# A NEW CONCEPT FOR MANIPULATING MACHINE TOOLS THROUGH A CNC SYSTEM

Tawfik El-Midany[1], Nihad El-Chazly[2], and Mahmoud El-Bayoumi[3]

## منظور جديد للتحكم في آلات الورش من خلال نظام خاص بالماكينات المبرمجة

ملخص : المصاعب التي واجهت الصناعة المحلية مثل عدم تطابق المنتجات و افتقارها للدقة بسبب عدم تساوى القدرات المهارية و العقلية للعمال، أدت إلى حمل الآلات التي تعتمد على التحكم الرقمي و ذات التحكم الرقمي المبرمجة بالحاسب الآلي لمثل فائدة كبيره لخطوط الإنتاج، و ذلك على الرغم من ألمانها المرتفعة و التكاليف العالية للصيانة و لأوقات التعطل. العمل الحالي يهدف إلى استكشاف الإمكانيات اللازمة لتصميم الأجزاء الكهربية و الميكانيكية المكونة لنظام التحكم و التغلب على مشاكل التصميم و البرمجة مع الأخذ في الاعتبار المقاصة بين بساطة دوائر التحكم و سهولة البرمجة المطلوبة. تم بناء نظام تحكم رقمي مبرمج بالحاسب الآلي للتحكم في الحركة الزاوية للمحركات الخطو به وتم استخدامه لقيادة مخرطة صغيره من خلال برنامج خاص سهل الاستخدام للحاسب الآلي وذلك بهدف اعتماد نظام تحكم منخفض التكلفة سهل البناء و سهل الصيانة لقيادة العربة و الرسما العرضية للمخرطة. تم اختبار النظام ووجد أداؤه في حدود الكفاءة المطلوبة مع الأخذ في الاعتبار الانخفاض الكبير في تكلفته عن النظم المثيلة مما يبشر بتطبيق هذا النظام على الماكينات التقليدية في مصانعنا بسهولة تامة و بأقل تكلفة، و هذا بدوره يقودنا إلى الجودة الشاملة، أحد متطلبات القرن الحادي و العشرين.

## ABSTRACT

*The local industry suffers from the unmatched inaccurate products due to the variance in labor skills and mentality, so it was beneficial to use NC and CNC machines in production lines, in spite of the big fixed cost, high maintenance cost and the high cost of idle time. The present work aims at investigating the ability of accomplishing the design of electrical and mechanical parts of the control system, and to overcome its problems, and the computer programming ones, taking into consideration the compromising between the*

1. Prof., Head of Production Engg. Dept., Faculty of Engineering Mansoura University.
2. Prof., Mechanical Engg. Dept., National Research Center
3. Research assistant, Mechanical Engg. Dept., National Research Center

*simplicity of both the controlling circuits and the computer program. A computerized numerical angular motion control system; based on a stepper motor, has been built. The control system is used to control a light duty lathe machine through a special personal and user friendly computer program. The aim is to achieve a low cost, easy to construct and easy to maintain , computerized control system guiding the carriage and cross-slide of the lathe. The system is found to be matching the desired accuracy, taking into consideration the cost reduction compared to similar systems.*

## 1. INTRODUCTION

Recently as a trend developing country's economy is getting biased towards liberal policies such as reduction of importing taxes, the local market and local limited industries started to suffer from the low prices of the high quality imported products. Advanced countries products showed a great potential to beat similar developing countries products, surprisingly, not only in both quality and price but also in technical features, as a direct result for the main difference between developing countries industries and other ones which is found to be in the level of manipulating and mastering machine tools.

The industrial problems in developing countries arise to be a direct result for not having a serious machine tools design and production plans. Since importing the machine tools is a costly operation for the developing countries [1], so the usually imported machine is from the universal purpose, bulky machines to satisfy the different factory needs with minimum number of machine tools, which lead us to face industrial tragedies like seeing a general purpose 3 mt length CNC lathe dedicated for producing a 10 mm length product, resulting in low productivity and huge over cost.

The local industries in the developing countries is incapable of designing and constructing bulky and highly specialized machine tools which necessitate importing them when needed but importing easy to ,design and construct, light duty and general purpose machine tools is a bad sign for future sense real production policies relay on mastering machine tool's , technology and cost, which give a merit to machine tools developing policies.

