DESIGN, CONSTRUCTION, AND OPERATION OF AN INDUSTRIAL TYPE ROBOT

Final Research Report
Submitted to the Morehead State University
Faculty Research Committee

by

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September 1982

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FORWARD

This research on robotics, involving the design, construction, and operation of a robot, was done by the author, with a grant funded by the Morehead State University Faculty Research Committee and with additional support provided by the Department of Industrial Education and Technology. Assistance was provided by the students in a special class, IET 399 Industrial Robotics and by students in various Industrial Education and Technology classes including machine tool technology, welding technology, electronics technology, and drafting and design technology.

The purpose of this research was to determine if a robot type device could be produced using commercially available electrical and mechanical devices or if the status of industrial robotics is such that they depend on devices that are unavailable from the manufacturers.

I. INTRODUCTION

A. Background

When numerical control, a process for controlling machines with a punched tape, was introduced to American industry in the early mid sixties, it was not feasable to develop teaching devices or aids due to the unavailability of technological devices. These devices were developed and only available by those companies manufacturing the numerical control machine tools. Therefore, it is significant to determine if a robot type device can be produced using commercially available devices.

B. Procedure

The general procedure followed in this research project was to accomplish one step at a time the various activities listed below. This procedure; discharged a twofold purpose; it served as a learning process and it permitted the author to determine that these activities could be brought to an issue of success.

1. Operate a stepping motor with a CIP Ohio Scientific Computer using Tiny BASIC programming
2. Design and construct the mechanical arm and base for the research robot (see page)
3. Test the mechanical operation of the mechanical arm
4. Design and construct the electrical interfacing required between a computer and the research robot (see page)
5. Write a machine language program to operate the arm of the research robot up and down only (see "Intelligent Robot Program Number 1 page)
6. Test the oparation of the program with light emitting diodes and debug the program

7. Test the complete system, robot--power supply--interfacing--program (That is operate the robot.)

8. Repeat steps 5, 6, and 7 with a program written in Heath Pittman Tiny BASIC (see Robot Program Number 2)

9. Repeat steps 5, 6, and 7 with a machine language program to operate all three stepping motors to provide action up and down, in and out, and clockwise and counterclockwise (see "Research Robot Program", Number 3, page)

10. Repeat step 9 with a Heath Pittman Tiny BASIC language program (see "Robotics Software for Three Axis Research Robot, page)

C. Definitions and Limitations

The definition of a robot used in this research is the definition adopted by the Robot Institute of America, November, 1979.

> "A Robot is a reprogrammable multifunctional manipulator designed to move material, parts, tools, or specalized devices, through variable programmed motions for the performance of a veriety of tasks"

This research project is an investigation of the extent to which a robot type device can be designed, constructed, and operated within one school year (two semesters) in an instructional setting.

D. Hypothesis

Hypothesis: A facimile of an industrial robot can be developed having the following characteristics:

1. Has a threshold repeatability within plus or minus 0.100 inch
2. Has the ability to manipulate a weight of at least three pounds
3. Has a yaw and roll characteristic of at least plus or minus 30 degrees
4. Has a machine path that is developed using a predetermined pattern to influence the microprocessor program
5. Has the ability to repeat a pattern one hundred times and still maintain positioning of the arm within 0.100 inches of the desired position

II. RESEARCH ROBOT--DESIGN AND CONSTRUCTION

A robot termed the Research Robot was constructed with the aid of students using primarily the equipment listed below:

No.	
1	Sola Power Supply 82-48-2301 48VDC 3A
1	Heath/Zenith ETW 3400 microcomputer 6800 MPU
1	Heath/Zenith EWA 3400 accessory I/O
3	Slo-Syn stepping motor SSZ5-1001 11.8VDC .44A/W 200 S/R 20 oz. in.
12	Crydom relay 5430 input 5VDC, output 55VDC, 4A
1	General Electric 3-5121B recorder
1	Motorola 6820 peripheral interface adapters
3	Dropping resistor 20 ohms 20 watts
1	Zenith H 19 video terminal

The first verson of the robot built used a direct drive on the stepping motor which provides the raise and lower motion. The robot jerked severely with each step of the stepping motor. This problem was solved by the use of a reduction gear.

Programs were written in Heath Pittman Tiny BASIC and proved to be extremely slow for all operations except "raise" and "lower". It may be possible to solve this problem by the use of a compiler but the Heath Company does not sell a compiler for their ETW 3400 micro-computer. By writing programs in machine language, the speed was improved, however, this proved to be very time consuming. The program entitled "Research Robot Program Number 3" required over one hundred hours to write and debug. It was written and then the output was fed via a 6820 peripherial interface adapter to light emitting diodes. These lights were used along with the microcomputer alphanumeric read outs to check each and every step in the program. Errors in programming or errors in thinking were corrected each time one step more in the program produced an improper result. This process is known as single stepping through the program.

It was found that the speed could be increased still further by using a higher supply voltage than the rated voltage on the motor and then using a dropping resistor in series with the power supply. The coils in the stepping motors are fed a square wave pulse to produce each step. In the motors used, two hundred steps produces one revolution. The time required for the motor coils to reach maximum current and therefore maximum strength is:

$$T = 5 \frac{L}{R}$$

where T is the time in seconds, L is the inductance in Henries and R is the resistance in ohms. As can be seen by the formula, the larger the value of R the quicker we reach maximum current and the faster we can feed pluses to the motors. As can be seen in the section titled "Tests and Measurements", the addition of the dropping resistance increased the maximum speed by a factor of slightly more than four times.

With the addition of the dropping resistors, the robot worked at a maximum speed of slightly less than 250 steps per second. This is satisfactory for classroom use but is not nearly fast enough for an industrial robot. Most industrial robots use stepping rates considerably higher than 250 steps per second, with rates anywhere form 300 to several thousand steps per second in use. Most large stepping motors will oscillate at speeds below 250 steps per second and this mechanical ossellation is so severe that the motor looses steps and its operation is noisey and very unsatisfactory.

Speeds of several hundred steps per second were obtained on another robot named the "Welding Robot" by using a SLO-SYN ST 101 translator rather than the slow acting Crydom relays to interface with the computer.

The robotics class IET 399 moved on to the design and construction of two other robots, the "Welding Robot" and the "Assembler Robot" as the limitations of the "Research Robot" became apparent.

III. RESEARCH ROBOT TESTS AND MEASUREMENTS

All tests and measurements were done using the Research Robot Program Number 3.

A. Maximum Number of Stepping Counts that can be Stored in MEMORY

1. Test procedure

The program was entered into the ET 3400 microcomputer and the mechanical coupling on the base rotation motor disassembled so the motor could run free. The program was then executed in the clockwise teach mode and allowed to run full steps, until the maximum count in memory was reached casuing a branch in the program, which stops the motor. The contents of memory locations 0106 and 0107 were then recorded and the maximum memory capacity was calculated. Each hexidecimal count at address 0107 represents 256_{10} total counts, since this register advances only after the register at 1016 counts to FF_{16} and returns to zero.

2, Test results

TABLE 1

Maximum Number of Stepping Counts that can be Stored in Memory

Memory Location	Hexidecimal Contents	Decimal Contents
0106	00	00
0107	FF + 1	65536
MAXIMUM COUNTS	65536	

B. Maximum Speed of Stepping Moror when Using Crydom Solid State Relays

1. Test procedure

The robot was operated in the manual mode and the speed of the rotation stepping motor was reduced by decreasing the time between the motor input pluses. This was accomplished by reducing the hexidecimal number at address 017A. This number was reduced by 1 after each test run of the robot until the robot stalled. Then the number was increased by 1 and the time required for the motor to make 100 revolutions was measured with a stop watch. Measurement with a stop watch was repeated five times and the average value was used to determine the maximum speed. The maximum speed in steps per second is 200 divided by the time required for one revolution. The stepping motor has 200 steps per revolution.

2. Test results

TABLE 2

Maximum Motor Speed

Run No	Seconds for Ten Revolutions	Maximum Speed Steps per Second	Hex Contents of Address 017A
1	8.0		04
2	8.2		04
3	8.0		04
4	8.1		04
5	8.0		04
Average	8.07	247	04

$$\frac{\text{Steps}}{\text{Second}} = \frac{\text{Steps}}{\text{Revolution}} \times \frac{\text{Revolutions}}{\text{Second}}$$

$$247 = 200 \times \frac{1}{.808}$$

C. Maximum Weight Capacity

1. Test procedure

A block of wood was placed in the hand of the robot and the hand circuit was energized to close the hand. The robot was then programmed to raise the hand to midposition. The motor speed used was 247 steps per second, the maximum speed. This was repeated many times and with each repeat trial an additional one quarter ounce weight was added to the block of wood. It was found that when the weight was excessive the block would fall from the jaws of the robot. The block and the added weights were then weighed after first revoving the last one quarter ounce weight. This test was repeated ten times.

