



TABLE OF CONTENTS

VALIDITY PAGE	ii
STATEMENT OF ANTI-PLAGIARISM	iii
FOREWORD	iv
ABSTRACT	vii
INTISARI	viii
TABLE OF CONTENTS	ix
TABLE OF FIGURES	xi
LIST OF TABLES	xii
CHAPTER I	1
1.1. Research Background	1
1.2. Research Problem	4
1.3. Research Objectives	4
1.4. Research Scopes	5
1.5. Research Benefit	5
1.6. Research Schematic	6
CHAPTER II	8
CHAPTER III	20
3.1. Turbine Flowmeter	20
3.2. K-Factor	21
3.3. Woltman Flowmeter	22
3.4. Calibration	24
3.5. Flow Rate	25
3.5.1. Classification of Flow	26
3.5.2. Classification Based on Temporal Variation	26
3.5.3. Steady Flow	26
3.5.4. Unsteady Flow	26
3.5.5. Classification Based on Spatial Variation	27
3.5.6. Uniform flow	27
3.5.7. Non-Uniform Flow (Varied Flow)	27
3.6. Water Flow Meter	28
3.6.1. YF-DN50 Hall-Effect Turbine Flow Meter	28
3.6.1.1. Working Principle of YF-DN50	28
3.6.1.2. Sensor Specifications	29
3.7. ESP32 Microcontroller	30
3.7.1. Specifications of ESP32	31
3.7.1.1. Communication Capabilities of ESP32	32
3.8. Kalman Filter Algorithm	33
3.8.1. Application of Kalman Filter	33
3.9. LCD 16×2	35
3.10. Logic Level Shifter	35
3.11. Firebase	36
CHAPTER IV	38
4.1. Research Stages	38
4.2. Model Design	39
4.3. Hardware Design	40
4.3.1. Experimental Setup Scheme	40
4.3.2. Sensor Node Hardware Scheme	41



4.3.3.	Receiver Node Hardware Scheme	41
4.4.	Software Design and Kalman Filter Algorithm	42
4.4.1.	Software System Design Overview	42
4.4.2.	Module Interrupt Handler	44
4.4.3.	Module Flow Rate Calculation	44
4.4.4.	Module Kalman Filter	46
4.5.	System Testing Plan	48
4.5.1.	System Functionality in Water Flow Measurement	50
4.5.1.1.	Conventional Method	50
4.5.1.2.	Kalman Method	50
4.5.1.3.	Functionalities of Sensor Data Transmission	50
4.6.	Design of Test Result Analysis	51
4.6.1.	Accuracy Analysis: Conventional vs. Kalman Filter	51
4.6.2.	Comparison with Closed-Loop Water Circulation Calibration Rig	51
CHAPTER V	53
5.1.	Hardware Implementation	53
5.1.1.	Implementation of Electronic Components	53
5.1.2.	Implementation of Mechanical Components	54
5.2.	Software Implementation - Sensor Data Acquisition	55
5.2.1.	JSON Payload Implementation	56
5.2.2.	createDocument Implementation	57
5.2.3.	updateDocument Implementation	58
5.2.4.	taskReading Implementation	59
5.3.	Analysis of Dataset	60
5.4.	Kalman Filter Implementation	61
5.5.	Implementation of Hardware Testing	63
CHAPTER VI	65
6.1.	Sensor Reading Results	65
6.1.1.	Sensor Readings Results with Kalman Filter	68
6.2.	Industrial Sensor Data Readings	72
6.3.	Web-Based Data Monitoring Results	75
6.4.	Raw Sensor Data Test Results	75
6.5.	Sensor Data with Kalman Filter Test Results	77
6.6.	Industrial Turbine Flowmeter Sensor Test Results	79
6.7.	Regression Linearity of Flow Rate from Different Turbine Flowmeter ..	80
6.7.1.	Linearity Regression of Raw Flow Rate Data	80
6.7.2.	Linearity Regression of Kalman Flow Rate Data	81
6.7.3.	Linearity Regression of Industrial Turbine Flow Rate Data	82
6.8.	Accuracy Comparison	83
6.9.	Comparison Between Raw Sensor Data and Kalman Filter	86
6.10.	Quantitative Evaluation using Mean Absolute Error (MAE) and Percentage (PE).....	87
6.11.	Cost Effectivity	91
CHAPTER VII	92
7.1.	Conclusion	92
7.2.	Suggestion	93
REFERENCES	94