Developing machine tools through using computer to control the motion of its mechanical mechanisms [2,3,4,5] is not that hard to accomplish task [6,7], even with out sacrificing the accuracy or speed [1], sense modern control ICs developed to handle this task with fewer parts and better performance [8,9].

Because of the difficulties forcing the local industry due to the sudden opening of the local markets in front of foreign products, and the running cancellation of local market production taxes, the local factories must chose between the alternatives leading to adopting a competitive production techniques.

The aim of the present work is to investigate a CNC actuator design and the construction ease and difficulties, as an attempt to prove that developing and using a CNC mechanisms is not as difficult to adopt [6,7] as it is said to be in local industry. A two step motor and electronic circuits specially designed and built for this purpose, both controlled by a IBM compatible PC, were employed to decide and control the proper required velocity, and acceleration of the desired motion of both steppers. A computer program has been developed to facilitate and familiarize the interaction between the system user and the CNC system in order to encourage the small industries to adopt this newly developed system.

## 2 THE DEVELOPED SYSTEM

The system is basically constructed to manipulate a light duty lathe by controlling its carriage and cross slide travel throughout the processing task, using a computerized electromechanical system. The system first thought of design was to leave the intersection line between the computer and the electronic circuits, floating, to give it the flexibility for reducing both system repair and maintenance cost, and system overall cost. The system principal design consisted of a computerized, electromechanical component, and stepper motors (SM) connected to a light duty lathe machine, see Fig. 1.

The new technique for stepper driving with the computer generates logic pattern by relying on external timing circuit is an approach developed to minimize the over all system complications specially the need for sophisticated inefficient timing algorithm, taking the

most benefit of the available high processing and communicating speeds featured in the new generations of computers.

The system consists of both software and hardware designed to accomplish the controlling task with maximum flexibility in modification and upgrading. The system is designed to relay on the specially developed software to cut-down the overall system cost and complixity, by shifting the majority of system duties to be handled by programming.

## 2.1 Software Description

In order to facilitate the system to the user, a special user-friendly program has been developed. This program is capable of dealing with the required part data through different treating steps till coming out, generating the controlling signals and delivering it to the control circuit. The program is internally divided into 5 sub-programs each of them accomplishes a specific function, see Fig.2.

### *2.1.1 Part Data Entry*

Through this sub-program the user is allowed to enter the part data using a special technique developed to simplify the part data entry. The proposed technique depends on dividing the required workpiece into smaller parts with easy to describe shapes. Each part is described by its two ends and their lengths, in Fig.3. The entered data is treated to describe the outer contour of the workpiece (workpiece geometry).This sub-program has the flexibility to keep entering the data required for the workpiece and finally to start for the assembly stage, ( Fig.4), allowing tight control on the work piece data entry.

### *2.1.2 Defining The Cutting Parameters*

This sub-program selects the most suitable cutting conditions for the work piece using a special data base designed for different workpiece materials.