TABLE 3

Maximum Weight Capacity

Run Number	Maximum Weight Ounces
1	5.0
2	5.0
3	4.5
4	4.75
5	4.75
6	4.5
7	4.75
8	4.75
9	4.75
10	5.5

MAXIMUM WEIGHT CAPACITY 4.25 Ounces

IV. CONCLUSIONS AND GENERALIZATIONS

This research project proved to be a great learning experience for the author and for the students involved.

It was found that no one student knew enough about mechanics, electronics, and programming to proceed on his own. A team approach is required with frequent communication between groups.

Time was not sufficient to provide for yaw and roll or to measure the repeatability on the research robot, however, the repeatability of the welding robot was measured and found to be better than 0.003 inches.

The Research Robot was not an exact copy of an industrial type robot however, it did imspire continuing research by the Industrial Robot class, various faculty members, and others. Specificly, a Welding Robot and an Assembly Robot are being designed and constructed.

Detroit Reamer and Tool Company, Troy Michigan is interested in producing and marketing the Assembler Robot.

The "off the shelf" components to build a robot are readily available from suppliers, however, combining these items to make a industrial type robot is extremely complex and time consuming.

V. SUMMARY

A robot named the Research Robot was designed and constructed by the author with help from Morehead State University students, and with support from the Morehead State University Faculty Research Committee and the Department of Industrial Education and Technology.

It was found that unlike the situation relative to numerical control machines, the necessary technological devices were readily available form suppliers.

The computer programs needed to control the robot were written in Heath Pittman Tiny BASIC and in machine language. It was found that the Tiny BASIC is too slow to be practical and a compiler to convert it to machine language was unavailable. The machine language programs provided for the higher speeds but were very time consuming to write and debug.

Major components used for the Research Robot were the Heath/Zenith microcomputer 6800 MPU, Crydom optically isolated solid state relays and

Slo-Syn stepping motors.

The maximum speed obtained, with the control circuit designed involving Crydom solid state optically isolated relays, was slow.

The Research Robot is complete with a mechanical arm, a hand, and microswitches used as a teach box. It can be operated in a manual, teach, or execute mode. It is a useful teaching device, but because of its slow speed, its lack of yaw and roll capability, its low weight capacity, it cannot be considered an industrial robot.

Tests and measurements of the Research Robot were made. The most significant result of these tests was related to the robots speed. The robots maximum speed of a few hundred motor steps per second as opposed to the maximum speed of several hundred to several thousand motor steps per second for an industrial robot means the Research Robot is unsatisfactory as an industrial robot.

Robotics research is continuing. A high speed Welding Robot has been designed and constructed. An Assembler Robot is under construction.

Detroit Reamer and Tool Company of Troy Michigan are negotiating with the University to commercially produce the Assembler Robot.

Photographs of the robot and the names of the students in the Industrial Robotics class are enclosed in this paper.

VI. SUGGESTIONS FOR FURTHER RESEARCH

Research by industry in robotics is still relatively new and development of small assembly type robots are now progressing at a rapid pace. Higher technology robots are being developed that can see and feel.

Research in small assembly robots using servo motors, stepping motors, hydraulics, and pnematics with emphasis on gaining high speeds is needed by industry.

Presently, industry is doing most of their own training in robotics because the colleges and universities have not met this need.

Research on curriculum development in robotics training is called for. As discussed in this report, it is very difficult to find a student knowledgable in computers, mechanics, digital electronics, and able to apply the high level technology required to design, construct, and operate a robot.

Research is also needed in curriculumn development related to robot applications engineering. When a manufacture thinks of buying a robot, he wants the robot supplier to furnish and install the complete system. This involves a study of interfacing the robot with various machines, and conveyors, costs of various possible alternatives, sequencing of contacts, power requirements, types of sensors, and a consideration of what type of microprocessors should be used, and of course what type of robot, if any, is suitable.

VII. APPENDIX

A. Programs and Operating Instructions

INTELLIGENT ROBOT PROGRAM NUMBER 1

PROGRAM DESCRIPTION:

The program which follows was written by Meade Roberts. It is designed to operate the Z (up/down) axis of a robot. The program is written in machine language for use with the Heath/Zenith model ET 3400 microcomputer which uses a motorola 6800 microprocessor.

CONNECTING THE COMPUTER TO THE ROBOT MOTOR:

The microcomputer is connected to a 6820 periferal interface adaptor (PIA). Connections are made as shown in figure 10-55 pins 10 through 17 are connected to data light emitting diodes (LEDS) to be used in testing the program.

The PIA has six registers in which data can be stored and from which data can be read. The programming of the PIA to work in the desired manner is called initialization. In the program which follows the initialization causes pins 10 to 17 (Port B) to act as an output port and pins 2 to 9 (Port A) to act as an input port. Output port B is located at address 8002 and input port A is located at address 8000. After initialization we can transfer data to the output port with the command STAA 8002. After this command whatever is in the accumulator A register will be fed to the LED's. After the program is tested the LED's may be disconnected and output port B is connected so that isolated relays control the power to the stepping motor. Pin 13 controls power to the red wire; pin 12, red/white wire, pin 11, green wire, pin 10, green/white wire. Slo-Syn brand stepping motors are used.

Initialization is lost if the computer is reset, therefore, the motors are stopped by means of the signal placed at the "input port A terminals," changing this input signal is also used to restart the motors.

STEPPING MOTORS

A stepping motor rotates a small amount (called a step) for each incoming pulse. A digital input to the motor in the correct sequence will accurately position the motor shaft to within as little as 0.36 degrees. This exact amount depends on the motor used. Each pulse should remain 50 milliseconds or more before changing to the next pulse.

The proper pulses to be fed to the colored motor leads from the 6820 PIA are as shown below, the black lead is ground.

Pin 13 Red	Pin 12 Red/white	Pin 11 Green	Pin 10 Green/White	Hex Value
1	0	1	0	A
1	0	0	0	8
1	0	0	1	9
0	0	0	1	1
0	1	0	1	5
0	1	0	0	4
0	1	1	0	6
0	0	1	0	2

POWER SUPPLY

Stepping motors require approximately 12 volts D.C. and usually less than 11 amps per motor. A series resistance is recommended for stepping down the supply voltage to the namplate voltage.

OPERATION

The program shown will cause the arm to raise to the height desired (the maximum number of half-steps is 255), the operation then stops the action. This is called the TEACH PHASE.

Next the operator starts the action again, the arm lowers to its starting position, waits, then raises to the same height as before and repeats this pattern indefinately.

This ability of the robot to respond to the action taken during the TEACH MODE is what makes it an intellegent robot. This feature also referred to as reprogramability, makes it possible for an operator who knows nothing about programming to effectively program a robot to do the task at hand.

STEP BY STEP PROCEDURE

1. Load the program into the microcomputer
2. Verify the program especially addresses 00, 08, and B1.
3. Set the Binary Data Switch to 0000 0001
4. Press "RESET" then "D· 000A". The D key is the Do key and 000A is the starting address.
5. Let the Z axis up/down motor run any number of half steps, up to a maximum of 255. Stop the up action by changing the Binary Data Switch to 0000 0000. This ends the TEACH MODE.
6. Start the arm down by changing the Binary Data Switch to 0000 0001.
7. The Z axis up-down motor will return to its starting point and wait about 9 seconds before repeating this up-down action indefinately.
8. All energy is removed from the motor if RESET is pushed. The motor will simply halt any time the Binary Data Switch is changed to 0000 0000. This does effect the count and restarting the program will put the arm in the wrong position. This can be avoided by writing a more complex program.

PROGRAM NUMBER 1

Hex Address	Hex Contents	Mnemonics	Comments
00	0A	A-1	Data for control of stepping motor
01	08	8-2	Stepping motor
02	09	9-4	In the Up direction
03	01	1-8	Half stepping sequence
04	05	5-10	Also shown
05	04	4-20	Are the numbers
06	06	6-40	used to
07	02	2-80	test the program.
08	00	00	No. of half steps completed during teach mode "up arm"
09	00	00	No. of half steps completed during executive mode "up arm"
0A	86	LDAA#	Load accumulator a immediate with zero
0B	00	00	Initialize PIA as follows.
0C	B7	STAA	Store the number in accumulator A at memory location.

