UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TEMPERATURE CONTROL DEVICE DESIGN FOR ELECTRIC KETTLE BY USING PID AND SLIDING MODE CONTROLLER

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electric and Electronic Engineering Technology (Industrial Robotics and Automation) with Honours.

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APPROVAL

This report is submitted to the Faculty of Electrical and Electronic Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Electric and Electronic Engineering Technology (Industrial Robotics and Automation) with Honours. The member of the supervisory is as follow:

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ABSTRAK

Kebanyakan cerek elektrik yang terdapat di pasaran bertujuan untuk melaksanakan satu tugas; untuk menyediakan air mendidih. Oleh itu, cerek tidak mampu menyediakan air panas pada suhu tertentu. Paparan suhu juga tidak disediakan untuk memudahkan rujukan pengguna. Disebabkan kekurangan ini, peranti yang boleh mengawal suhu air mengikut keperluan pengguna direkabentuk dalam projek ini. Untuk menganalisa keberkesanan kawalan suhu air, dua jenis algoritma kawalan digunakan iaitu PID dan SMC. Peranti prototaip dibangunkan untuk menguji keberkesanan litar dan pengawal yang direka. Peranti ini juga dilengkapi dengan paparan suhu semasa dan suhu yang dikehendaki ditetapkan oleh pengguna. Untuk tujuan analisis, peranti ini diuji pada suhu rujukan 40^{o}C, 50^{o}C dan 70^{o}C dengan isipadu air 500ml. Adalah didapati bahawa kedua-dua pengawal dapat mengawal suhu air di dalam cerek dengan tindakbalas yang baik. Untuk perbandingan prestasi, pengawal PID memerlukan set pemalar pengawal yang berlainan untuk suhu rujukan yang berbeza, manakala untuk pengawal SMC, hanya satu set pemalar pengawal sahaja boleh digunakan untuk pelbagai suhu yang dikehendaki.

ABSTRACT

Most electric kettles that are available in the market are intended to perform one task; to provide hot boiled water. Therefore, the kettle does not capable to prepare warm water at specific temperature. There is also no temperature display provided to facilitate user usage. Due to these constraints, a device that can control the water temperature according to consumer needs is designed in this project. To analyze the effectiveness of water temperature control, two types of control algorithm are used which are PID and SMC. A prototype device is developed to test the effectiveness of the designed circuit and controller. This device also equipped with current temperature display and desired temperature set by user. For analysis purpose, the device is tested for 45^{o}C, 50^{o}C and 70^{o}C of desired temperature at 500ml water volume. It is found that both controllers are able to control water temperature inside kettle with acceptable response. As performance comparison, PID controller require different set of controller gains for different desired temperature, while for SMC controller, same controller gain can be applied for wide range of desired temperature.

DEDICATION

This thesis is dedicated to my parents, who taught me that even the largest task can be accomplished if it is full with hardship. Special thanks to Dr Mohd Badril Bin Nor Shah, my supervisor for his countless hours of encouraging, reflecting, reading and most of all patience throughout the entire process. Finally, I would like to thank all my friends, who have been so supportive along the way doing my thesis.

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LIST OF ABBREVIATIONS

SMC	Sliding Mode Controller
PID	Proportional Integral Derivative
CPU	Central Processing Unit
ADC	Analog to Digital Converter
PIC	Peripheral Interfaced Controller
MCS	Micro Controller System
CMOS	Complementary Metal-Oxide-Semiconductor
IDE	Integrated Development Environment
PWM	Pulse With Modulation
USB	Universal Serial Bus
ICSP	In-System Programming
AC	Alternating Current
DC	Direct Current
SDA	Serial Data
SCL	Serial clock
HVAC	Heating ventilation and Air Conditioning
HTC	Hybrid temperature Control
IAE	Integral Absolute error
SSD	Seven Segment Display
SSR	Solid State Relay

CHAPTER 1

INTRODUCTION

An electric kettle is designed to prepare boiled water by using electric power. Electric current flows into heating element and turn it into energy to heat water. This electric kettle will stop heating the water if the temperature reaches 100^{o}C, which is the boiling point of the water. Figure 1.1 shows a common electric kettle used to boil water.

Figure 1.1: A common of electric kettle

An electric kettle that is always used at home to boil water is not equipped with the ability to control the water temperature and temperature display. This causes the electric kettle to have disadvantage if the user wishes to heat water at a certain temperature. Therefore, PID controller can be used to achieve such feature. This controller is widely used in many applications due to simple configuration and convenience to be implemented in any programmable devices.

Beside that sliding mode controller (SMC) also can be used to control the water temperature as it can control the electrical power that heats the water (Nagi et al., 2009). SMC is an efficient robust controller and has been broadly examined and actualized to diverse applications in process control (Yuan et al., 2016). SMC require sliding surface to provide sliding motion of the controlled response to fulfill the design specifications. Hence, desired water temperature can be achieved by implementing SMC controller with minimal fluctuations.

1.1 Statement of the Purpose

The purpose of this report is to develop temperature control device with the aid of controllers which can control different value of temperature.

1.2 Problem Statement

Electric kettle is usually used for boil water. Electric kettle can only carry only one purpose, to produced boiled water. Since the electric kettle has such a constraint as having no temperature display and the ability to control the water temperature at a certain temperature, it will be very attractive if the electric kettle has the ability to set the water temperature by ourselves.

