



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  
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**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.



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## 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
$T_s$	Settling time
$V_N$	Error cost function to be minimized