Hex Address	Hex Contents	Mnemonics	Comments
0D	80	80	8000. 0000 is now stored in PIA Data Direction
0E	00	00	Register A.
0F	86	LDAA#	See
10	04	04	Heath
11	B7	STAA	Figure 10-55.
12	80	80	04 is now stored in PIA control register A
13	01	01	and side A is now an input port.
14	86	LDAA#	
15	FF	FF	
16	B7	STAA	
17	80	80	
18	02	02	Side B now output port
19	86	LDAA#	
1A	04	04	
1B	B7	STAA	
1C	80	80	
1D	03	03	
1E	7D	TST	Test address 0008 and
1F	00	00	if it contains a number other than zero
20	08	08	
21	26	BNE	move to address
22	1C	50	73 and lower the arm to its starting position.
23	CE	LDX#	Load index register
24	00	0D	with
25	00	00	zero.
26	A6	LDAA,X	Load accumulator A with the first number
27	00	00	in the "up" half step sequence.
28	B7	STAA	output this number
29	80	80	at the
2A	02	02	output port.
2B	BD	JSR	Jump to time delay subroutine
2C	00	00	at address
2D	BC	BC	BC.
2E	08	INX	Increment index register
2F	01	NOP	no operation
30	01	NOP	no operation
31	7D	TST	Test
32	80	80	input
33	00	00	port A
34	27	BEQ	if binary data switch equals zero branch
35	27	27	to address 5D.
36	7D	TST	Test contents of address B1. And if it
37	00	00	contains a zero (indicating we are in the
38	B1	B1	teach mode)
39	27	BEQ	Branch to address 49
3A	0E	0E	otherwise increment the number at address
3B	7C	INC	09 to record
3C	00	00	the execute
3D	09	09	mode count.
3E	D6	LDAB	Since we must be in execute mode here, compare the
3F	09	09	contents of address 08 and 09

Hex Address	Hex Contents	Mnemonics	Comments
40	D1	CMPB	and if the "up"
41	08	08	Count is incomplete
42	26	BNE	Branch to address 4C
43	08	08	To raise the arm one more half step.
44	20	BRA	if count complete branch to address 0064
45	1E	1E	To wait before starting down
46	01	NOP	
47	01	NOP	
48	01	NOP	
49	7C	1NC	Number of half steps taken by motor Z going up
4A	00	00	to be stored
4B	08	08	at address 08.
4C	8C	CPX#	Compare the contents of
4D	00	00	the index register
4E	08	08	with 08.
4F	26	BNE	if index register does not contain 08 branch
50	D5	D5	back to address 26 and continue sequence
51	20	BRA	otherwise branch back to 23 to start
52	D0	D0	proper "up" stepping sequence over again.
53	01	NOP	
54	00	00	same number as that at 08-to be decreased to zero as arm is lowered
55	02	02-80	
56	06	06-40	
57	04	04-20	
58	05	05-10	
59	01	01-8	Output sequence to reverse Z motor (down)
5A	09	09-4	
5B	08	08-2	
5C	0A	0A-1	
5D	7D	TST	Test input
5E	80	80	Port A
5F	00	00	and
60	27	BEQ	if it is zero test it again,
61	FA	FA	that is wait.
62	01	NOP	otherwise continue program.
63	01	NOP	
64	CE	LDX#	two
65	FF	FF	second
66	FF	FF	delay
67	09	DEX	before
68	26	BNE	going
69	FD	FD	down.
6A	01	NOP	
6B	96	LDAA	Store the number of up
6C	08	08	counts
6D	97	STAA	also at
6E	54	54	address 54. (Decrement as arm lowers).
6F	01	NOP	
70	01	NOP	
71	01	NOP	
72	CE	LDX#	"Lower arm" (reverse motor).

Hex Address	Hex Contents	Mnemonics	Comments
73	00	00	
74	55	55	
75	A6	LDAA,X	
76	00	00	
77	B7	STAA	
78	80	80	
79	02	02	
7A	BD	JSR	
7B	00	00	
7C	BC	BC	
7D	7A	DEC	Decrement the number of down-counts
7E	00	00	remaining as shown at
7F	54	54	address 54.
80	08	lNX	
81	7D	TST	
82	80	80	
83	00	00	
84	27	BEQ	If input port contains zero
85	D7	D7	branch to address 5D.
86	7D	TST	Test contents of address 54 (number of
87	00	00	down counts
88	54	54	remaining.
89	2D	BLT	Branch if reverse complete
8A	09	09	to address 94.
8B	8C	CPX#	Otherwise compare the contents
8C	00	00	of the index register
8D	5D	5D	with the number 5D.
8E	26	BNE	If index register does not contain 5D
8F	E5	E5	Branch back to address 75 and continue sequence
90	20	BRA	otherwise branch back to 72 to start proper
91	E0	E0	down sequencing over again
92	01	NOP	
93	01	NOP	
94	86	LDAA#	
95	CC	CC	
96	97	STAA	Store CC at location B1 to indicate
97	B1	B1	arm lowering completed.
98	7F	CLR	Prepare to
99	00	00	raise arm
9A	09	09	in execute
9B	73	COM	mode by
9C	00	00	storing FF at
9D	09	09	address 09.
9E	01	NOP	
9F	86	LDAA#	long delay (9 seconds)
A0	09	09	the number here is the number of
A1	CE	LDX#	seconds of delay
A2	F3	F3	
A3	80	80	
A4	09	DEX	

Hex Adress	Hex Contents	Mnemonics	Comments
A5	26	BNE	
A6	FD	FD	
A7	4A	DECA	
A8	26	BNE	
A9	F7	F7	
AA	01	NOP	
AB	01	NOP	
AC	01	NOP	
AD	01	NOP	
AE	7E	JMP	Jump to
AF	00	00	address 23
B0	23	23	again.
B1	00	00	Reserved for "CC" to indicate that arm
B2	01	NOP	lowering is now complete and all steps
B3	01	NOP	are now part of the execute mode.
B4	01	NOP	
B5	01	NOP	
B6	01	NOP	
B7	01	NOP	
B8	01	NOP	
B9	01	NOP	
BA	01	NOP	
BB	01	NOP	
BC	C6	LDAB#	Time delay between each motor step
BD	FF	FF	FF is 1.5 sec. 33 is 0.3 sec. 11 is 0.1 sec.
BE	5A	DECB	
BF	26	BNE	
C0	FD	FD	
C1	7C	iNC	
C2	00	00	
C3	C7	C7	
C4	26	BNE	
C5	F6	F6	
C6	39	RTS	Return to 2E
C7	00	00	
C8	01	NOP	Program ends here

(one axis-tiny basic)

PROGRAM DESCRIPTION

The following program was written by Greg Wilder. It is designed to operate one axis (Z-up/down) of a robot. This program was written using Heath Tiny Basic on the Heath/Zenith ET3400 microcomputer, which is connected to a zenith video terminal.

I. GENERAL

The microcomputer is connected to a 6820 PIA. This PIA has two parallel port. Port A is configured to act as an input port, and Port B is an output port.

The program has the capability to run the stepping motors in either the Full step or Half step mode. Also you can select clockwise or counter-clockwise operation, and the rate of speed of the motors.

Switches are connected to port A to select either a Learn Mode or an execute mode. While in the Learn Mode, the motor will run until a switch is pressed activating a stop. Then when the execute mode is selected the motor will repeat the exact pattern it experienced in the Learn Mode.

II. SPECIFIC

Tiny Basic has a limited set of Basic commands. It is an integer Basic, and you cannot use arrays.

Below are the commands of Tiny Basic:

LET	LOAD	INPUT	REM
RUN	SAVE	PRINT	IF(THEN)
END	GOTO	GOSUB	RETURN
BYE	LIST	CLEAR	RND
USR			

The program outputs the stepping sequence for the motors, using Port B. Most Basics have two commands, Peek and Poke to get information in and out of a computer. Poke will output a number and Peek will input a number. The format for POKE is 100 POKE M, D where M is the memory location where the data goes (in this case the address of the PIA) and D is the data (stepping sequence). The format for Peek is 100X=PEEK (M), where M is the memory location (address of PIA) and X will contain the input information.

On Tiny Basic there is no Peek and Poke commands, however, you can call the Peek & Poke functions by implementing the USR command. A USR command calls a machine language routine while in Basic. To execute a Poke in Heath Tiny Basic: 100 N = USR (7192, L, J). Where L is the location you want to poke the data J into. For Peek the line looks like: 100 N = USR (7188, L). Where L is the memory location you want to input from and N will contain the input data.

So to run the motors, you will poke data to Port B, and for inputs you will peek Port A.

III. ENTERING TINY BASIC

STEPS

(1) Turn on ET 3400 and Zenith Video Terminal
(2) Press "Reset" on microcomputer
(3) Now type "D 1400". D is the Do Key
(4) On video terminal type "G1C00" and return key

You are now in Heath-Tiny Basic.

