DESIGN AND ANALYSIS OF A PROTOTYPE

MULTI-TOOL END EFFECTOR

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Dedicated to my parents

and guardians

DESIGN AND ANALYSIS OF A PROTOTYPE MULTI-TOOL END EFFECTOR

by

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THESIS

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ABSTRACT

Automated multi-task assembly applications are becoming predominant in many industries today. A single robot workstation may be required to perform several assembly tasks or manufacturing processes by using a method of quick tool change. A conventional method of quick tool change involves mounting a quick change adapter on the robot wrist which automatically performs tool changes at a specified tool bin location on the peripheral work area of the robot. However, the main disadvantages of this "QUICK-CHANGE" method are the inherent increase in non-productive time during every tool change operation and also leads to increase wear on the manipulator during those motions.

To increase efficiency, a prototype robot-mounted quick change multi-tool end effector for screwdriving applications was developed and tested for its performance. It can accomodate for four different tools and provide automatic tool changes as desired. Feedback sensing for desired depth, torque and tool position were also incorporated. Robot programming using AML was used as a tool to control the entire operation of the multi-tool end effector.

Results showed that there was an overall 30% increase in time saved by using multi-tool scheme over conventional quick change method.

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INTRODUCTION

Flexible automation involving assembly will be predominant in the near future simply because assembly requirements occur in every segment of manufacturing. Robots are being evaluated, not only to do simple repetitive tasks, but also to perform more complex jobs in an ever widening variety of sophisticated applications. Some of these applications may require special end effector (or end-of-arm tooling) such as drills, welding guns, spray guns, water jet cutters, or screwdrivers. An end effector (or end-of-arm tooling) is simply a device that attaches to the wrist of the robot arm and enables the general-purpose robot to perform specific tasks [1].

Although robot manufacturers have made significant progress in robot arm technology, the area of end effector research and development has been largely overlooked [2]. An inhibiting factor in implementing robots for assembly automation is the inability of the end-of-arm tooling system to be interchangeable among many tools. Obviously, if the robot could perform multiple tasks within a single work station, more value can be added to the material at one station which will facilitate cost justification.

Multi-tasking -- the use of a single robot to complete more than one directive without intervention [3], require that a method of tool exchange be incorporated into the robot work cell. The conventional method of robots attaining the multi-tool capability is known as QUICK CHANGE. It involves a quick change adapter mounted on the robot arm which can then pick up and replace any of a family of manufacturing and assembly tools located on an outer edge of the work cell in specifically located bins. However, this tool exchange method increases non-productive time and causes mechanical wear on the robot arm. Another feasible alternative is for the end effector to carry those necessary tools with it. This tool change device is known as automatic quick change, multi-tool end effector and will allow the robot to select the required tool without moving to a specified tool location. This is especially useful in large work envelop environment and leads to better utilization of robot productive time as well as reducing mechanical wear of the robot manipulator.

Since such an end effector is to be mounted on the manipulator, certain design considerations have to be met :

(1) must be light weight;

(2) must be sufficiently quick in tool changing;

(3) must produce better or equivalent positional accuracy as in conventional applications;

(4) must be simple and economical in design.

The objective of this thesis is to design, build and analyze a prototype quick change, multi-tool end effector. As a by product of this thesis, screw driving application requiring different screw heads (flat-head, phillip head, etc) using the IBM 7535 Robot Manufacturing System was implemented. However, the design concept of the end effector may be easily extended to other assembly tasks. The IBM 7535 manipulator is selected for its vertical rigidity needed for the intended application. It has four degrees of freedom but only two dimensional work area.

The following chapter discusses in detail the IBM 7535 Robot Manufacturing System. Chapter 3 provides an overview design synthesis and operation of the prototype multi-tool end effector, including the programming concepts for automatic tool change and error detections for torque and depth during screwdriving process. Chapter 4 gives a complete discussion on the relevant performance characteristics and evaluations of the multi-tool end effector in the area of repeatability, rigidity, error analysis as well as efficiency in terms of time saved as compared to conventional quick change system. Results indicated that production time can be reduced as much as 30% by utilizing the multi-tool end effector.

