Cairo University

Design and Implementation of Pole Placement Self Tuning Regulator on Arduino Embedded Platform

By:

Mostafa Ahmad Mohammad Hassanin

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
ELECTRICAL POWER AND MACHINES ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Design and Implementation of Pole Placement Self Tuning Regulator on Arduino Embedded Platform

By:
Mostafa Ahmad Mohammad Hassanin

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
ELECTRICAL POWER AND MACHINES ENGINEERING

Under Supervision of

Prof. Dr. Ahmed Bahgat Gamal Bahgat
Electrical Power and Machines Department
Faculty Of Engineering, Cairo University

Prof. Dr. Hassan Mohammad Rashad Emara
Electrical Power and Machines Department
Faculty Of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Design and Implementation of Pole Placement Self Tuning Regulator on Arduino Embedded Platform

By:

Mostafa Ahmad Mohammad Hassanin

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
ELECTRICAL POWER AND MACHINES ENGINEERING

Approved by the Examining Committee

Prof. Dr. **Ahmed Bahgat Gamal Bahgat,** Thesis Main Advisor

Prof. Dr. **Hassan Mohammad Rashad Emara**, Advisor

Prof. Dr. **Ahmad Mohammad Fahim Sakr**, Internal Examiner

Prof. Dr. **Radwan Hassan Abdul-Hameed**, External Examiner
Faculty Of Engineering, Helwan University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Engineer's Name: **Mostafa Ahmad Mohammad Hassanin**
Date of Birth: 18/02/1985
Nationality: Egyptian
Email: mamech@windowslive.com
Phone: 01003904847
Address: Misr Al Gadidah, Roxy, Cairo

Registration Date: 1/10/2015
Awarding Date: / / 2018
Degree: Master of Science
Department: Electrical Power and Machines Engineering

Supervisors:

Prof. Dr. Ahmed Bahgat Gamal Bahgat

Prof. Dr. Hassan Mohammad Rashad Emara

Examiners:

Prof. Dr. Radwan Hassan Abdul-Hameed Faculty Of Engineering, Helwan University	External Examiner
Prof. Dr. Ahmad Mohammad Fahim Sakr	Internal Examiner
Prof. Dr. Ahmed Bahgat Gamal Bahgat	Thesis Main Advisor
Prof. Dr. Hassan Mohammad Rashad Emara	Advisor

Title of Thesis:

Design and Implementation of Pole Placement Self Tuning Regulator on Arduino Embedded Platform

Keywords:

Pole placement – Self Tuning Regulator – System Identification – Embedded Controller – Arduino Platform

Summary:

In this thesis an embedded controller with its autotuner are implemented on Arduino platform using pole placement technique for controller design. The Indirect Self-Tuning Regulators (STR) strategy is used for autotuner design, while Least Squares (LS) Method is used for parameters estimation of proposed plant model. Creation of Arduino based pole placement controller with indirect STR auto-tuner is needed to accelerate and facilitate the development in field of controller implementation on a standard platform like Arduino, also it will open the road for further research in field of realization of many other topics in control theory.

Acknowledgement

Around 7 years ago (in 2010), I heard for the first time about the terms “System Identification” and “Parameters Estimation”, and in fact the concept seemed to me very interesting and appealing, as you can know how the system behaves, even if you do not know its parameters from a direct modeling process. Actually these 2 terms were my entrance to the world of control theory, as I became eager to learn more about these concepts, and more importantly how to apply them on real processes.

The path towards this knowledge was not easy at all, and one of reasons is because there are many things are not written in references, and you have to exert much effort to try it and to get your own conclusions.

After extensive effort and much patience, today this thesis became complete thanks to Allah, The Most Gracious, The Most Merciful, and I hope that someday this kind of practical work to be implemented with industrial entities, for sake of benefit for both academia and industry. I would like to thank all who supported me in this journey to achieve this eventually.

Table of Contents

List of Figures

List of Symbols

A	System model denominator polynomial
A_0	Observer polynomial
A_m	Reference model denominator polynomial
a_1 and a_2	System model denominator polynomial coefficients
a_{m1} and a_{m2}	Reference model denominator polynomial coefficients
B	System model numerator polynomial
$B+$	System model zeros to be canceled
$B-$	System model zeros to be retained
B_m	Reference model numerator polynomial
$\bar{B}_m$	Remaining polynomial from B_m term after factorization
b_1 and b_2	System model numerator polynomial coefficients
C	Electrical capacitance
E	Error vector
g	Gravitational constant
h	Water head
I	Electrical current intensity
MO	Maximum overshoot
N	Number of samples in parameter estimation process
Q	Electrical charge quantity
q	Forward shift operator
q_{in}	Inlet flow rate
q_{out}	Outlet flow rate
R	Electrical resistance
r	Pole second norm
r_1	Pole placement controller R term polynomial coefficient
$R(q)$	Pole placement controller design polynomial R term
$R'(q)$	Remaining polynomial from R term after factorization
$S(q)$	Pole placement controller design polynomial S term
s	Laplace transform operator
s_1 and s_0	Pole placement controller S term polynomial coefficients
T	Sampling time
$T(q)$	Pole placement controller design polynomial T term
Ts	Settling time
V_N	Error cost function to be minimized