LIST

```
1    C=0
2    C=C+1
3    PR
4    IFC< 10GOTO2
5    PR"ENTER THE DELAY (0-15)";
6    INPUTZ
7    PR
9    REM##########  INITIALIZATION##############################
10   X=USR(7192,32771,0)
20   X=USR(7192,32770,255)
30   X=USR(7192,32771,4)
31   X=USR(7192,32769,0)
32   X=USR(7192,32768,255)
33   X=USR(7192,32769,4)
34   X=USR(7192,32768,0)
35   X=USR(7192,32769,0)
36   X=USR(7192,32768,0)
37   X=USR(7192,32769,4)
38   X=USR(7188,32768)
39   PRX
40   PR
41   PR"FULL STEP= POS. #    HALF STEP= NEG. #";
42   INPUTO
43   IFO<OGOTO2000
50   PR
51   PR"ENTER POSITIVE NUMBER FOR CLOCKWISE, NEG. FOR CCW";
52   INPUTD
60   IFD<OGOTO500
80   PR
81   PR"MOTOR NOW MOVING CLOCKWISE"
82   PR
100 C=0
105 L=32770
110 X=USR(7192,L,10)
115 GOSUB1000
120 X=USR(7192,L,9)
125 GOSUB1000
```

```
130 X=USR(7192,L,5)
135 GOSUB1000
140 X=USR(7192,L,6)
145 GOSUB 1000
210 C=C+1
220 IFC<17GOTO0110
230 GOTO5
250 X=USR(7192,L,0)
260 END
500 REM***** C CLOCKWISE *****
501 PR
502 PR"MOTOR NOW MOVING CCUNTERCLOCKWISE"
503 PR
505 L=32770
506 U=1
520 X=USR(7192,L,6)
521 U=U+1
522 E=USR(7188,32768)
523 IFE=1THENGOTO800
525 GOSUB1000
530 X=USR(7192,L,5)
531 U=U+1
532 E=USR(7188,32768)
533 IFE=1THENGOTO800
535 GOSUB1000
540 X=USR(7192,L,10)
541 U=U+1
542 E=USR(7188,32768)
543 IFE=1THENGOTO800
545 GOSUB1000
550 X=USR(7192,L,10)
551 U=U+1
552 E=USR(7188,32768)
553 IFE=1THENGOTO800
555 GOSUB1000
625 GOTO520
630 GOTO5
800 REM** EXTERNAL STOP HAS BEEN PRESSED**********
810 PR
811 PR"HIT RESET SWITCH (#2) TO RESET MOTOR TO ZERO"
820 E=USR(7188,32768)
825 IFE=2THENGOTO850
827 GOTO820
850 REM***** RESET MOTOR**********
855 Q=0
860 X=USR(7192,L,10)
865 Q=Q+1
867 IFQ<UTHENGOTO0910
870 X=USR(7192,L,9)
875 Q=Q+1
877 IFQ<UTHENGOTO0910
880 X=USR(7192,L,5)
885 Q=Q+1
```

```
887 IFQ< UTHENGOTO910
890 X=USR(7192,L,6)
895 Q=Q+1
897 IFQ < UTHENGOTO910
900 GOTO860
910 REM**** MOTOR RESET ASK  FOR COMPUTER REPEAT******
912 PR
915 PR"MOTOR NOW RESET, HIT SWITCH #3 TO RUN THROUGH SEQUENCE"
920 E=USR(7188,32768)
925 IFE=4THEN GOTO940
927 GOTO920
940 REM **** RERUN MOTOR********
942 W=1
950 X=USR(7192,L,6)
951 GOSUB1000
952 W=W+1
955 IFW<UTHENGOTO6000
960 X=USR(7192,L,5)
961 GOSUB1000
962 W=W+1
965 IFW<UTHENGOTO6000
970 X=USR(7192,L,9)
971 GOSUB1000
972 W=W+1
975 IFW<UTHENGOTO6000
980 X=USR(7192,L,10)
981 GOSUB1000
982 W=W+1
985 IFW<UTHENGOTO6000
990 GOTO950
1000 F=0
1010 F=F+1
1020 IFF<ZTHENGOTO1010
1030 RETURN
2000 REM########## HALF STEP####################
2005 L=32770
2100 PR
2110 PR
2120 PR"ENTER NEG. # FOR CCW   POS. # FOR CW";
2130 INPUTD
2140 PR
2150 IFD<0GOTO2500
2200 REM###### CLOCKWISE#######################
2201 PR
2202 PR"MOTOR MOVING HALF STEP  CLOCKWISE"
2203 PR
2210 C=0
2220 X=USR(7192,L,10)
2225 GOSUB1000
2230 X=USR(7192,L,8)
2235 GOSUB1000
2240 X=USR(7192,L,9)
2245 GOSUB1000
```

```
2250 X=USR(7192,L,1)
2255 GOSUB1000
2260 X=USR(7192,L,5)
2265 GOSUB1000
2270 X=USR(7192,L,4)
2275 GOSUB1000
2280 X=USR(7192,L,6)
2285 GOSUB1000
2290 X=USR(7192,L,2)
2296 GOSUB1000
2300 C=C+1
2310 IFC<17GOTO2220
2320 GOTO5
2500 REM#####  CCW HALF STEP ##################
2501 PR
2502 PR"MOTOR MOVING HALF STEP COUNTERCLOCKWISE"
2503 PR
2505 L=32770
2510 C=0
2520 X=USR(7192,L,2)
2525 GOSUB1000
2530 X=USR(7192,L,6)
2535 GOSUB1000
2540 X=USR(7192,L,4)
2545 GOSUB1000
2550 X=USR(7192,L,5)
2555 GOSUB1000
2560 X=USR(7192,L,1)
2565 GOSUB1000
2570 X=USR(7192,L,9)
2575 GOSUB1000
2580 X=USR(7192,L,8)
2585 GOSUB1000
2590 X=USR(7192,L,10)
2595 GOSUB1000
2600 C=C+1
2610 IFC<17GOTO2520
2630 GOTO5
6000 REM**** MOTOR RUN THRU SEQUENCE******
6010 PR
6011 PR
6020 PR"MOTOR NOW HAS BEEN RUN THRU SEQUENCE."
6050 PR
6055 PR"WANT TO RESET AND RESEQUENCE (YES=1)";
6060 INPUTR
6070 IFR=1THENGOTO800
6099 END
```

RESEARCH ROBOT PROGRAM NUMBER 3
Machine Language Program for Three Motors and a Hand

PROGRAM DESCRIPTION:

The program which follows was written by Meade Roberts to operate three stepping motors on a robot. The program is written in machine language for use with the Heath/Zenith model ET 3400 microcomputer trainer which uses a motorola 6800 microprocessor. The teach mode can be done with the trainer; the exicute mode requires the addition of the Heath/Zenith EWA 3400 microcomputer accessory to increase the number of memory locations from approximately 1/2K to 4 1/2K.

Addresses 0000 to 00C4 and 0100 to 11FF are available to the user. Addresses 00C5 to 00FF are reserved. For example the software interrupt routine starts at address 00FA.

ADVANTAGES OVER PROGRAM NUMBER 1:

This program can:
a) be stopped and then restarted at any time during the teach or execute mode
b) control three stepping motors
c) run at four different speeds
d) reset all counts to zero each time the program is asked to learn a new task
e) halt if the number of half steps taken exceeds 65,025
f) open and close the hand by manual or automatic means
g) wait for a proper input if the binary data switch is improperly set
Also we can:
h) place the hand at any point in the working envelope by use of the binary data input switches in any order
j) teach the robot to grip and wait;lower, rotate; extend; release and wait; return to the starting point selected in "h" above and then repeat the entire process

SPECIAL FEATURES:

The teach mode will cause the robot arm to lower, rotate, extend. Manual operations cause the reverse raise, rotate, retract. Since these manual operations all have only one fast speed, fine adjustments of the starting position must be done in the teach mode. When the exact starting position is obtained, the program is ready to start in the teach mode at address 0000.

All empty memory locations show 3E, the stop instruction.

The eight step sequence starting at 00BD always starts at this address and always stops, if a stop is requested, after the sequence gets to address 00C4. Because of this,the number of counts stored is always a multiple of 8.

Test numbers 8421 8421 and 1248 1248 and 8,8,8,8 are used at addresses 00BD, 01A7, and 01AF, 01B7, 010C0, 01D0 to operate lights rather than motors. This is useful when testing the program at slow speeds.

In the execute mode the hand always closes after returning to the start position and it always opens just after it extends (out).