Chapter 2

IBM 7535 ROBOT SYSTEM

The IBM 7535 Manufacturing System consists of three main components [4]:

1. Manipulator
2. Controller and Control Panel
3. Programming System.

2.1 Manipulator

The IBM 7535 manipulator consists of a two-jointed arm structure and has 3.5 degrees of freedom. The IBM 7535 manipulator is depicted in figure 2.1. The joints of the arm, called Theta 1 and Theta 2, provide 2 degrees of freedom through their swivel motion. Theta 1 is referred to as the shoulder joint and Theta 2 is referred as the elbow joint. Precision positioning in the X-Y horizontal plane is provided by these two joints. The end-of-arm rotation or roll, called the R-axis provides the third degree of freedom. The end-of-arm only provides a half degree of freedom through limited up/down movement of a Z-axis shaft. This is because there is no precise motion control of the Z-axis shaft and it can only assume an extreme up or down position. This is labeled as the Z-axis.

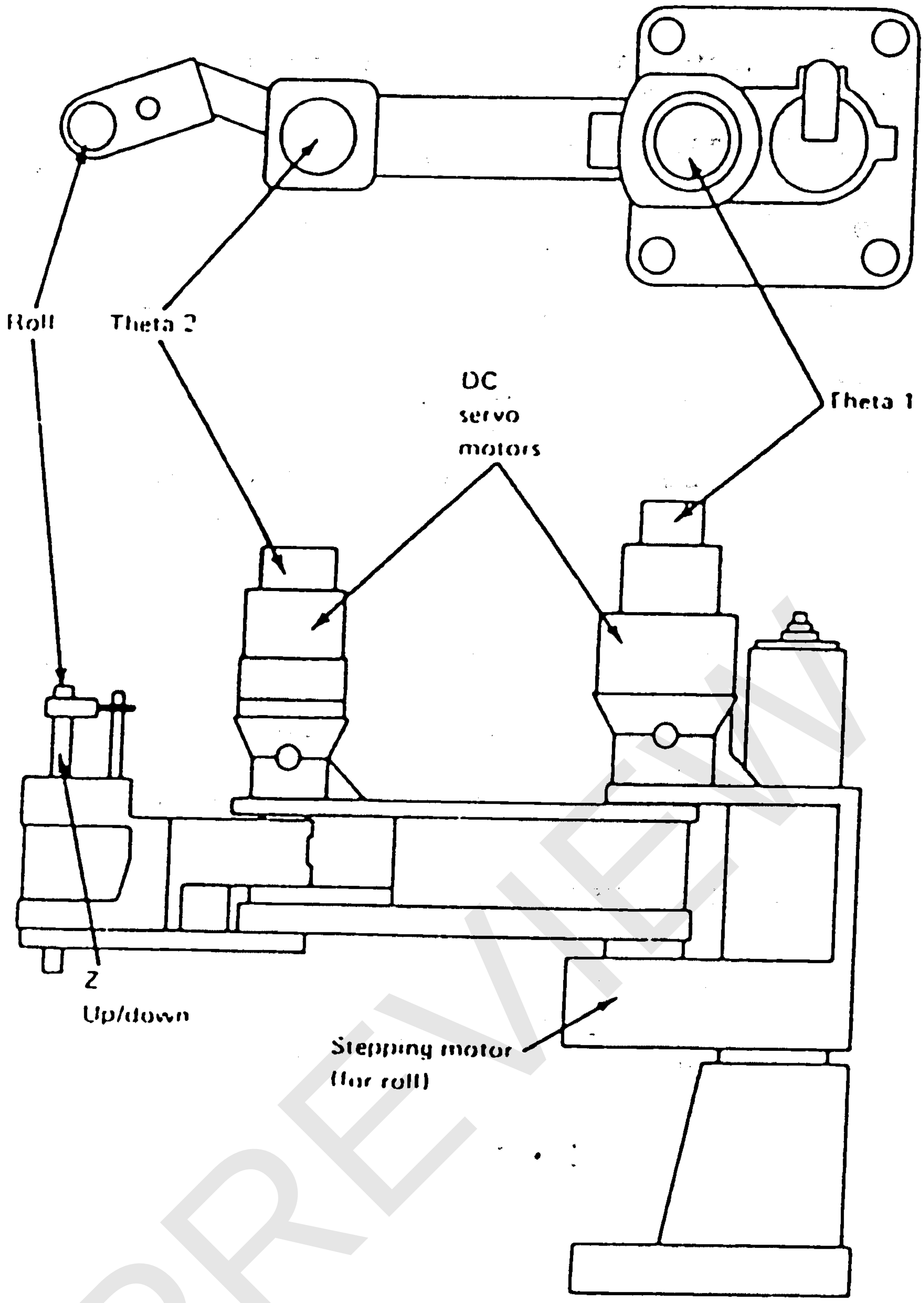

Figure 2.1 IBM 7535 Manipulator

Motion control of the IBM 7535 manipulator is achieved by using electric motor and air pressure. A closed loop servo-system using direct current, 24 volt servo motors provide the swivel motion for the Theta 1 and Theta 2 axes. Horizontal compliance is achieved through the use of these servo motors. Horizontal compliance is the ability to absorb horizontal loading on the manipulator and be rigid in the vertical direction . This is inherent in this kind of robot which is capable of absorbing horizontal loading applied to the manipulator and yet able to return to the designated target position.

Compliance of the Roll-axis is accomplished through the stepper motor compliance and streching actions of the drive belt. The Roll-axis is driven through a drive belt coupled to a 24 volt direct current stepper motor located below the Theta 1 axis. This type of structural arrangement allows for positioning the Roll-axis such that the X and Y orientation of the end-of-arm tool remains still as the manipulator moves.

An external air supply drives the air cylinder that raises and lowers the Z-axis shaft. The Z-axis shaft is either fully lowered or fully raised by the activation of the air supply controlled by the 7535 controller. End-of-arm tooling is securely attached to the lower end of the Z-axis

shaft. Appendix B lists all specifications of the IBM 7535 robot manipulator.

The area that the manipulator can reach is called the work area or work envelope. Figure 2.2 depicts the dimensions and shape of the work area for the IBM 7535 robot. This work area is defined in (x,y) cartesian coordinates in which the (0,0) origin is located at the center of the Theta 1 axis. Even though the Z-axis has an up and down position, the work area of the manipulator is considered to be two dimensional.

