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| العنوان: | Design of Microprocessor Interfacing for Practical Applications |
| المؤلف الرئيسي: | Shaarawi, Mohamed Ibrahim |
| مؤلفين آخرين: | Hegazy, Ahmed Dawood، Mahmoud, Safwat Mahrous(super) |
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# ABSTRACT

The research objective is a study for changing conventional machine tool to a computerized numerically controlled (CNC) machine tool by using the microcomputer XT . A lathe was taken as an example for this study .

The types of CNC systems were studied , and reference-pulse system was chosen to be followed in the system design .

A software program is developed by using assembly language for the 8088 microprocessor . Several turning functions , and different kinds of interpolation were achieved by this program : Rapid traverse , fixed-cycle turning , program hold , linear interpolation , clockwise circular interpolation , and counterclockwise interpolation .

For the different types of interpolation functions the required path was obtained with an error in the range of a single BLU throughout the complete path .

The software program is developed to be easily changed according to the parameters required by the system , thus increasing the flexibility .

An interfacing circuit is implemented to drive two stepping motors simulating the two drives (X and Z) of a lathe . This circuit is used also to monitor the different outputs from the I/O port used to control the two stepping motors .

A simulation model for the lathe is set up , with counters connected to count the number of BLUs for both axes .

# ملخص البحث


يتناول البحث المقدم دراسة تحويل التحكم فى المعدات الميكانيكية من تحكم يدوى إلى تحكم رقمى وذلك بإستخدام الحاسب الشخصى X T ، وقد تم أخذ المخرطة كمثال لهذه الدراسة .

تـــم دراســـة أنظمـة التحكـم الرقمى بإستخدام الحاسب الآلى ، وقد أختير نظام نبضة المرجع ( Reference – Pulse ) لتطبيقه فى التصميم ، وهذا النظام يعتمد على توليد النبضات اللازمة لتشغيل المحركات الدرجية من الحاسب الآلى وذلك بإستخدام البرنامج المنفذ بلغة التجميع للمجهز الدقيق 8088 ، وذلك للحصول على أقصى سرعة ممكنة لتنفيذ البرنامج ، ثم يتم إدخال هذه النبضات إلى دائرة المواجهة بين الحاسب الآلى والمحركات وذلك لتنفيذ وظائف المخرطة المختلفة ، وقد تم تصميم البرنامج بطريقة تسمح بتغييره بسهولة حسب الإحتياج ، مما يضفى المرونة على النظام .

وقد تم عمل دائرة المواجهة لتحريك محركين درجيين وذلك لمحاكاة حركة المحاور الخاصة بالمخرطة - وذلك فى محورى ( س ، ع ) ، وقد أستخدمت الدائرة أيضاً لمراقبة الخرج من الحاسب الآلى.

كما تم عمل نموذج لمحاكاة المخرطة وذلك بتركيب نظام على المحركات يسمح بعد وحدات القياس الأساسية ( BLU ) ، لكل محور .

وقد تم فى هذا البحث تنفيذ الوظائف الآتية :

١ ـ العبور السريع (Rapid Traverse ).

٢ ـ الدورة الثابتة (Fixed Cycle) .

٣ ـ إيقاف البرنامج (Program Hold ).

٤ ـ التوليد الخطى (Linear Interpolation) .

٥ ـ التوليد الدائرى مع عقارب الساعة (Circular Interpolation Clockwise) .

٦ ـ التوليد الدائرى عكس عقارب الساعة (Circular Interpolation Counterclockwise ).

وقد تم الحصول على الأشكال المطلوبة بالدقة اللازمة حيث حققت نسبة خطأ فى حدود وحدة قياس أساسية واحدة .