CODES USED:

If the binary data switch is set as shown, the robot will operate as indicated:

Switch Position			Operation
1	0000	0001	Execute mode
2	0000	0010	lower · teach mode
3	0000	0011	raise · manual mode
4	0000	0100	In manual mode
5	0000	0101	Out teach mode
6	0000	0110	Clockwise teach mode
7	0000	0111	Counterclockwise manual mode
8	0000	1000	Close hand manual mode
9	0000	1001	Open hand manual mode
X	0001	XXXX	Wait use this most of the time
X	1XXX	XXXX	Wait, then record count in teach mode

Since only one 8 bit output part is used (PIA 6820), a demultiplexer is used to decode the upper four bits of output and thus select the proper motor (or the hand). The circuit is wired in such a way that the output shown will select the devices indicated:

PIA Output		Device Selected
0	0000 XXXX	No action halt
1	0001 XXXX	Up-down motor
2	0010 XXXX	In-out motor
3	0011 XXXX	Rotation motor
40	0100 0000	Hand open
41	0100 0001	Hand closed

MOTOR SPEEDS:

Motor speeds are determined by the number the program loads into addresses 0051, 0052, and 0053. The program is written so that 0051 always contains 30 and the contents of 0052 and 0053 are as shown in the chart:

ACTION	APPROX. DELAY	HEX CONTENTS OF 0052	0053
Hand-close	1 sec.	10	00
lower -teach	1 sec.	10	00
Clockwise-teach	0.1 sec.	00	90
Out-teach	20 ms.	00	20
Hand-open	1 sec.	10	00
All manual	4 ms	00	04
All execute	4 ms	00	04

STEP BY STEP PROCEDURE

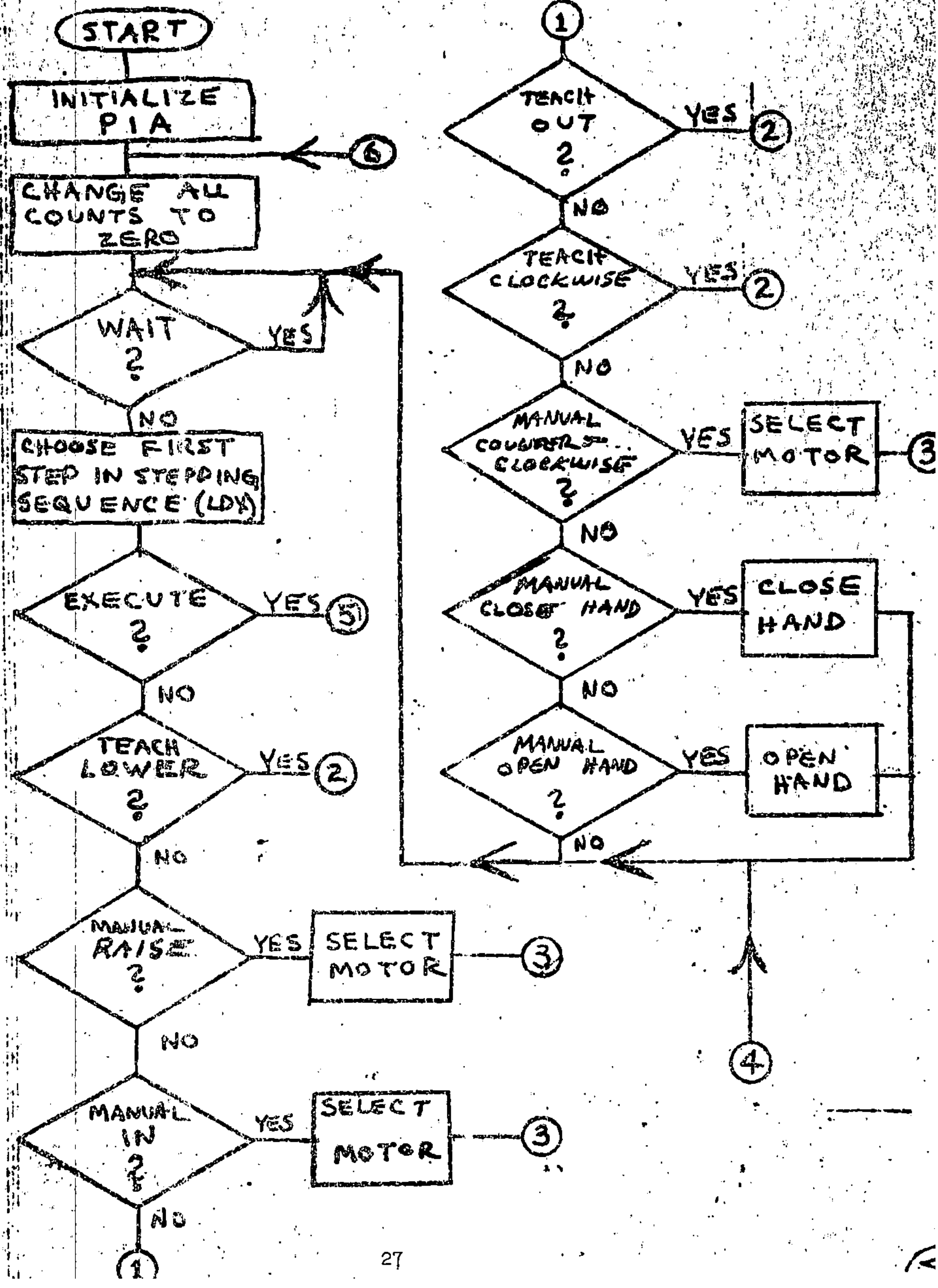
1. Turn off power supply to motors and turn it on only after you are ready for step 5. If you forget-fuse on power supply will burn out.
2. Load the program into the microcomputer and verify.
3. Set the Binary Data Switch to 0001 0000 (binary 16) (bit 4 up)
4. Press RESET then D 0000 to start the program.

[illegible]

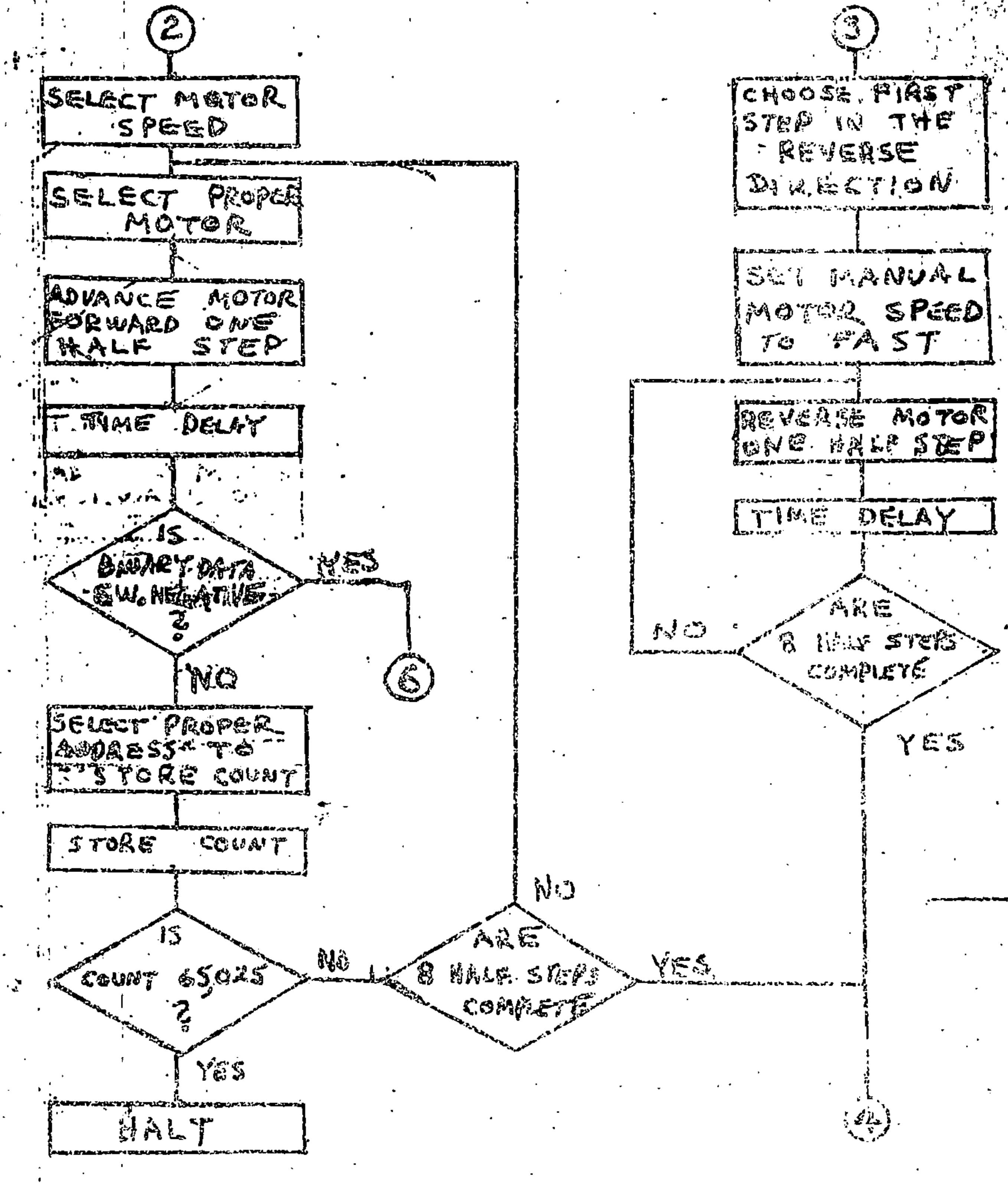
If the optically isolated relays light up, turn the switch on the computer trainer from on to standby and back on again. The optically isolated relays must stay off. Repeat step 4.

