AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

A NEW DESIGN APPROACH FOR MECHATRONIC CONTROL SYSTEMS

BY

MAGDY MOHAMED ABDEL-HAMEED

A THESIS
Submitted for The
Degree of Doctor of Philosophy
In
Mechanical Engineering
(Design and Production Engineering)

Supervised By

Prof. Dr. Mohamed Y. Afifi

Prof. of Applied Mechanics,
Design and Production
Engineering Department,
Faculty of Engineering,
Ain Shams University,
Cairo

Prof. Dr. Farid A. Tolbah

Prof. of Automatic Control,
Design and Production
Engineering Department,
Faculty of Engineering,
Ain Shams University,
Cairo

1994

بسم الله الرحمن الرحيم

بسم الله الرحمن الرحيم

Dedicated to

my parents,

wife and daughters

EXAMINERS COMMITTEE

Name, Title & Affiliation **Signature**

1-Prof. Dr. Mohamed A. R. Ghonaimy
Prof. of Computer Systems,
Computer & System Engineering Department,
Faculty of Engineering,
Ain Shams University.

2-Prof. Dr. Sayed Desouki Hassan
Prof. of Automatic Control,
Aeronautics Department,
Faculty of Engineering,
Cairo University.

3-Prof. Dr. Mohamed Y. Afifi
Prof. of Applied Mechanics,
Design and Production Engineering Department,
Faculty of Engineering,
Ain Shams University, Cairo
(Supervisor)

STATEMENT

This dissertation is submitted to the faculty of engineering, Ain Shams University for the Degree of doctor of Philosophy in Mechanical Engineering.

The work included in this thesis was carried out by the author in the Department of Design and Production Engineering, Ain Shams University, From September 1989 to September 1993.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

Date :

Signature :

Name: Magdy M. Abdel-Hameed

ACKNOWLEDGEMENTS

Praise be for God, Lord of the world , By whose grace this work has been completed.

The author wishes to express his deepest thanks to Professor Dr. Mohamed Y. Afifi for his valuable supervision throughout this work.

The author wishes also to thank Professor Dr. Farid A. Tolbah for his unlimited help and great interest in carrying out this work.

The author wishes to express his great gratitude to the late professor Dr. Mohamed M. Nigm for his supervision of this work from 1991 till day of his death and asks God to have mercy upon him.

The author owes his deepest thanks and appreciation to Professor Dr. Talat F. Refai for reading and correcting the linguistic manuscript.

The author thanks Eng. M. A. Hassan, Director of Herion Works in Egypt who provided pneumatic components for the experimental work.

ABSTRACT

The objectives of the present work are to investigate the following areas and develop the corresponding appropriate procedures.

- A design procedure of a sequential controller is suggested. This procedure is based on:
  - a mathematical approach in order to obtain an optimum design of such controller.
  - a mechatronic control system to provide low cost control, high performance and high reliability.

  This procedure is an alternative method to the relay ladder or programmable controller ladder logic to achieve relatively simple software and minimum execution time.

- Experimental Verification of the proposed design procedure using different experimental working media (pneumatics, electronics and microprocessor based controllers).

The details of the proposed design procedure is established and is applied to different case studies.

The results of the proposed procedure is tested experimentally using pneumatic components, electronic gates and microprocessor based controllers. Both theoretical and experimental results were found to be in agreement which proves the convenience of the proposed method. Also the comparison between the results obtained from the proposed method and the conventional method proved the advantages of the proposed method.

THESIS SUMMARY

Chapter 1: Literature Survey And Problem Statement

This chapter is devoted to survey the previous work concerned with the attempts used to design sequential controllers in mechatronic systems, hard and flexible, especially used to drive fluid (pneumatic and hydraulic) power systems. The mechatronic control system concept and its activities are elaborated.