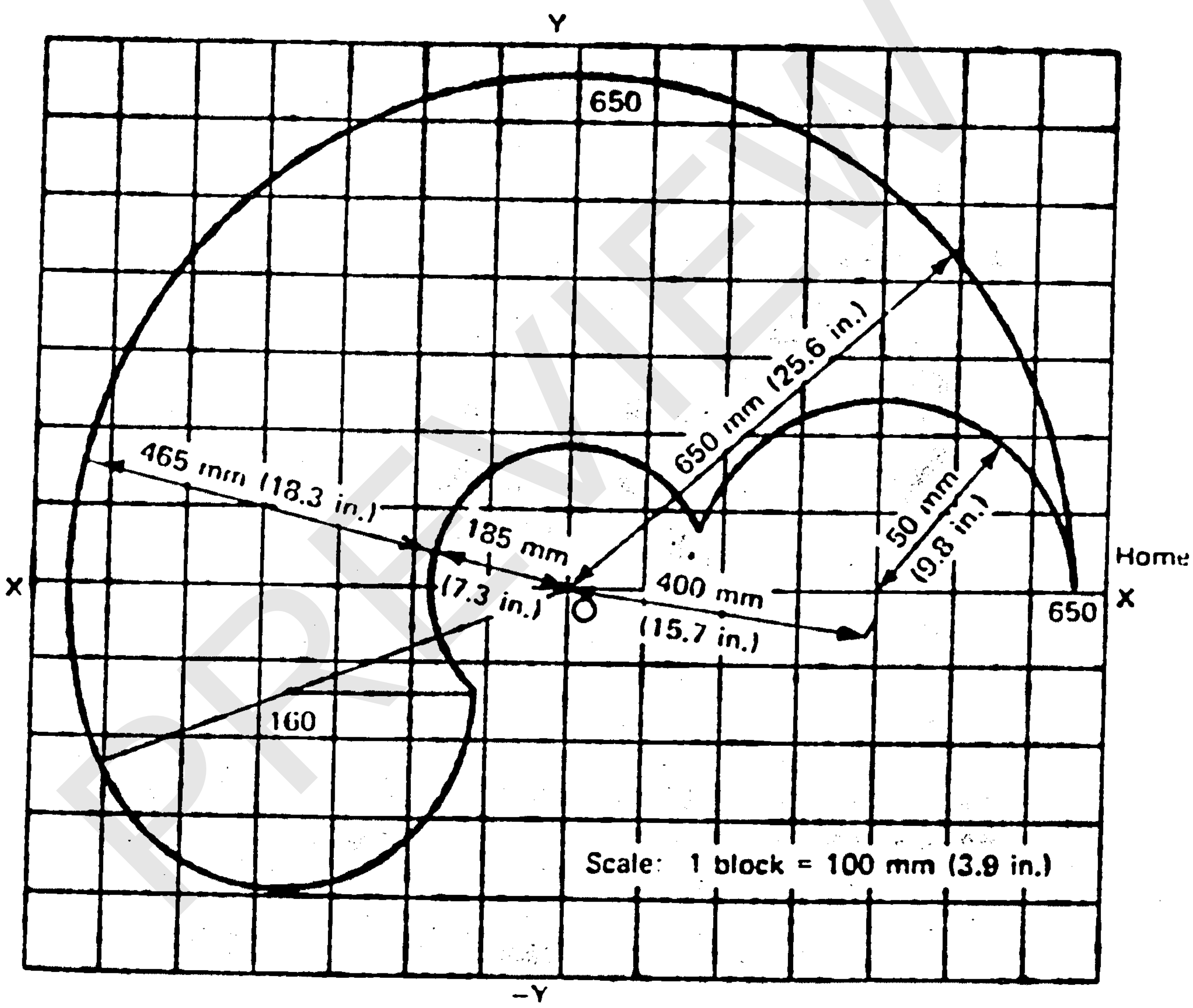

Figure 2.2 IBM 7535 Work Area

2.2 Controller and Control Panel

The controller serves to control the manipulator operation. A microprocessor coordinates the manipulator's movement and monitors its speed and positioning. The controller also receives, stores and executes application programs. Up to five programs may be stored in separate storage partitions in the controller. However, the total amount of information stored is limited to 6000 bytes. Figure 2.3 depicts the IBM 7535 controller. The controller