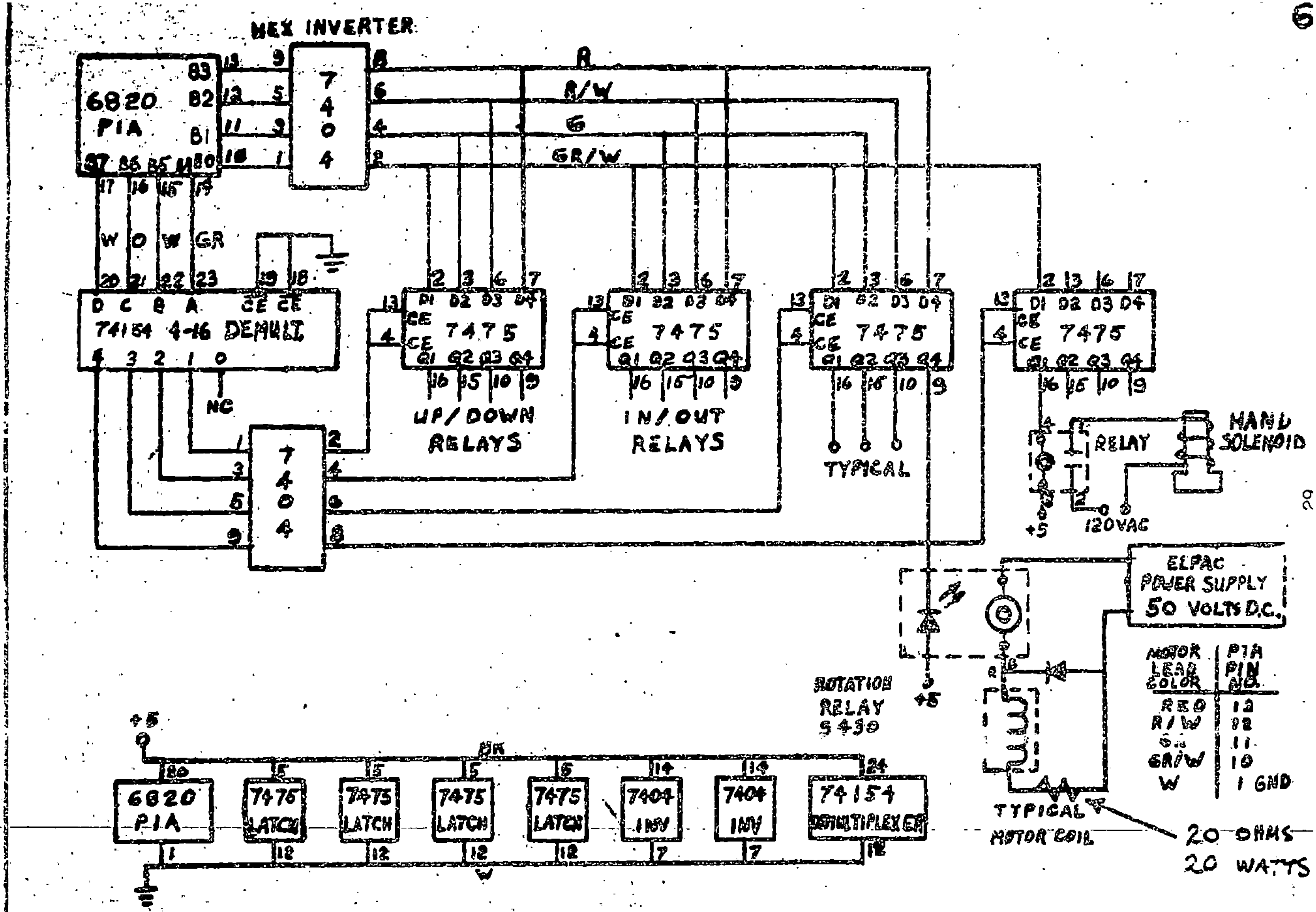
5. A. Turn the DC power supply on. B. Raise Binary Data switch 1-lower switch 4-arm lowers. - raise switch 4-arm stops. C. raise switch 1 and 2 lower switch 4-arm rotates clockwise-raise switch 4 arm stops D. lower switch 1, raise switches 0 and 2, lower switch 4-arm goes out-raise switch 7 arm stops and counts are erased. This is the only time to use switch 7.
6. We are now ready to start the teach mode. Lower switch 0, 2, raise switch 1, lower switch 7. arm lowers-raise switch 4 arm stops. Repeat steps 5C, and 5D but use switch 5 instead of 7.
7. To "execute" raise Binary Data Switch 0.
8. Reverse motor operations may be used only during step 5. No counts are stored during reverse motor operations.
9. The hand operates automatically; closing just before the arm starts to lower; opening just after the arm goes out.
10. Turn the motor power supply off, before turning the computer to stand-by or to off. This will avoid blowing the fuse on the motor power supply.

FLOW CHART 4


START
INITIALIZE PIA
6
CHANGE ALL COUNTS TO ZERO
WAIT ?
YES
NO
CHOOSE FIRST STEP IN STEPPING SEQUENCE (LDY)
EXECUTE ?
YES
5
NO
TEACH LOWER ?
YES
2
NO
MANUAL RAISE ?
YES
SELECT MOTOR
3
NO
MANUAL IN ?
YES
SELECT MOTOR
3
NO
1
1
TEACH OUT ?
YES
2
NO
TEACH CLOCKWISE ?
YES
2
NO
MANUAL COUNTER-CLOCKWISE ?
YES
SELECT MOTOR
3
NO
MANUAL CLOSE HAND ?
YES
CLOSE HAND
NO
MANUAL OPEN HAND ?
YES
OPEN HAND
NO
4

FLOW CHART (CONTINUED) 5





MOREHEAD STATE UNIVERSITY	RESEARCH ROBOT OPTICALLY ISOLATED RELAYS	SEC.
SCALE:	DATE: 4-28-82	DRAWN BY: J. LAVALLEY APPROVED MSR SHEET

HEX ADD.	HEX CONT.	MNE-MONIC	COMMENTS
0000	86	LDAA#	Start initialization of PIA.
0001	00	00	See Figure 10-55.
0002	B7	STAA	A side is input port.
0003	80	80	
0004	00	00	
0005	86	LDAA#	
0006	04	04	
0007	B7	STAA	
0008	80	80	
0009	01	01	
000A	86	LDAA#	
000B	FF	FF	
000C	B7	STAA	
000D	80	80	
000E	02	02	
000F	86	LDAA#	
0010	04	04	
0011	B7	STAA	
0012	80	80	
0013	03	03	Complete initialization-B side output port.
0014	CE	LDX#	Change all counts to zero; counts are located at
0015	01	01	0100
0016	00	00	
0017	6F	CLRX	
0018	00	00	to
0019	08	INX	
001A	8C	CPX#	
001B	01	01	010D.
001C	0E	0E	
001D	26	BNE	Branch to 0018
001E	F8	F8	All counts now zero.
001F	3F	SW1	Go to address 00FA and wait.
0020	CE	LDX#	Choose first step in stepping sequence.
0021	00	00	
0022	00	00	
0023	B6	LDAA	Load accumulator a with
0024	80	80	the number in the Binary Data Switch.
0025	00	00	
0026	4A	DECA	Decrement accumulator A.
0027	27	BEQ	Branch if Binary Data Switch input
0028	40	40	is 0000 0001 to address 01D0 via 0069 to "execute"
0029	4A	DECA	one motor at a time.
002A	27	BEQ	Branch, if original input was 0000 0010, to
002B	2F	2F	address 005B to "lower" teach mode
002C	4A	DECA	
002D	27	BEQ	If original input was 0000 0011 go to
002E	1B	1B	address 016D via 004A, 00AE, and 0127
002F	4A	DECA	to "raise" manual mode
0030	27	BEQ	If input 0000 0100 go to 0142
0031	51	51	via 0083 to "in" manual.
0032	4A	DECA	
0033	27	BEQ	If input 0000 0101 go to 017A

```
0034  52  52     VIA 0087 to "out" teach.
0035  4A  DECA
0036  27  BEQ    If input 0000 0101 go to
0037  5E  5E     0096 to "clockwise". teach.
0038  4A  DECA
0039  27  BEQ    If input 0000 0111 go to 0142
003A  48  48     VIA 0083 to "counterclockwise" manual
003B  4A  DECA
003C  27  BEQ    If input 0000 1000 go to
003D  0E  0E     004C to "close hand" manual.
003E  4A  DECA
003F  27  BEQ    If input 0000 1001 go to
0040  02  02     0043 to "open hand" manual
0041  20  BRA    otherwise
0042  DC  DC     Go to 001F and wait.
0043  86  LDAA#  Start to open hand
0044  40  40
0045  B7  STAA#
0046  80  80
0047  02  02     Hand now open.
0048  20  BRA
0049  D5  D5     Branch back to 001F and wait.
004A  20  BRA    See 002E.
004B  62  62     Branch forward to 0170 VIA 00AE.
004C  7E  JMP    See 003D and 0129.
004D  01  01
004E  29  29
004F  C6  LDAB#  Time delay starts here.
0050  30  30     Deci seconds of delay if addresses 52-3 contain 1000.
0051  CE  LDX#
0052  --  --     0200 changes deci seconds to centiseconds approx.
0053  --  --     0030 changes deci seconds to milliseconds approx.
0054  09  DEX
0055  26  BNE    Branch to 0054.
0056  FD  FD
0057  5A  DECB
0058  26  BNE    Branch to 0051.
0059  F7  F7     Time delay ends
005A  39  RTS    Return to 007B or to 0178.
005B  7F  CLR    Lower teach mode starts here.
005C  00  00     Set lower motor speed.
005D  53  53
005E  86  LDAA#
005F  10  10
0060  97  STAA
0061  52  52
0062  86  LDAA#  Select the lower motor.
0063  10  10
0064  97  STAA
0065  70  70
0066  7E  JMP
0067  01  01
0068  C0  C0
0069  7E  JMP    See 0028.
```