There are many uses for boiling water at a certain temperature. For example, at temperature of $37^{o}C$, the guardian can prepare formula milk and avoid scalding their baby (Brown, 2012). In addition, the perfect temperature for brewing a cup of coffee, it required heated water of $93^{o}C$ (Pons, 2017).

By using electronic devices to get the desired water temperature in everyday life, users no longer have to buy expensive water heater to meet the requirements. By using only cheap electric kettle and device that is developed in this project, users are able to obtain the desired temperature of water as they need. In addition, water from water dispenser is used for healthy purpose since all the desired temperatures are not reaching 100^{o}C which is the boiling point.

PID controllers are the foremost widely-used style of controller for industrial application (Umesh, 2013). There are three main parameters concerned in PID controller; Proportional (P), Integral (I) and Derivatives (D). Stability of the system will improve by derivative mode and it allows proportional gain to increase while integral gain decrease, that will increases speed of the controller response. Desired water temperature set by user can be achieved with proper tuning of PID gains. However, PID may require tedious task to tuning the controller gain. Furthermore, different set of PID gains are required to cover wide range of different condition of a system. Therefore, a nonlinear controller such as SMC can be used to overcome these shortcomings.

SMC is an advanced controller which can be used to control linear and nonlinear, fast and slow dynamical system. It is derived from bang-bang controller, with some modification is made to the switching part to provide more appropriate control signal to plant. Similar to PID, SMC also has a controller gains that need to be tuned to obtain the desired performance.

1.3 Objectives

The aims of this project are:

a) To design a circuit of temperature control device for electric kettle.

b) To design PID and SMC Controller that capable to regulate water temperature at the desired level set by user.

c) To develop temperature control device complete with user interface and temperature display.

1.4 Work Scope

This project concentrates on controlling water temperature inside electric kettle based on desired level of water temperature set by user. To achieve all the objectives, following the five elements must be acknowledged:

a) Circuit design

Microcontroller-based circuit that is designed for this project combine with 7-segment display, potentiometer and temperature sensor.

b) Controller design

To provide the precise water temperature in electric kettle based on desired temperature set by user. Closed loop control of PID and SMC is designed is for temperature control algorithm.

c) Hardware Prototype

To verify the efficiency of the developed device and designed controller, a hardware prototype of this project is developed.

d) Type of electric kettle

Cheap electric kettle is used and it is connected to the developed device.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review provides reader with background information of a research by searching for relevant written documents, such as journal article, thesis, books and project papers. With total understanding of the subject matter, information can be summarized and provide a right direction in developing this project. This chapter will provides literature review on microcontroller, sliding mode control, PID controller, temperature sensor and related previous research for temperature control.

2.2 Microcontroller

A microcontroller is a whole coordinated on a solitary chip that joins all the features that are found in microchip (Ajao et al., 2015). Microcontroller basically contains of clocks and counters, interrupt, Central Processing Unit (CPU), ports for input and output, memory and analog to digital converters (ADC) on a single chip.

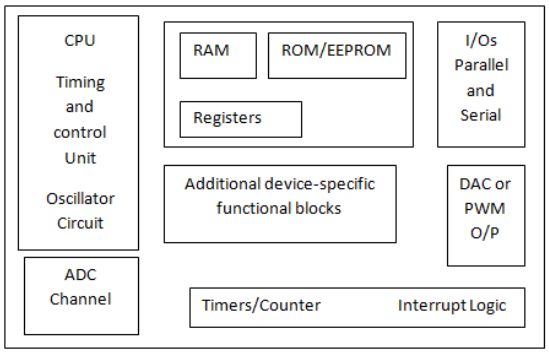

Figure 2.1: Microcontroller system

Microcontroller is characterized by their bits, instruction set, memory/devices and memory architecture. There are three types of microcontroller family**.** AVR8051 and PIC are three types of microcontroller. The 8051 is an 8-bit microcontroller designed by Intel (A.P. Godse, 2012, p.2). 8051 was optimized for single bit Boolean operation and 8-bit math. A.P Godse and A.D Godse identify that family-MCS-51 includes 8031, 8051, and 8751 microcontrollers.

Table 2.1: MCS-51 family (Godse and Godse,2012)

	Internal memory		Timer/Event Counter	Interrupts
Device	Program	Data		
8052AH	8 K × 8 ROM	256 × 8 RAM	3 × 16-bit	6
8051AH	4 K x 8 ROM	128 x 8 RAM	2 × 16-bit	5
8051	4 K x 8 ROM	128 x 8 RAM	2 x 16-bit	5
8032AH	None	256 × 8 RAM	2 × 16-bit	6
8031AH	None	128× 8 RAM	2 × 16-bit	5
8031	None	128 × 8 RAM	2 × 16-bit	5
8751H	4 K x 8 ROM	128 × 8 RAM	2 × 16-bit	5
8751H-12	4K x 8 ROM	128 x 8 RAM	2 x 16-bit	5

Peripheral Interface Controller (PIC) is a group of minimal cost, have higher performance capability, CMOS and completely static microcontroller. PIC is interesting and attractive features which are suitable for a wide range application.