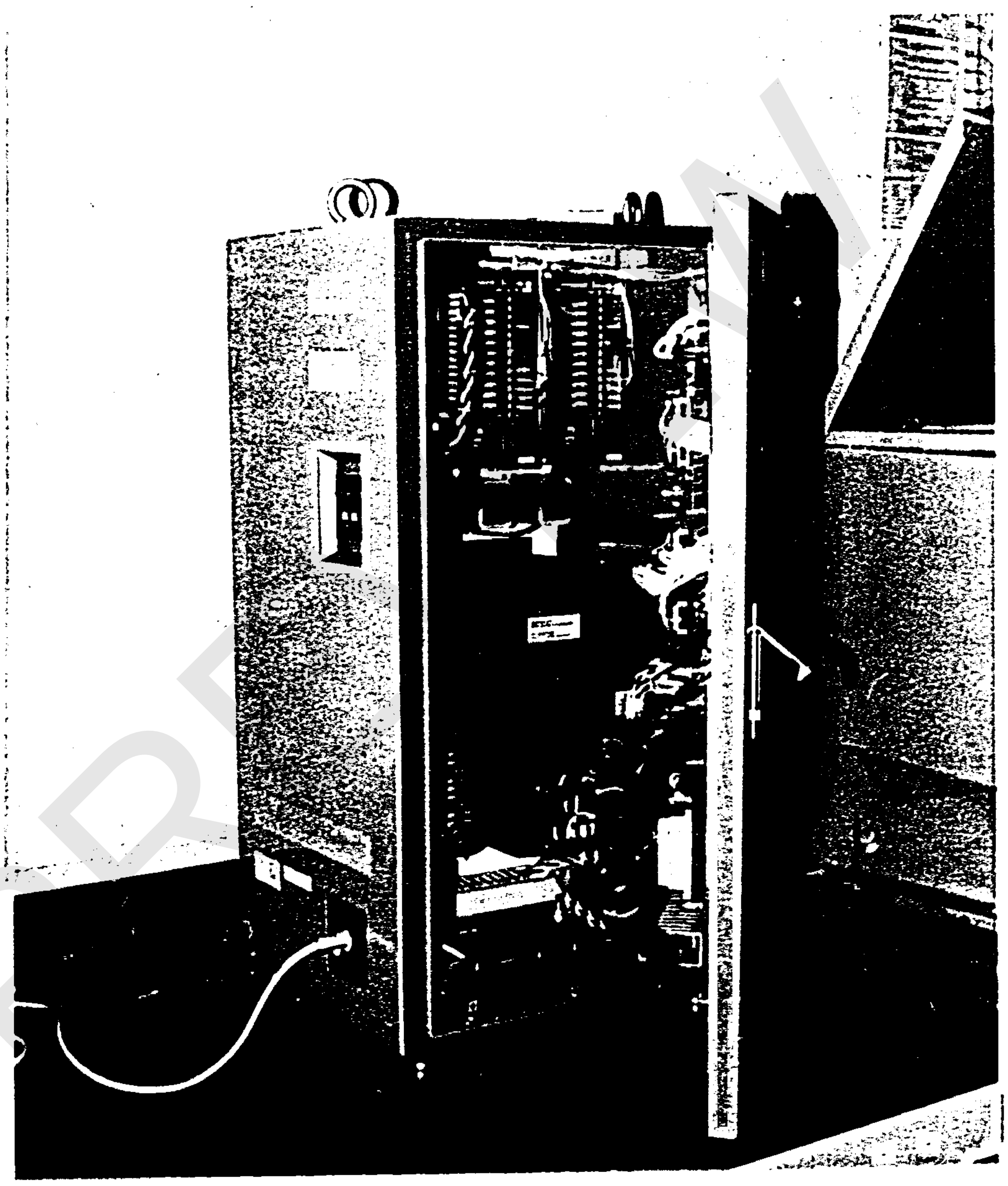

Figure 2.3 IBM 7535 Controller

has the ability to operate peripheral devices during manipulator action by the use of 16 digital output (DO) ports and 16 digital input (DI) ports. Digital input points monitor switch closures external to the 7535 system and activate DO relays for control of external voltage not to exceed 24 volts DC at 2 amperes. These digital input and output ports are accessed using the DI/DO box, which is connected to the controller. This is shown in figure 2.4. Appendix C lists the specifications for the IBM 7535 controller.