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## LIST OF ABBRIVIATIONS

| | |
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| BCD | Binary Coded Decimal . |
| BLU | Basic Length Unit . |
| CNC | Computerized Numerical Control . |
| DAC | Digital to Analog Converter . |
| DDA | Digital Differential Analyzer . |
| DNC | Direct Numerical Control . |
| DPU | Digital Processing Unit . |
| LSI | Large Scale Integration . |
| NC | Numerical Control . |
| SCR | Silicon Controlled Rectifier . |

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Ain Shams University
Faculty of Engineering

# Design of Microprocessor Interfacing for Practical Applications

*By*

Eng. MOHAMED IBRAHIM SHAARAWI

*A THESIS*

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Electrical Engineering

*Supervised by*

Prof. Dr. SAFWAT MAHROUS MAHMOUD
Ain Shams University

Prof. Dr. AHMED DAWOOD HEGAZY
Military Technical College

*CAIRO - 1990*

## EXAMINERS COMMITTEE

| Name , Title & Affilliation | Signature |
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| 4- Prof. Dr. Safwat Mahrous Mahmoud<br>Ain Shams University | |

Date : / 9 / 1990

# STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering .

The work included in this thesis was carried out by the author in the department of Electronics and Computer Engineering , Ain Shams University , from 9/11/1987 to 1/9/1990 .

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

NAME :Mohamed Ibrahim Shaarawi

SIGNATURE :

DATE :

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I wish to express my sincere gratitude , deepest thanks , and appreciation to Professor Dr. Safwat Mahrous Mahmoud , and Professor Dr. Ahmed Dawood Hegazy for their faithful supervision , continuous encouragement , indispensable help , helpful discussions , valuable advice , and care during the course of this accomplishment .

I wish to thank my colleagues , and everybody who helped in any way in completing this work .

Finally , I wish to extend my gratitude to my parents and family for their understanding , support , and patience that made this work possible .

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# CHAPTER 1

# INTRODUCTION

The declining cost of minicomputers and microcomputers is changing the look of the factory floor . Although the application of computers to manufacturing has been somewhat slow , distinct trends can be observed . These include an increase in the use of computer-controlled machine tools , the application of new manufacturing systems such as laser-beam cutters , and the appearance of a new generation of industrial robots in the production lines .

## 1.1 Basic Concepts of Manufacturing Systems

Modern manufacturing systems and industrial robots are advanced automation systems that utilize computers as an integral part of their control . Computers are now vital part of automation They control stand alone manufacturing systems , such as various machine tools , welders , and laser-beam cutters . They run production lines and are beginning to take over control of an entire factory . Even more challenging are the new robots performing various operations in industrial plants and practicing in the full automation of factories .

It is well to keep in mind that an automatically controlled

factory is nothing more than the latest development in the industrial revolution that began in Europe two centuries ago and progressed through the following stages :

1- Construction of simple machines and mechanization started in 1770 , at the beginning of this revolution .

2- Fixed automatic mechanisms and transfer lines for mass production came along at the turn of this century . The transfer line is an organization of manufacturing facilities for faster output and shorter production time . The cycle of operations is simple and fixed ,and is designed to produce a certain product .

3- Next came machine tools with simple automatic control , such as plugboard controllers to perform a fixed sequence of operations and copying machines in which a stylus moves on a master copy and simultaneously transmits command signals to servodrives .

4- The introduction of numerical control (NC) in 1952 opened a new era in automation . NC is based on digital computer principles , which was a new technology at that time .

5- The logical extension of NC was the computerized numerical control (CNC) for machine tools , in which a minicomputer is included as an integral part of the control cabinet .

6- Industrial robots were developed simultaneously with CNC

systems . The first commercial robot was manufactured in 1961 , but it did not play a major role in manufacturing until the late 1970s .

7- A fully automatic factory which employs a flexible manufacturing system (FMS) and computer-aided design /computer aided manufacturing (CAD/CAM) techniques is the next logical extension . FMS means a facility that includes manufacturing cells , each cell containing a robot serving several CNC machines , and an automatic material handling system interfaced with a central computer . [1]

The new era of automation , which started with the introduction of NC machine tools , was undoubtedly simulated by the digital computer . Digital technology and computers enabled the design of more flexible automation systems , namely systems which can be adapted by programming to produce a new product in a short time . Today manufacturing systems are becoming more and more flexible with progress in computer technology and programming techniques .

## 1.2 Real Time Systems

Whenever a computer system is required to acquire data , emit data , or interact with its environment at precise times , the system is said to be a real time computer system . All computer systems are in some sense real time systems . For the control of

processes or mechanisms , a real time system is a system whose temporal performance (response time , data-acquisition period , etc. ) is of critical importance to the industrial systems to which it is connected . [2]

As the number of critically time-dependent tasks in a computer system grows , careful thought must be given to the computer programs (software) so that all real time constraints are satisfied .