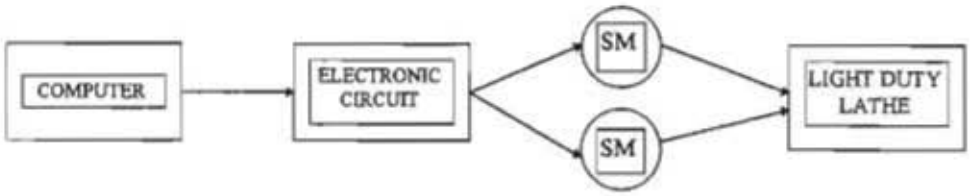


Fig. 1 The developed system layout

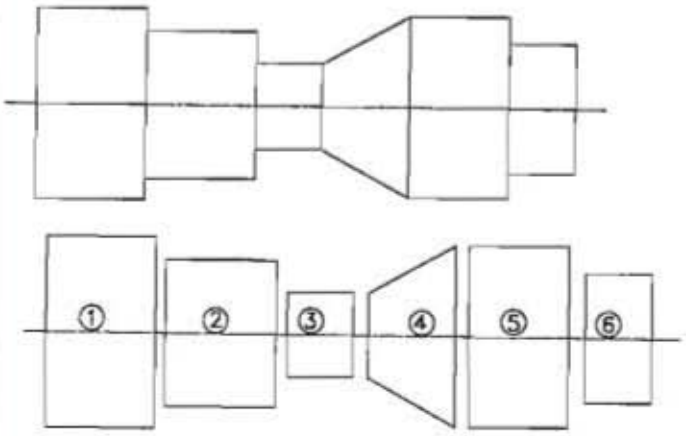


Fig.3 Workpiece geometry data

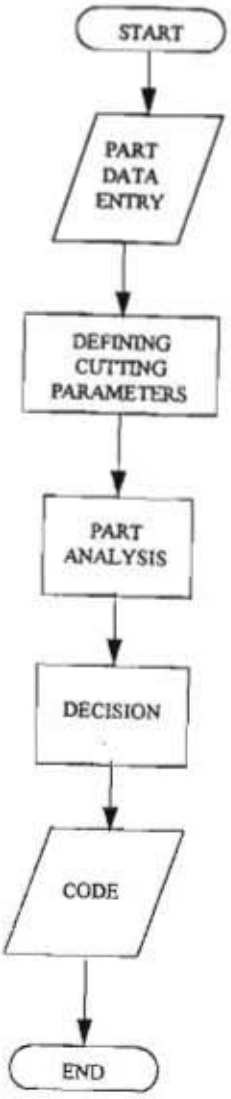


Fig.2. Program block diagram.

#### 2.1.3 Part Analysis

Part analysis sub-program determines the rough cutting surface contour taking into consideration the finishing depth of cut, according to stored data base, see Fig.5.

#### 2.1.4 Decision

Decision stage, bas been built in the main program to decide the cutting surfaces sequences according to stored data base. This information is based on work shop practice and to deduce the shortest and best cutting tool path through the whole operations, see Fig.6.

#### 2.1.5 Code

This section of the program, is the most important part of the main program. It converts the previously deduced cutting tool path into a special controlling code capable of driving the developed electromechanical interface between the computer and the lathe to accomplish the required carriage and cross slide motions, so carrying out the required machining task.

### 2.2 Hardware Description

1. The computer as the most powerful computational tool with its enormous, still increasing speeds still has to communicate with different systems in order to transform this huge computational capabilities to a real world beneficial activities, such as controlling electrical and electromechanical devices ... etc.

2. The computer exchanges data mainly through standard input/output (I/O) devices which passed through a lot of developing data exchange history, these standard (I/O) devices are divided into three groups: Input devices (keyboard, mouse, and light pens), Output devices (display screen, printer, plotter, etc.), and Input/Output devices, which are the computer standard devices capable of both collecting data from the computer and sending data to the computer, for example:

a. **Serial Port** is the least common denominator of computer communication since it basically deals with sending data through nothing more than two wires, a data signal line,

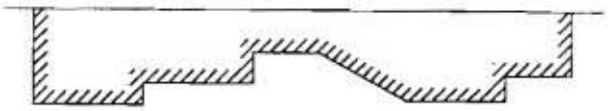

Fig.4 Workpiece final shape

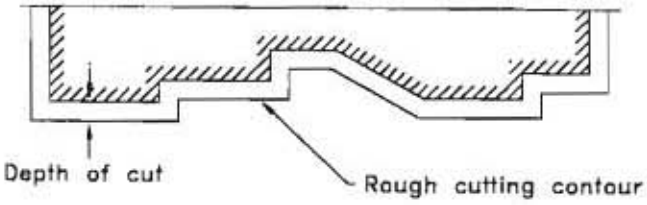


Fig.5 Determining the rough cutting surfaces


Fig.6 Decision making for the required sequence of operations

and a ground to extended distances, resulting in a real reduction in overall communication cost, but after all serial communication is not that trouble free thing.

**b. Parallel Ports** are well-defined, convenient, fast and probably the most trouble-free connection with the computer as long as the used cables is not longer than 3 mt. to avoid the crosstalking problem. Parallel refer to the fact that this port conducts signal through eight separate wires, one for each bit of the data byte, so the bits signal runs in parallel from and to the computer [10]. The computer parallel port is designed according to the Transistor Transistor Logic (TTL) family specification as an inhibited standard for the IBM and compatible, levels of signal voltage and current is so well defined.

