UNIVERSITI PUTRA MALAYSIA

DESIGN AND DEVELOPMENT OF A MICRO-BASED FUZZY LOGIC TEMPERATURE CONTROLLER FOR PORTABLE COOLER

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By

ABDUL HALIM BIN MOHD HANAFI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATION

This thesis is dedicated to my parent and wife for their constant support, love and guidance during all moments of my life.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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October 2007

Chairman: **Mohammad Hamiruce Marhaban, PhD**

Faculty: **Engineering**

High demand to store breast milk, vaccines or other perishable items in developing communities is encouraging the development of portable cooler box. Portable cooler box also provides new way to store perishable items in remote locations. Furthermore, it believes that in the long term, fuzzy logic temperature control cooler box prove to be advantageous alternatives to the existing systems such as On-Off and PID controller cooler box. Due to this reason, portable cooler box with fuzzy logic temperature control is developed in this research. An attempt has been made to control the temperature of thermoelectric cooler (TEC) box by using Fuzzy Logic Control (FLC). The TECs operate on DC current and can control the cooling temperature by adjusting the value of DC current through thermoelectric. The MC68HC711E9-EVBU provides a low-cost and high-performance solution for TEC control. Earlier systems used many analog circuits to perform temperature control. The

use of MC68HC711E9-EVBU allows the task to be handled by software. The suitable fuzzy rule has been prepared and implemented to control the temperature. In this research, a minimum hardware required due to the advanced capabilities of the processor. It is observed that the response of the FLC is faster than the conventional controller. In this work, a systematic design approach for the implementation of a microcontroller based data logger for recording the FLC variables is presented. The developed portable cooler box in this research can be used to maintain the temperature of the cooler at 15^{o}C, thereby making it suitable for breast-feeding milk storage for 24 hours. Furthermore, the proposed system has been intentionally developed for the user convenience due to its portability and low power consumption.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

REKABENTUK DAN PEMBANGUNAN SATU LOGIK SAMAR MICRO-BASED PENGAWAL SUHU UNTUK PENYEJUK MUDAH ALIH

Oleh

ABDUL HALIM BIN MOHD HANAFI

Oktober 2007

Pengerusi: **Mohammad Hamiruce Marhaban, PhD**

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Permintaan yang tinggi bagi menyimpan susu badan, vaksin dan barang-barang segar di dalam masyarakat membangun telah menggalakkan pembinaan kotak sejuk mudah alih. Kotak penyejuk mudah alih juga menyediakan kaedah terkini untuk menyimpan barang-barang segar semasa lokasi bergerak. Tambahan pula, dipercayai bahawa pada jangka masa panjang, kotak sejuk kawalan suhu logik samar terbukti menjadi alternatif yang berguna berbanding sistem yang sedia ada seperti kotak penyejuk kawalan On-Off dan PID. Berdasarkan pada sebab ini, kotak sejuk mudah alih dengan kawalan suhu logik samar dibina didalam kajian ini. Oleh itu, pelbagai usaha telah dijalankan untuk mengawal suhu bagi kotak penyejuk termoelektrik (TEC) menggunakan Kawalan Logic Samar (FLC). Penyejuk termoelektrik beroperasi pada arus terus (DC) dan boleh mengawal suhu penyejuk dengan mengubah nilai bagi arus terus (DC) yang melalui termoelektrik. MC68HC711E9-EVBU menyediakan kos yang rendah

dan penyelesaian kepada prestasi tinggi bagi kawalan termoelektrik. Sistem-sistem yang sedia ada menggunakan banyak litar analog untuk menghasilkan kawalan suhu. Fungsi MC68HC711E9-EVBU adalah membenarkan tugas-tugas tersebut diambil alih oleh perisian. Hukum-hukum berasaskan samar yang bersesuaian bagi sistem telah disediakan dan dijalankan untuk mengawal suhu. Didalam kajian ini, perkakasan yang minimum diperlukan berikutan daripada kebolehan pemproses yang tinggi. Daripada permerhatian yang dijalankan, didapati bahawa tindakan atau respon pengawal logik samar adalah lebih laju daripada pengawal biasa. Didalam kajian ini, pendekatan rekabentuk yang sistematik untuk merekod keluaran FLC menggunakan pengumpul data dikemukakan. Kotak sejuk mudah alih yang telah dibina didalam kajian ini boleh digunakan untuk mengekalkan suhu penyejuk pada suhu 15^{o}C yang membolehkan ianya sesuai sebagai penyimpan susu badan bagi tempoh 24 jam. Tambahan pula, sistem yang dicadangkan ini memang dibangunkan untuk memudahkan pengguna berdasarkan kepada kebolehannya untuk bergerak dan menggunakan kuasa yang rendah.