On the other hand in a large time shared system such as a central university campus computer , no such high priority response time can be fairly granted to one user's task . In a time shared computer system , one user's program is allowed to run for a short time , called a 'time slice' , and then another program runs and so forth . Thus as the number of users increase the total time required to service all users increases and each user will see an increase in the time required to complete the task (the system response time) . Such a system is unsuited to real time applications .

Although the most obvious feature of a real time computer system is its close temporal coupling with an industrial process or system , another characteristic is the need of a bug free and robust software . Since many microcomputer based real time systems are unattended and operating without human supervision , it is desirable that if a failure occurs , it does not produce a catastrophic result . The failure should be detected and a graceful recovery should be executed .

## 1.3 Fundamentals of Numerical Control

Controlling a machine tool by means of a prepared program is known as numerical control , or NC . NC equipment has been defined by the Electronic Industries Association (EIA) as "A system in which actions are controlled by the direct insertion of numerical data at some point . The system must automatically interpret at least some portion of this data ."

In a typical NC system the numerical data which is required for producing a part is maintained in a punched tape and is called the part program . The part program is arranged in the form of blocks of information , where each block contains the numerical data required to produce one segment of the workpiece . The block contains , in a coded form , all the information needed for processing a segment of the workpiece such as : the segment length, its cutting speed , feed etc. . Dimensional information and the contour form are taken from an engineering drawing . Dimensions are given separately for each axis of motion . Cutting speed ,feed rate and auxiliary functions (coolant on and off , clamp , gear changes etc .) are programmed according to the surface finish and tolerance requirements .

Compared with a conventional machine tool , the NC system replaces the manual actions of the operator . In conventional machining a part is produced by moving a cutting tool along a workpiece by means of handwheels , which are guided by an operator . Contour cuttings are performed by an operator by

sight . On the other hand , operators of NC machine tools need not be highly skilled . They only have to monitor the operation of the machine , operate the tape reader , and usually replace the workpiece . However , since the operator works with a sophisticated and expensive system , intelligence , clear thinking and especially good judgment are essential qualifications of a good NC operator .

Preparing the part program for a NC machine tool requires a part programmer . The part programmer must possess knowledge and experience in mechanical engineering fields . Knowledge of tools , cutting fluids , use of machinability data , and process engineering are all of considerable importance .

The part dimensions are expressed in part programs by integers . Each unit corresponds to the position resolution of the axis of motion and will be referred to as the basic length unit (BLU) . The BLU is also known as the "increment size" or "bit weight" , and in practice it corresponds approximately to the accuracy of the NC system .

In NC machine tools each axis of motion is equipped with a separate driving device which replaces the handwheel of the conventional machine .

Axis of motion means an axis in which the cutting tool moves relative to the workpiece . This movement is achieved by the motion of the machine tool slides . The main three axes of motion will be referred to as the X , Y , and Z axes . The Z axis is perpendicular to both X and Y in order to create a right-hand

coordinate system , such as shown in Fig. 1.1 .

The NC machine tool system contains the machine control unit (MCU) and the machine tool itself , as shown in Fig. 1.2. The MCU has to read and decode instructions to the control loops of the machine axes of motion , and to control the machine tool operation .

Figure 1.3 shows the coordinate system of a drilling machine , a milling machine , and a lathe .

## 1.4 Advantages of Numerical Control Systems

The primary motivations for the development of NC systems for machine tools were the demand for high accuracy in manufacturing of complicated parts , combined with the desire to shorten production time .

The feature of high flexibility is substantially significant in modern manufacturing , also the manufacturing machine has to be economical in use even where a small quantity of parts is produced. This is solved by NC and CNC systems , when a new product is required , only the part program has to be changed .

The NC machine tool has the following advantages , compared with other machining methods:

1] A full flexibility ;a part program is needed for producing a new part .

2] Accuracy is maintained through the full range of speeds and feeds .

3] A shorter production time .

4] The possibility of manufacturing a part of complicated contour .

5] Easy adjustment of the machine , which requires less time than with other manufacturing methods .