006A	01	01	
006B	D0	D0	
006C	3E	3E	
006D	A6	LDAA,X	Start motor.
006E	BD	BD	
006F	8B	ADDA#	Choose proper motor or hand by adding
0070	--	--	10, 20, 30 (see addresses 0067, 0091, and 0095).
0071	B7	STAA	Output signal on output port.
0072	80	80	
0073	02	02	
0074	08	INX	
0075	01	NOP	
0076	DF	STX	Store stepping count at addresses 00B0 and 00B1.
0077	B0	B0	
0078	BD	JSR	Jump to time delay sub-routine at 004F.
0079	00	00	
007A	4F	4F	
007B	7D	TST	Test contents of address 8000 (Binary Input Switch)
007C	80	80	If it contains a positive number
007D	00	00	Branch forward to 00A5 to wait
007E	2A	BPL	
007F	25	25	otherwise
0080	7E	JMP	Jump to 0014 to change all counts to zero
0081	00	00	and wait for bit 7 to be set down
0082	14	14	
0083	7E	JMP	Jump to 0142 to "in" or "counterclockwise manual
0084	01	01	
0085	42	42	
0086	3E	3E	
0087	7F	CLR	Teach "out" starts here.
0088	00	00	
0089	52	52	
008A	86	LDAA#	Set "out" motor speed.
008B	20	20	
008C	97	STAA	
008D	53	53	
008E	7E	JMP	Jump to 01AF
008F	01	01	
0090	AF	AF	
0091	3E	3E	
0092	86	LDAA#	Select in/out motor.
0093	20	20	
0094	20	BRA	Branch to 0064 to STAA and Start motor.
0095	CE	CE	
0096	7E	JMP	Teach clockwise starts here.
0097	01	01	
0098	B7	B7	
0099	01	NOP	
009A	7F	CLR	
009B	00	00	
009C	52	52	
009D	86	LDAA#	
009E	90	90	
009F	97	STAA	Set motor speed

00A0	53	53	
00A1	86	LDAA#	Select rotation motor.
00A2	30	30	
00A3	20	BRA	Branch to 0064 to STAA and start motor.
00A4	BF	BF	
00A5	01	NOP	
00A6	96	LDAA	Determine proper address to store count.
00A7	70	70	
00A8	81	CMPA#	
00A9	10	10	
00AA	27	BEQ	
00AB	6F	6F	Branch forward to 011B to record raise count.
00AC	20	BRA	Branch forward to 0136 via 0116.
00AD	68	68	
00AE	20	BRA	See also 002E and 004A.
00AF	77	77	Branch forward to 0170 via 0127
00B0	--	--	Forward stepping count (0 to 8)
00B1	--	--	Reverse stepping count (0 to 8)
00B2	DE	LDX	Load stepping count into index register.
00B3	B0	B0	
00B4	8C	CPX#	Compare the contents of the
00B5	00	00	index register with
00B6	08	08	0008 and
00B7	26	BNE	if 8 steps are not completed
00B8	B4	B4	Branch back to address 006D and
00B9	7E	JMP	continue to step motor otherwise jump
00BA	00	00	back to 001F to start proper raise
00BB	1F	1F	stepping sequence again.
00BC	01	NOP	
00BD	0A	2-01	Stepping motor half step sequence
00BE	09	6-02	also shown are the numbers used to
00BF	05	4-04	test the program.
00C0	06	5-08	
00C1	0A	1-01	Hex numbers used are
00C2	09	9-02	for full steps
00C3	05	8-04	
00C4	0A	A-08	
00C5			
00C6			
00C7			
00C8			
00C9			
00CA			
00CB			
00CC			
00CD			
00CE			
00CF			
00D0			
00D1			
00D2			
00D3			
00D4			
00D5			
00D6			

00D7			
00D8			
00D9			
00DA			
00DB			
00DC			
00DD			
00DE			
00DF			
00E0			
00E1			
00E2			
00E3			
00E4			
00E5			
00E6			
00E7			
00E8			
00E9			
00EA			
00EB			
00EC			
00ED			
00EE			
00EF			
00F0			
00F1			
00F2			
00F3			
00F4			
00F5			
00F6			
00F7			
00F8			
00F9			
00FA	7D	TST	If the Binary Data Switch is
00FB	80	80	Set to 1000 0000
00FC	00	00	or higher-wait,
00FD	2B	BMI	But if bit 7 is not a "one"
00FE	FB	FB	Return to the program,
00FF	3B	RTI	Just following the SWI instruction.
0100	--	--	
0101	--	--	Additional steps completed during teach lower.
0102	--	--	Steps completed during teach lower ÷ 255.
0103	--	--	Additional steps completed during execute "lower".
0104	--	--	Steps completed during execute lower ÷ 255.
0105	--	--	CC indicates return to start complete, now in execute mode.
0106	--	--	Additional steps completed during teach clockwise.
0107	--	--	Steps completed during teach clockwise ÷ 255.
0108	--	--	Additional steps completed during execute clockwise.
0109	--	--	Steps completed during execute clockwise ÷ 255.
010A	--	--	Additional steps completed during teach out.
010B	--	--	Steps completed during teach out ÷ 255.
010C	--	--	Additional steps completed during execute out.

