raspberry pi zero w60

Figure 3. 27 Putty pi for raspberry in default settings61

Figure 4. 1 Program MQTT in node red using ESP8266 for MQ-9 sensor.....62

Figure 4. 2 Panel chamber using PCF8591 (before).....63

Figure 4. 3 Panel chamber using ESP8266 (after).....63

Figure 4. 4 New mechanical heater in the environmental test chamber65

Figure 4. 5 Placement of sensors in the chamber.....65

Figure 4. 6 Side view of the environmental test chamber (open panel).....66

Figure 4. 7 Side view of the environmental test chamber (closed panel)66

Figure 4. 8 Front view of the environmental test chamber67

Figure 4. 9 Temperature control and monitoring humidity, air pressure, and CO dashboard in the chamber68

Figure 4. 10 Flow program as a whole for control and monitoring chamber in Node Red69

Figure 4. 11 Flow PID programming in node red.....71

Figure 4. 12 Function program PID in node red72

Figure 4. 13 Flow program MQTT for node MCU72

Figure 4. 14 Function program for MQ-9 sensor.....73

Figure 4. 15 Program to scan the sensor that has been wiring on the I2C pin.....73

Figure 4. 16 BMP180 sensor reading program73

Figure 4. 17 Function programm for BMP18073

Figure 4. 18 PID control response set point 40°C with $K_p = 14$, $K_i = 0.068$, $K_d = 371$ 76

Figure 4. 19 PID control response set point 40°C with $K_p = 8$, $K_i = 0.1$, $K_d = 1$76

Figure 4. 20 PID control response set point 40°C with $K_p = 2.7$, $K_i = 0.1$, $K_d = 1$77

Figure 4. 21 Temperature response of the system for 30C, 35C, 40C and 45 C showing PID controller characteristics. Room temperature is 27C.....77

LIST OF TABLES

Table	Page
Table 2.1 Characteristics of P, I and D controllers (Ang et. al., 2005; Li et al., 2006)	24
Table 2.2 ZN tuning method (Nasution, 2007).....	27
Table 2.3 Previous Study	33
Table 2 4.1 DHT22/AM-2302 technical specifications	40
Table 3.1 DHT22/AM-2302 technical specifications	40
Table 3.2 Control registers values for different internal over sampling setting (oss)..	42
Table 3.3 MQ-9 sensor specifications	44
Table 3.4 AC light dimmer module specification.....	45
Table 4.1 GPIO port usage raspberry pi zero w.....	64
Table 4.2 GPIO port usage ESP8266 NodeMCU	64
Table 4.3 Estimated Cost Detail	78
Table 4.4 Comparison price list detail	78