6] The need for a highly skilled and experienced operator is avoided .

7] The operator has free time ; this time may be used for looking after other machining operations .

On the other hand , the main disadvantages of NC systems are:

1] A relatively high cost .

2] More complicated maintenance ; a special maintenance crew is desirable .

3] A highly skilled and properly trained part programmer is needed .

## 1.5 Classification of NC Systems

The classification of NC machine tool systems can be done in four ways :

1. According to the type of the machine : Point-to-point versus contouring (continuous path ) .

2. According to the structure of the controller : hardware based NC versus CNC .

3. According to the programming method : incremental versus absolute.

4. According to the type of control loops : open-loop versus closed-loop .

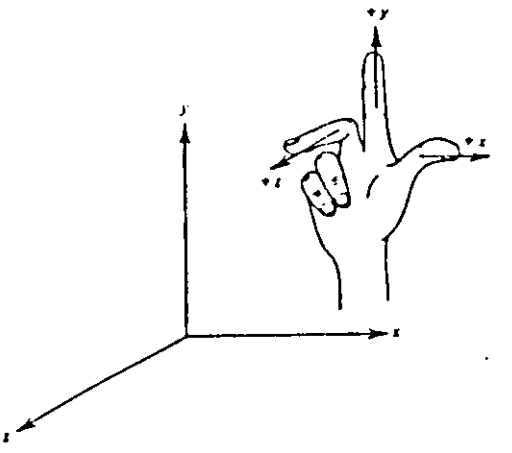

Fig.1.1 A right-hand coordinate system .



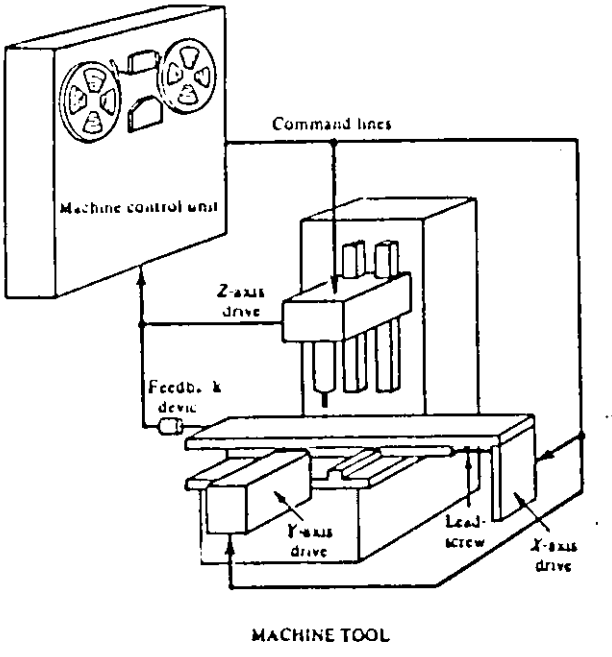


Fig.1.2 Nume: ical control systems .