Chapter 2: Design Of The Proposed Sequential Controllers

The primary objective of this chapter is to derive a convenient approach to design sequential controllers in mechatronic systems. The design procedure to design the hardwired sequential controllers based on mathematical rules is investigated in order to discard the trial and error methods. Also the design procedure to design flexible sequential controllers based on the concept of mechatronic is proposed. The modeling of fluid components has been included to be suitable for the implementation of the proposed method. Finally applications of the suggested methods on different case studies are discussed.

Chapter 3: Experimental Work

In this chapter, the experimental part of the present work is presented. The experimental system consists of the following three main parts:

1- **Pneumatic Power System:** The pneumatic power system is designed to represent a punching process model required to punch two holes.

2- **Sequential Controller:** The function of the sequential controller is to drive the pneumatic power system. Three types of sequential controllers are used pneumatic, electronic and a microprocessor based controller.

3- Data Acquisition System: The data acquisition system is based on a PC computer with an 80486 processor with a clock speed of 33 Mhz, and an Analog to Digital and Digital to Analog converter.

Chapter 4: Results and Discussions

This chapter is devoted to evaluate the results of the experimental work results. Comparison between different tested controllers is provided concerning the function, performance, cost, reliability and repairability analysis.

Chapter 5: Conclusions

The conclusions derived from the thesis are given where a generalized coordinated approach has been established for the design of sequential controllers in mechatronic systems. The derived method is based on mathematical rules instead of trial and error concepts. It has been proven that the application of the proposed method has the following advantages compared to the application of the well known methods: lesser number of components, higher performance, lower cost, higher reliability and ease of maintenance. Different trends to future researches are presented.

NOMENCLATURE

-	Don't care condition
a_i	*i*th input variable
A	Input states set
A-	Retraction Position of piston A
A+	Advance position of piston A
A_i	*i*th bit in port A
AC	Alternating current
ALU	Arithmetic and logic unit
b_j	*j*th internal state variable
B	Internal states set
B_i	*i*th bit in port B
B-	Retraction Position of piston B
B+	Advance position of piston B
BCC	BASIC conventional controller program
BPC1	The first BASIC proposed controller program
BPC2	The second BASIC proposed controller program
C	Confidence level
C.	Conventional
C_i	*i*th capacitor
C-	Retraction Position of piston C
C+	Advance position of piston C
CPU	Central processing unit
CSC	The conventional sequential controller program
DAS	Data acquisition system
DC	Direct current
Dc	Decimal number
D_i	*i*th diode
ELS_i	*i*th electric limit switch
exe.	executable
f_i	*i*th output function
F	Output function
F_i	*i*th flip flop
g_j	*j*th memory function
G	Next state function
G_i	*i*th gate
GND	Ground
Mhz	Megahertz
IC	Integrated circuit
IN	Input
I/O	Input/ output

k_s	Number of rows in a primitive flow table
LS_i	*i*th limit switch
PSC1	The first proposed sequential controller program
PSC2	The second proposed sequential controller program
q	Total number of internal states
Q	Sequential system
m	Total number of outputs
MPU	Microprocessor units
n	Total number of inputs
n_c	Number of columns input combinations) in a primitive flow table
NC	Normally closed
NO	Normally open
OUT	Output
P	Pressure
P.	Proposed
Pb_i	*i*th push button
P_c	Compressor
PC	Programmable controller
PIO	Parallel input output ports
PLS_i	*i*th pneumatic limit switch
PPA	Parallel printer adapter
R_s	System reliability
R_i	*i*th resistance
Rt	Reset of an R-S flip flop
S	Output states set
SOL_i	*i*th solenoid
SR	Sampling rate
St	Set of an R-S flip flop
S_k	*k*th output variable
t	Time
T_i	*i*th transistor
TTL	Transistor transistor logic
TV_i	*i*th throttle valve
U	Conditioning unit
V	Volt
V_i	*i*th valve
X	X axis
Y	Y axis
WL	Number of waiting loops

ILLUSTRATIONS

Tables (Note: Tables are at the end of each chapter)

Figures (Note: Figures are at the end of each chapter)

Plates