TABLE OF FIGURES

Figure 3.1 Main parts of a Turbine Flowmeter (AutomationForum Co, 2020) ...	20
Figure 3.2 2-wire passive magnetic pickup sensor (Mortenson T, 2020)	21
Figure 3.3 3-wire active Hall Effect sensor (Mortenson T, 2020)	21
Figure 3.4 The K-factor should be flat, but the actual plot shows a drop off at low flow rates and a viscosity hump (Crabtree, 2009)	22
Figure 3.5 Horizontal turbine Woltman flowmeter (Crabtree, 2009)	23
Figure 3.6 Vertical turbine Woltman flowmeter (Crabtree, 2009)	23
Figure 3.7 Plan Do Check and Action Approach (PDCA) Scheme (ISO 17025:2017)	24
Figure 3.8 Steady Flow VS Unsteady Flow	26
Figure 3.9 Uniform Flow VS Non-Uniform Flow	27
Figure 3.10 Half Effect Sensor	29
Figure 3.11 ESP32 Pinout	31
Figure 4.1 Research Stages	38
Figure 4.2 Global Diagram of the Equipments	40
Figure 4.3 Hardware Design for Sensor Node	41
Figure 4.4 Hardware Design for Receiver Node	42
Figure 4.5 Software System Design	43
Figure 4.6 Interrupt Handler Diagram	44
Figure 4.7 Flow Rate Calculation Diagram	45
Figure 4.8 Kalman Filter Diagram	47
Figure 4.9 Experimental Testing Flow	48
Figure 5.1 Schematics of Electronic Components	53
Figure 5.2 The PCB Design of the Schematics	54
Figure 5.3 PCB Layout Implementation Results	54
Figure 5.4 Finalized 3D Model Visualization	55
Figure 5.5 Sensor Acquisition Code Syntax	56
Figure 5.6 Payload Json Syntax	57
Figure 5.7 createDocument Syntax	58
Figure 5.8 updateDocument Syntax	58
Figure 5.9 taskReading Syntax	59
Figure 5.10 Kalman Filter Code	61
Figure 6.1 Data Readings on the Web Application	75
Figure 6.2 Linearity Regression of Raw Data Flow Rate	81
Figure 6.3 Linearity Regression of Kalman Flow Rate Graph	82
Figure 6.4 Linearity Regression of Industrial Turbine Flow Rate	83
Figure 6.5 Correction Chart	85



LIST OF TABLES

Table 2.1 Comparison Research and Result	18
Table 3.1 Technical Specifications of YF-DN50	30
Table 3.2 Technical Specifications of ESP32	31
Table 4.1 Component Lists for Research Object	40
Table 6.1 Flowmeter Readings at 30 L/min	65
Table 6.2 Flowmeter Readings at 50 L/min	66
Table 6.3 Flowmeter Readings at 80 L/min	66
Table 6.4 Flowmeter Readings at 100 L/min	67
Table 6.5 Flowmeter Readings at 150 L/min	67
Table 6.6 Flowmeter Readings at 200 L/min	68
Table 6.7 Flowmeter Readings at 30 L/min with Kalman Filter	69
Table 6.8 Flowmeter Readings at 50 L/min with Kalman Filter	69
Table 6.9 Flowmeter Readings at 80 L/min with Kalman Filter	70
Table 6.10 Flowmeter Readings at 100 L/min with Kalman Filter	70
Table 6.11 Flowmeter Readings at 150 L/min with Kalman Filter	71
Table 6.12 Flowmeter Readings at 200 L/min with Kalman Filter	71
Table 6.13 Industrial Flowmeter Readings at 30 L/min	72
Table 6.14 Industrial Flowmeter Readings at 50 L/min	72
Table 6.15 Industrial Flowmeter Readings at 80 L/min	73
Table 6.16 Industrial Flowmeter Readings at 100 L/min	73
Table 6.17 Industrial Flowmeter Readings at 150 L/min	74
Table 6.18 Industrial Flowmeter Readings at 200 L/min	74
Table 6.19 Raw Data Results	76
Table 6.20 Kalman Filter Sensor Data Results	77
Table 6.21 Industrial Turbine Sensor Data Results	79
Table 6.22 Accuracy Comparison	84
Table 6.23 The results of the calculation from the Raw Experimental Flowmeter Data	88
Table 6.24 The calculation results of the Kalman Experimental Flowmeter Data	88
Table 6.25 Results of the Industrial Turbine Flowmeter Data	89