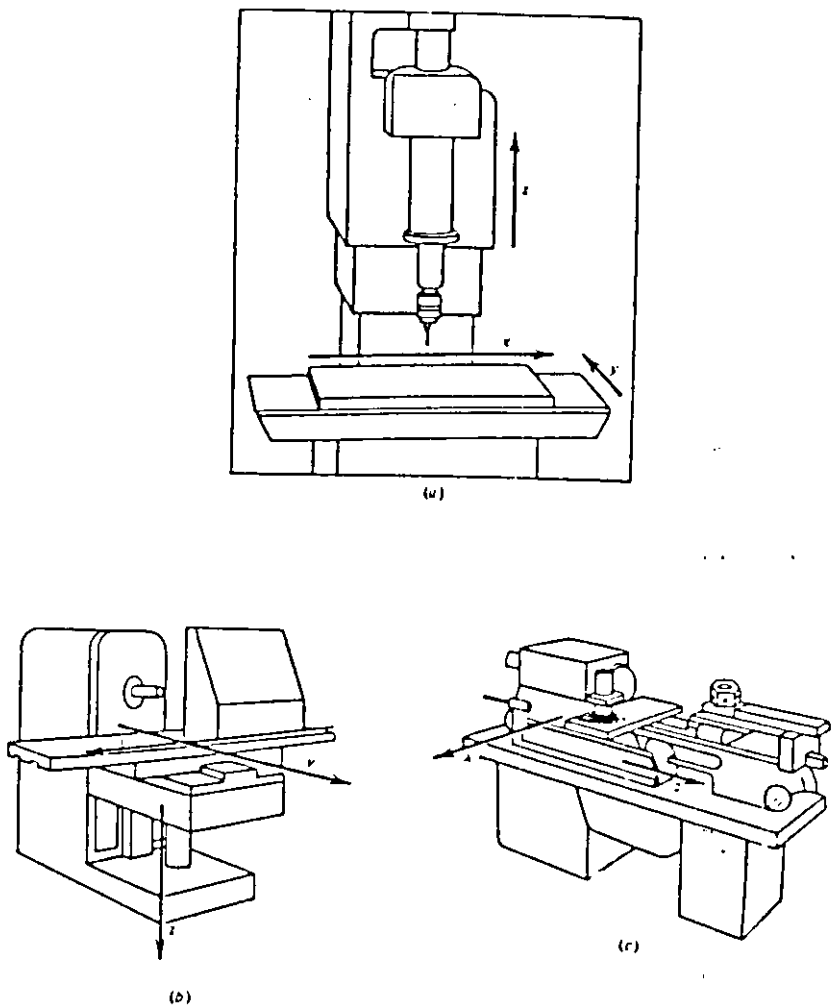

Fig.1.3 Coordinate systems in machine tools .

(a) Drilling (b) Milling (c) Lathe

### 1.5.1 Point to Point and Contouring

*Point-to-point systems* . In a point-to-point (PTP) NC machine ,the path of the cutting tool and its feed rate while travelling from one point to the next are without any significance . Such system would require only position counters for controlling the final position of the tool upon reaching the desired point , a good example is the drilling machine

*Contouring systems* . In contouring, or continuous path, systems, the tool is cutting while the axes of motion are moving , as , for example , in a milling machine .

In contouring machines , the position of the cutting tool at the end of each segment together with the ratio between the axial velocities determine the desired contour of the part, and at the same time the resultant feed also affects the surface finish . In this case , a velocity error in one axis causes a cutter path position error , the system has to contain continuous position control loops in addition to the position counters . Each axis of motion is equipped with a separate position loop and counter . Dimensional information is given separately for each axis and is fed through the Data Processing Unit (DPU) to the appropriate position counter . The programmed feed rate , however is that of the contour and has to be processed by the DPU in order to provide the proper velocity commands for each axis . This is done by means of an *interpolator* ,which is contained in the DPU of contouring systems .

### 1.5.2 NC and CNC

The NC systems which were produced in the sixties used electronic hardware based upon digital circuit technology . The CNC systems which were introduced in the early seventies , employ a minicomputer or microcomputer to control the machine tool and eliminate ,as far as possible , additional hardware circuits in the control cabinet . The trend away from hardware based NC to software based equipment brings an increase in the system flexibility and an improvement in the possibility for correcting part programs using the CNC computer .

The digital controller in hardware based NC systems employs voltage pulses , where each pulse causes a motion of 1 *Basic length unit* (BLU) in the corresponding axis direction . In these systems a pulse is equivalent to 1 BLU

Pulse = BLU

In the computer the information is arranged , manipulated , and stored in the form of binary words . Each word consists of a fixed number of bits . In the CNC computer each bit represents 1 BLU .

Bit = BLU

### 1.5.3 Incremental and Absolute Systems

An *incremental system* . is the one in which the reference point to the next instruction is the endpoint of the preceding operation . When considering an incremental system both the programming method

and the feedback device are in incremental form .

An *absolute system* . is the one in which all moving commands are referred to one reference point , which is the origin and is called the zero point . The position commands are given as the absolute distance from that zero point .

The most significant advantage of the absolute system over the incremental one is in cases of interruptions that force the operator to stop the machine . With absolute system it returns to the same position where it was interrupted , this is impossible with an incremental system .

A further advantage of the absolute system is the possibility of easily changing the dimensional data in the part program .

Incremental systems , however , have the following advantages over absolute ones :

1. Easy inspection of the part program .
2. The performance of the incremental system can be checked by a closed loop tape .
3. Mirror image programming is facilitated with incremental system .