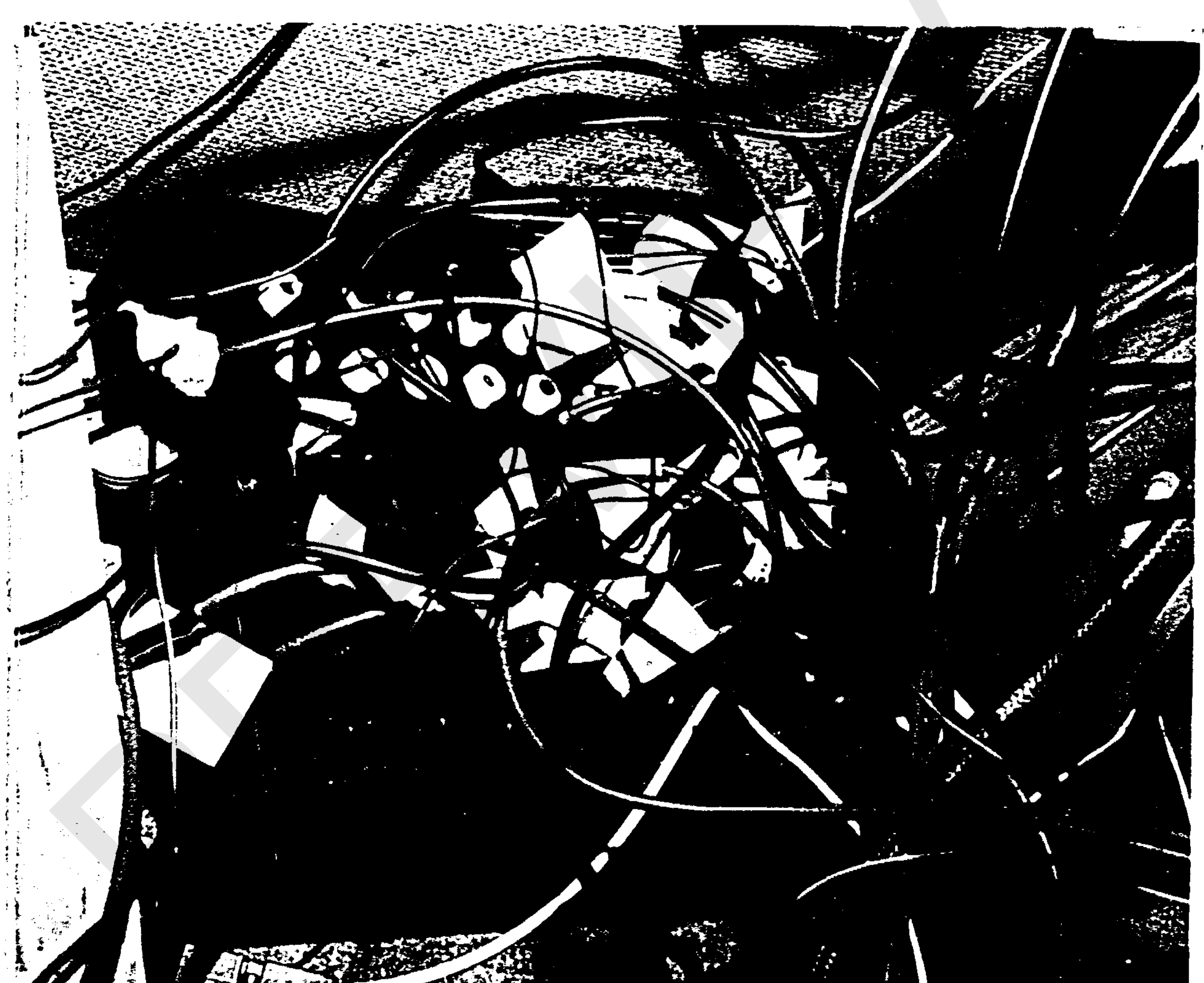

Figure 2.4 IBM 7535 Controller DI/DO Box

The control panel provides the operator interface to the controller and manipulator. It contains an emergency kill button, pressure-sensitive keys, and error condition status board. This allows the operator to : choose manual or automatic operations; control each axis manually; enable communications between personal computer and controller; and determine power, status and error conditions. Figure 2.5 depicts the IBM 7535 control panel.