**3. The Proposed Circuit:** the main concept taken in the circuit design is to cut down the circuit cost and to keep it as simple as possible without sacrificing its performance, simplicity is often said to be the ultimate sophistication. The circuit communicates with the computer through the parallel port to transform a specially treated data into a physical controlling signals capable of achieving the controlling operation. The circuit duty could be divided into 5 sub-duties each of which accomplishes a specific function, Fig.7 illustrates the complete circuit.

### *3.1 Buffering And Level Shifting*

This portion of the circuit is designed to buffer the computer parallel port output to achieve a higher safety for the computer port against any circuit break-down, and to shift the computer Transistor Transistor Logic ( TTL ) signals level to Complementary Metal Oxide Semiconductor ( CMOS ) recommended operating voltage level to increase the circuit noise-immunity.

### *3.2 Latching The Port Data*

After the computer port data is buffered and level is shifted, the data is latched using a pair of 4076 ICs each contains a 4 D type Registers, the data is latched as soon as it is available from the port, then the circuit declares that it is busy and incapable of receiving another signal temporarily.

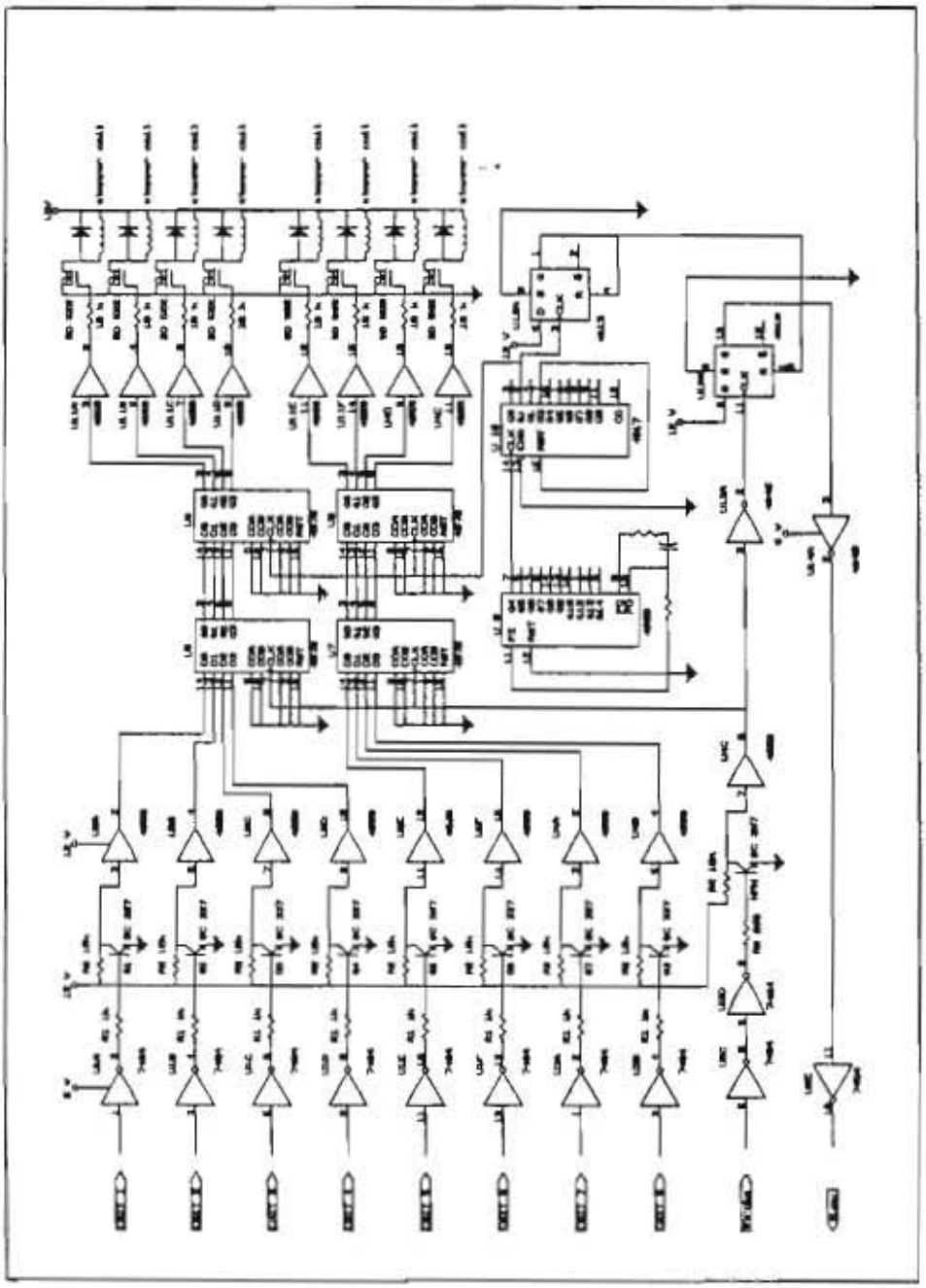

Fig. 7 The designed circuit

### 3.3 Clock

The portion of the circuit which is responsible for the harmony of operation through precise timing is a 4060 timer/divider, it is used to generate the required clock pulses, getting different frequencies through the divider featured in this timer. The 4060 output is fed to 4017 decade counter connected as /n divider to allow much flexibility in achieving required frequencies, see Fig.8.

### 3.4 Precise Timing Latching

The latched port data is available but without real timing since the computer is responsible for data sending without timing obligations, so a pair of 4076 ICs is used to load the previously latched port data in precise timing, synchronized with the circuit declaration need for the next data byte as soon as the port can send it, and so on. See Fig.9.

### 3.5 Power Switching

Since the signals is originally designed to be the logic level pattern of the power signals required to drive the stepper motors, it is used to switch the power using a set of V grove MOS Field Effected Transistors (EFTs) V-MOS-e FETs. A logic level reduction is carried out using 4050 non inverting buffers to match the V-MOS-e FETs driving requirements, see Fig.10.

## 3 CONCLUSION

* *The developed system configuration is capable of driving mechanical systems through modifications in power switching and stepper motors. It is a new concept for manipulating machine tools through a CNC system to overcome the suffering of the local industry from the unmatched inaccurate products due to the variance of labor skills and mentality.*

* *Further modifications through the developed system could be accepted, to enhance the system capabilities and to extend its range of applications.*