Most modern CNC systems permit application of both incremental and absolute programming methods . These CNC systems provide the user with the combined advantages of both methods.

### 1.5.4 Open Loop and Closed Loop Systems

Every control system , including NC systems , may be designed as an open loop or a closed loop control . The term open loop

control means that there is no feedback , and the action of the controller has no information about the effect of the signals it produces .

The open loop NC systems are of digital type and use stepping motors for driving the slides . A stepping motor is a device whose output shaft rotates through a fixed angle in response to an input pulse . The stepping motors are the simplest way for converting electrical pulses into proportional movement , and they provide a relatively cheap solution to the control problem . Since there is no feedback from the slide position the system accuracy is solely a function of the motor's ability to step through the exact number of steps which is provided at its input . Figures 1.4 , 1.5, show an open loop control system for a two-axis machine, and an incremental open loop control for PTP system .

The closed loop control measures the actual position and velocity of the axis and compares them with the desired references . The difference between the actual and the desired values is the error . The control is designed in such a way as to eliminate , or reduce the error to a minimum , namely the system is of a negative feedback type .

In NC systems both the input to the control loop and the feedback signals may be a sequence of pulses , each pulse representing a BLU unit . The digital comparator correlates the two sequences and gives , by means of a digital-to-analog converter (DAC) , a signal representing the position error of the system , which is used to drive the motor . Figure 1.6 shows a block diagram of closed loop incremental PTP system .

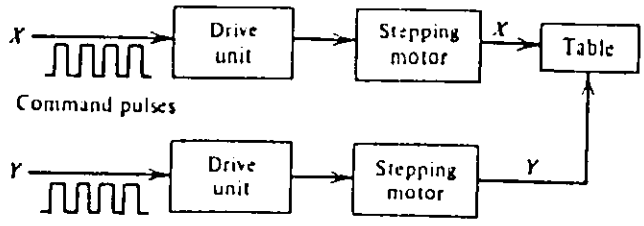


Fig.1.4 Open loop control system for a two-axis machine .

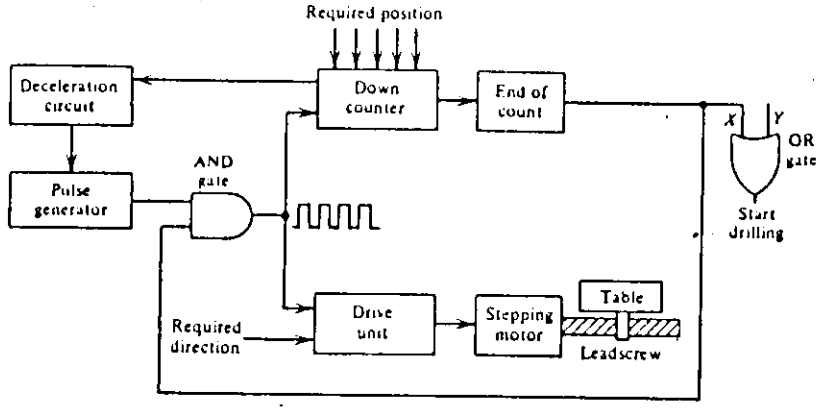


Fig.1.5 Incremental open loop control for PTP system .

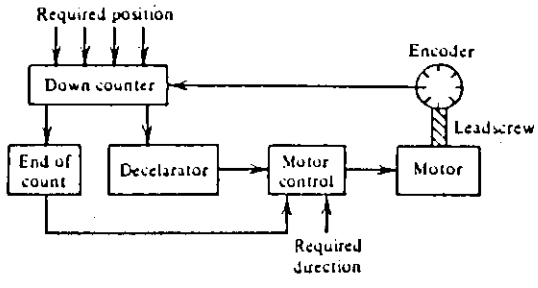


Fig.1.6 Closed loop incremental PTP system .

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# تصميم دوائر المواجهة للتطبيقات العملية باستخدام المجهز الدقيق

مقدمة من
مهندس / محمد إبراهيم شعراوى

رسالة
مقدمة للحصول على درجة الماجستير فى الهندسة الكهربية

تحت إشراف
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