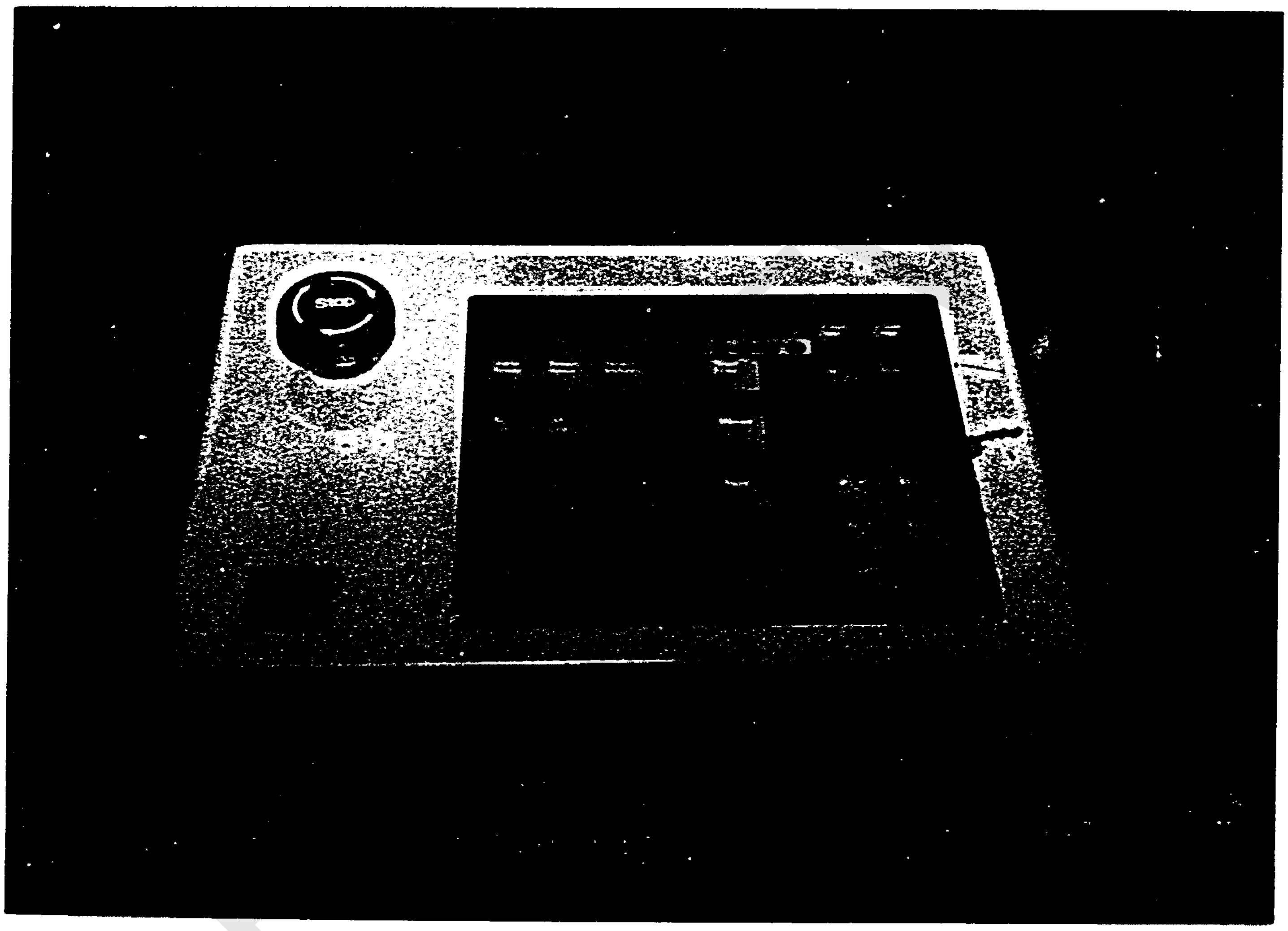

Figure 2.5 IBM 7535 Control Panel

2.3 Programming System

The programming system that communicates with the IBM 7535 robot is an IBM Personal Computer. A robot programming language, termed as A Manufacturing Language (AML) and the IBM Personal Computer enable the user to create, convert, and transmit application programs to the controller. The computer and AML also allow the operator to use the teach/move functions of the 7535 manipulator.

The controller's limitation of data storage is overcomed by using the personal computer which is capable of storing unlimited number of application programs on diskettes. Any of the diskette-stored application programs can be down-loaded into the controller quickly.

An RS-232 wire cable provides the communication link between the computer and the controller. If communication with the controller is not needed, the RS-232 wire cable can be detached and the computer can then be used for stand-alone activities. Figure 2.6 depicts the IBM Personal Computer.