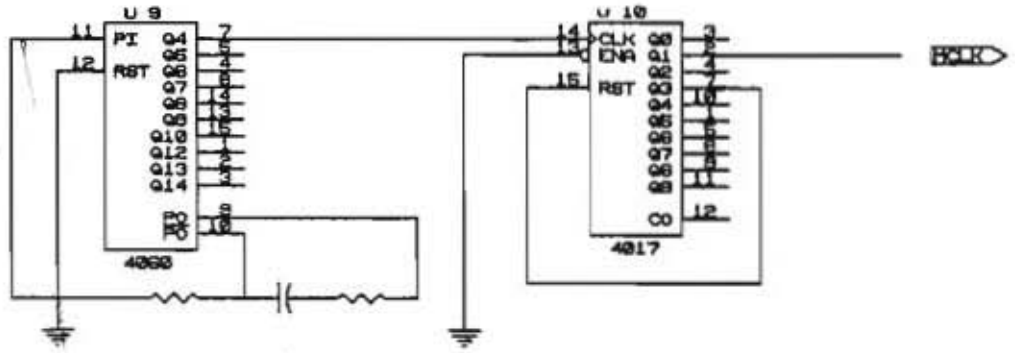


Fig. 8 Master clock circuit

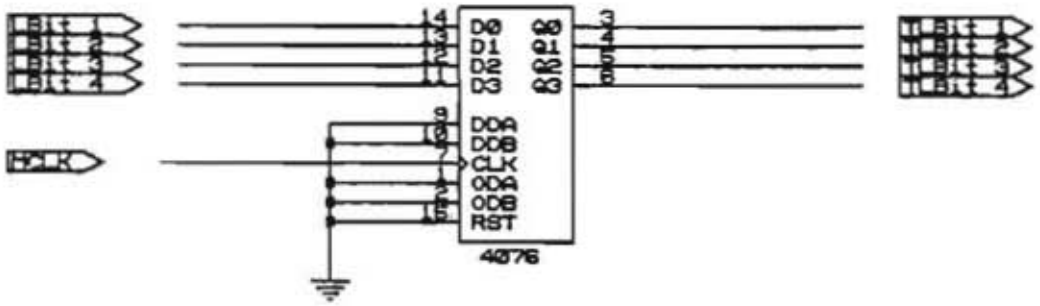


Fig. 9 Precise timing latching circuit

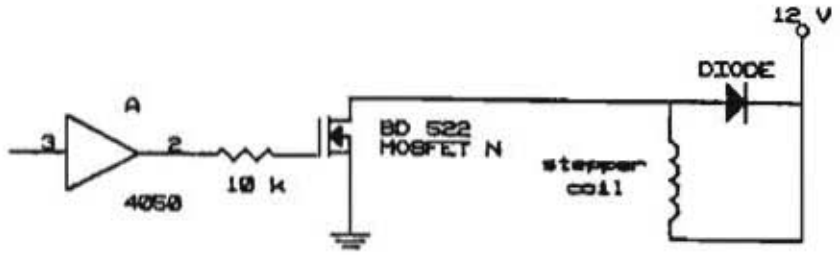


Fig. 10 Power switching circuit

* *The system in hand has been designed to overcome many of other systems complications such as the need for timing algorithm. The developed hardware and software cut down the overall system cost, and complications.*

* *The developed computer control system guides the carriage and cross-slide of the lathe machine. Desired accuracy and cost reduction compared with similar systems have been maintained.*

## REFERENCES


1. *Warneck, M.M., " DEVELOPMENT OF A MICROCOMPUTER BASED X-Y PLOTTER: A PRELIMINARY REPORT ", International Journal of Computer Applications in Technology, V 6, n 2, pt 3, p 141-146, 1993.*
2. *Balkovoj, A.P.; Kozachenko, V.F., Kudryashov, A.L., " A SMALL-SIZED SYSTEM FOR CONTROLLING STEPPING MOTORS BY USING PERSONAL COMPUTERS ", Elektrotekhnika n 7, p53 July 1994.*
3. *Knight, Terence, Zilouchian, A. ,Szabo, B., " DESIGN AND IMPLEMENTATION OF POSITION FEEDBACK CONTROLLERS FOR AN X-Y TABLE ", Proceeding of the IEEE SOUTHEASTCON. 1994.*
4. *Fadul, Faisal, Arnold, Louis, " MODULAR CNC SYSTEM FOR MULTI AXIS MOTION DEVICES ", Computer in industry, V 20, n 2, p 203 - 208 Aug 1992.*