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I certify that an Examination Committee met on 30th October 2007 to conduct the final examination of Abdul Halim Bin Mohd Hanafi on his Master of Science thesis entitled "Design and Development of a Micro-Based Fuzzy Logic Temperature Controller For Portable Cooler" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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Date: 29 January 2008

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date: 21 February 2008

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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ABDUL HALIM BIN MOHD HANAFI

Date: 27 December 2007

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LIST OF ABBREVIATIONS

A/D	Analog/Digital
AC	Alternating Current
ACCA	Accumulator A
ACCB	Accumulator B
ADC	Analog to Digital Converter
ALU	Arithmetic Logic Unit
ANSI	American Natioanal Standards Institude
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
Av	Voltage Gain
AxIDE	Axiom Integrated Development Environment
BASIC	Beginner's All-purpose Symbolic Instruction Code
Bi_2Te_3	Bismuth Telluride
BJT	Bipolar Junction Transistors
C	Centre Trapezoid
COG/COA	Centre of Gravity / Area
COM	Centre-of-Maximum
COM1	Communication One
COP	Coefficient of Performance
CPU	Central Processing Unit
D	Derivative Control
DA	Direct to Air System

DC	Direct Current
DFUZOUT	Defuzzification Output
DIP	Dual In-line Package
DSP	Digital Signal Processing
E	Error
EEPROM	Electrically Erasable Programmable Read-Only Memory
EOR	End of Rules
EORM	End of Rules Marker
EPROM	Erasable Programmable Read-Only Memory
FINDSEG	Find Segment
FIU	Fuzzy Inference Unit
FLC	Fuzzy Logic Control
FLTCCB	Fuzzy Logic Temperature Control Cooler Box
FOUTSUM	Fuzzy Out Sum
FOUTSUMH	Fuzzy Out Sum High
FOUTSUML	Fuzzy Out Sum Low
FUZOUT0	Fuzzy Output 0
FUZOUT1	Fuzzy Output 1
FUZOUT2	Fuzzy Output 2
GUI	Graphical User Interface
HEX	Hexadecimal
Hz	Hertz
I	Integral Control
I/O	Input/Output

IC	Integrated Circuit
IDIV	Divide Operation
IFMIN	IF minimum
IGBT	Isolated Gate-Base Transistor
IMCP2	Input Membership Function Cold Point Two
IMCS2	Input Membership Function Cold Slope Two
IMHS1	Input Membership Function High Slope One
IMNEP2	Input Membership Function Negative Error Point Two
IMNES2	Input Membership Function Negative Error Slope Two
IMNP1	Input Membership Function Normal Point One
IMNS1	Input Membership Function Normal Slope One
IMNS2	Input Membership Function Normal Slope Two
IMPES1	Input Membership Function Positive Error Slope One
IMZP1	Input Membership Function Zero Point One
IMZS1	Input Membership Function Zero Slope One
IMZS2	Input Membership Function Zero Slope Two
INMFBLK	Input Membership Function Block
$INPUT_{ERROR}$	Input of Error
$INPUT_{TEMP}$	Input Temperature
IN_{TEMP} MF_{COLD}	Input Temperature Membership Function Cold
IN_{TEMP} MF_{COLD}P1	Input Temperature Membership Function Cold Point One
IN_{TEMP} MF_{COLD}P2	Input Temperature Membership Function Cold Point Two
IN_{TEMP} MF_{COLD}S1	Input Temperature Membership Function Cold Slope One
IN_{TEMP} MF_{COLD}S2	Input Temperature Membership Function Cold Slope Two

IN_{TEMP} MF_{HOT}	Input Temperature Membership Function Hot
IN_{TEMP} MF_{HOT}P1	Input Temperature Membership Function Hot Point One
IN_{TEMP} MF_{HOT}P2	Input Temperature Membership Function Hot Point Two
IN_{TEMP} MF_{HOT}S1	Input Temperature Membership Function Hot Slope One
IN_{TEMP} MF_{HOT}S2	Input Temperature Membership Function Hot Slope Two
IN_{TEMP} MF_{NORMAL}	Input Temperature Membership Function Normal
IN_{TEMP} MF_{NORMAL}P1	Input Temperature Membership Function Normal Point One
IN_{TEMP} MF_{NORMAL}P2	Input Temperature Membership Function Normal Point Two
IN_{TEMP} MF_{NORMAL}S1	Input Temperature Membership Function Normal Slope One
IN_{TEMP} MF_{NORMAL}S2	Input Temperature Membership Function Normal Slope Two
$IN_{TEMP}MF_{COLD}$GR	Input Temperature Membership Function Cold Grade
KB	Knowledge-based
kHz	Kilohertz
L	Left Trapezoid
LCD	Liquid Crystal Display
LOOPCOUN	Loop Count
LSB	Least Significant Bit
MCU	MicroController Unit
MF	Membership Function
MF GRADE	Membership Function Grade
MIN-MAX	Minimum-Maximum
MOD	Operation Mode
MODA	Operation Mode A
MODB	Operation Mode B

MOM	Mean-of-Maximum
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MPU	Micro Processor Unit
MSB	Most Significant Bit
mV	Milli Volt
OUTMF	Output Membership Function
OUTMF0	Output Membership Function 0
OUTMF1	Output Membership Function 1
OUTMF2	Output Membership Function 2
P	Proportional Control
PC	Personal Computer
PCBDL	PC-Based Data Logger
PD0	Port D Zero
PD1	Port D One
PI	Proportional and Integral Control
PID	Proportional, Integral and Derivative Control
PWM	Pulse Width Modulation
R	Right Trapezoid
R/W	Read/Write
RAM	Random Access Memory
RISC	Reduced Instruction Set Computer
ROM	Read-Only Memory
RS	Register Select
RUL1	Rules 1