5. *Innes, Richard. " INDUSTRIAL APPLICATIONS OF STEPPER MOTOR SYSTEMS ", IEE Colloquium on stepper motors and their control, london, UK, IEE Colloquium, n 17, Jan 25, 1994.*
6. *Kim, Jeong-Du; Kim, Myung-Hwan, " STUDY ON DESIGN OF CNC LATHE FOR EDUCATION AND APPLICATION ", International Journal of Production Economics, v 25, n 1-3, p 169-180, Dec 1991.*
7. *Inaga, Tashiyuki, Hashimoto, Hideyuki, Tsuchima, Kazunori, " CIRCULAR PATH CONTROL OF HORIZONTAL TWO LINK ROBOT DRIVEN BY STEPPING MOTOR", Transaction of the japan Society of Mechanical Engineers, Part C, v 60, n 570, p 612-617, Feb 1994.*
8. *Oberwallner, Christian, Sturzer, Manfred, " IC DRIVER FOR TWO-PHASE STEPPER MOTORS: BETTER PERFORMANCE, FEWER PARTS ", Siemens components, v 27, n 1, p 25-28, Jan-Feb 1992.*
9. *Amaratunga, Gehan; Kwan, Kin-wah; Tso, M.; Crawley, Engl, " SINGLE-CHIP CMOS IC FOR CLOSED LOOP CONTROL OF STEP MOTORS ", IEEE Transaction on Industrial Electronics, v 36, n 4, p 539-544, Nov 1989.*
10. *Winn L. Rosch, " HARDWARE BIBLE ", First printing, 1992.*
11. *Paul Horowitz, Winfield Hill, " THE ART OF ELECTRONICS ", Second edition, 1989.*
12. *Murry Sargent, Richard L. Shoemaker, " THE IBM PERSONAL COMPUTER FROM THE INSIDE OUT ", Adison-Wesley, Revised edition, 1986.*
13. *Say, M.G., Taylor, E.O., " DIRECT CURRENT MACHINES ", ELPS & PITMAN, Second edition, 1982.*
14. *Allen L. Watt, " USING ASSEMBLY LANGUAGE ", Que Corporation, 1987.*