010D	--	--	Steps completed during execute out ÷ 255.
010E	3E	3E	
010F	3E	3E	
0110	3E	3E	
0111	20	BRA	See 0154
0112	9F	9F	Branch back to 00B2.
0113	3E	3E	
0114	3E	3E	
0115	3E	3E	
0116	20	BRA	See 00AC
0117	1E	1E	Branch forward to 0136.
0118	3E	3E	
0119	3E	3E	
011A	3E	3E	
011B	7C	INC	Store the lower
011C	01	01	Count at
011D	01	01	0101 and if
011E	26	BNE	The register is not full
011F	92	92	Branch back to 00B2 to continue stepping
0120	7C	INC	Otherwise add A count at
0121	01	01	0102
0122	02	02	and
0123	26	BNE	then
0124	8D	8D	Branch back to 00B2 to continue stepping
0125	20	BRA	But if count is 65,025 branch
0126	0C	0C	To 0133 and stop.
0127	20	BRA	See 002E.
0128	44	44	Branch forward to 016D.
0129	86	LDAA#	Start to close hand
012A	41	41	
012B	B7	STAA	
012C	80	80	
012D	02	02	
012E	7E	JMP	Finish closing hand and go back to 001F
012F	00	00	and wait.
0130	1F	1F	
0131	3E	3E	
0132	3E	3E	
0133	3E	WAI	Halt - count is excessive.
0134	01	NOP	
0135	01	NOP	
0136	81	CMPA#	Determine proper count address (continued)
0137	20	20	
0138	27	BEQ	
0139	16	16	Branch forward to 0150 to record out count.
013A	81	CMPA#	
013B	30	30	
013C	27	BEQ	
013D	22	22	Branch forward to 0160 to record clockwise count.
013E	3E	3E	
013F	3E	3E	
0140	3E	3E	
0141	3E	3E	
0142	B6	LDAA	"in" and "counterclockwise" manual starts here

```
0143  80   80
0144  00   00
0145  81   CMPA#
0146  04   04
0147  27   BEQ    If Binary Data Switch is set to 0000 0100 (in)
0148  51   51     Branch forward to select "in" motor at 019A
0149  86   LDAA#  otherwise select rotation motor.
014A  30   30
014B  B7   STAA
014C  01   01
014D  80   80
014E  20   BRA
014F  23   23     Branch forward to 0173 to start motor
0150  7C   INC    Store "out" count - sequence similar to
0151  01   01     011B to 0126.
0152  0A   0A
0153  26   BNE
0154  BC   BC     Branch back to 00B2 via 0111.
0155  7C   INC
0156  01   01
0157  0B   0B
0158  26   BNE
0159  B7   B7     Branch back to 00B2 via 0111.
015A  20   BRA
015B  D7   D7     Branch back to 0133 to stop.
015C  3E   3E
015D  3E   3E
015E  3E   3E
015F  3E   3E
0160  7C   INC    Store clockwise count-sequence similar to
0161  01   01     011B  to 0126
0162  06   06
0163  26   BNE
0164  AC   AC     Branch back to 00B2 via 0111.
0165  7C   INC
0166  01   01
0167  07   07
0168  26   BNE
0169  A7   A7     Branch back to 00B2 via 0111.
016A  20   BRA
016B  C7   C7     Branch back to 00B2 via 0133.
016C  3E   3E
016D  86   LDAA#  Manual raise starts here
016E  10   10     Select motor
016F  B7   STAA
0170  01   01
0171  80   80
0172  01   NOP
0173  CE   LDX#   Choose starting position of stepping sequence
0174  01   01
0175  A7   A7
0176  7F   CLR    Set manual speed
0177  00   00
0178  52   52
0179  86   LDAA#
```

```
017A  04   04     Fastest manual speed
017B  97   STAA
017C  53   53
017D  A6   LDAA,X Reverse motor one step
017E  00   00
017F  8B   ADD#   Choose proper motor by hand by adding
0180  --   --     10, 20 or 30 (see 006D).
0181  B7   STAA   Output signal on output port
0182  80   80
0183  02   02
0184  08   INX
0185  FF   STX    Store stepping count at 00B0 and 00B1
0186  00   00
0187  B0   B0
0188  BD   JSR    Jump to time delay sub-routine at 004F
0189  00   00
018A  4F   4F
018B  FE   LDX    Load stepping count into index register
018C  00   00
018D  B0   B0
018E  8C   CPX#
018F  01   01
0190  AF   AF
0191  26   BNE    If 8 steps not completed
0192  EA   EA     Branch back to 017D for one more step
0193  7E   JMP    otherwise go back to 001F and
0194  00   00     Look for wait signal before
0195  1F   1F     Starting stepping sequence again.
0196  3E   3E
0197  3E   3E
0198  3E   3E
0199  3E   3E
019A  86   LDAA#  Select "in" motor
019B  20   20
019C  B7   STAA
019D  01   01
019E  80   80
019F  20   BRA
01A0  D2   D2     Branch back to 0173 to start motor.
01A1  3E   3E
01A2  3E   3E
01A3  3E   3E
01A4  3E   3E
01A5  3E   3E
01A6  3E   3E
01A7  06   A-08   Reverse sequence
01A8  05   8-04   Also shown are outputs to run testing lamps
01A9  09   9-02   and half step sequence
01AA  0A   1-01
01AB  06   5-08   Hex numbers used are
01AC  05   4-04   for full steps
01AD  09   6-02
01AE  0A   2-01
01AF  C6   LDAB#  Remove chip enable from
```

01B0	06	6-8	Clockwise motor without advancing
01B1	F7	STAB	The clockwise motor
01B2	80	80	
01B3	02	02	
01B4	7E	JMP	
01B5	00	00	
01B6	92	92	
01B7	C6	LDAB#	Remove chip enable from up motor
01B8	06	6-8	without advancing the up motor
01B9	F7	STAB	
01BA	80	80	
01BB	02	02	
01BC	7E	JMP	
01BD	00	00	
01BE	9A	9A	
01BF	3E	3E	
01C0	C6	LDAB#	Remove chip enable from
01C1	C6	6-8	Out motor without advancing out motor
01C2	F7	STAB	
01C3	80	80	
01C4	02	02	
01C5	7E	JMP	Return to 006D to start motor
01C6	00	00	
01C7	6D	6D	
01C8			
01C9			
01CA			
01CB			
01CC			
01CD			
01CE			
01CF			
01D0	C6	LDAB#	Execute mode starts here
01D1	06	6-8	Remove chip enable from out motor
01D2	F7	STAB	without advancing out motor
01D3	80	80	
01D4	02	02	
01D5			
01D6			
01D7			
01D8			
01D9			
01DA			
01DB			
01DC			
01DD			
01DE			
01DF			
01E0			
01E1			
01E2			
01E3			
01E4			

4. Research Robot Program Using Heath Pittman Tiny BASIC

The Heath/Zenith ET 3400 microcomputer can be programmed using the Heath Pittman Tiny BASIC language provided we use the Zenity H 19 smart terminal along with the 6800 PIA.

a. The 6820 PIA

The 6820 PIA (Peripheral Interface Adapter) was developed to support the microprocessor. It greatly simplifies interfacing the MC6800 with the external world. The PIA does routine tasks, thus leaving the microprocessor free to handle more important jobs.

The PIA has two 8 bit I/O parts which can each be specified as either an input or an output part. I used port A as an input port. This port was connected to microswitches which act as a small Teach Box. Port B was an output port which sends data out to control to motors.

The PIA must be initialized to act as you want. Each Port must be specified as either input or output. Below is the procedure, in Tiny BASIC, to make Port A input and Port B output.

```
X = USR (7192,32771,0)
X = USR (7192,32770,255)      Make Port B Output
X = USR (7192,32771,4)        Regain Access to Port B Output Reg.
X = USR (7192,32769,0)
X = USR (7192,32768,0)        Make Port A Input
X = USR (7192,32769,4)        Regain Access to Port A Input Reg.
```

In Heath Tiny BASIC, the "USR" statement is used to input and output data through the PIA. Below are two statements, one to output and one to input data.

```
X = USR (7192.32770,10)       Output to value 10 to Port B
X = USR (7188,32768)          "X" contains the value of Port A
```

b. Relay Driver Board

Since the PIA does not have enough current to supply the motors, an interface/drive board must be used

The eight data lines from Port B of the 6820 PIA are used to control which motor operates. The upper four bits (See fig. 1) are connected to a 74154 demultiplexer. This demultiplexer then selects which motor will receive the data to make it step.

The lower four bits are the actual data lines. These are connected to four 7475 latches. When one of the 7475 latches is selected by the 75154, then it passes the data through.

The outputs of the latches are connected to relays which drive the motors. The relays may be either mechanical or solid state type.

c. Program Description

The program was written in Heath Tiny BASIC. BASIC is very slow for operating stepping motors and machine language subroutines should be used to do the actual stepping of the motors.

Lines 30-75 initialize the PIA to get data in and out of the computer. Lines 80-93 store the full step sequence for the motors. The next section, lines 100-400 print the various options for controlling the robot in either the Teach or Execute mode.

When the appropriate option is selected, the program starts moving the motor. Eash step is stored. Port A is constantly checked to see if a Stop command has been entered on the microswitch and to the selected motor stops. The number of steps the motor took is stored in memory. The program then returns to the menu for the next operation.

If the option for execute is entered, the program goes to lines 1000-

1400. Here the previously stored counts are recalled. The appropriate motor is then moved the proper number of steps.

d. Step by Step Procedure

The Heath 6800 microcomputer must be connected with the Heath EWA memory I/O accessory by the gray ribbon cable. The RS232 connector on the Zenith video terminal must be connected with the jack on the rear of the I/O accessory.

1. Turn on all equipment.
2. Type "Do 1400" on 6800 microcomputer.
3. Type "G1C00" on video terminal; hit "RETURN".
4. Put the tape (3 Axis Teach Program 5-116) in the recorder.
5. Rewind tape, place recorder in Play Mode.
6. Type "LOAD" on video terminal and hit the "RETURN" key.
7. Program is loaded when the computer prints a colon on video screen.
8. When program is loaded, type "RUN" and hit the "RETURN" key.
9. Program should now display list of options.
10. Select one of the teach options.
11. Let the axis move to the desired postion.
12. When Axis is at Position, move switch #0 on the microswitch up (on Heath Microcomputer).
13. Now you return to the menu and can repeat with new axis.
14. If uou select #1, Execute, the Robot will perform the various moves you taught it.

```
[illegible] IFX=5THENA=32
1170 IFX=6THENA=48
1171 IFX=7THENA=48
1175 IFX=8THENA=64
1176 IFX=9THENA=64
1190 I=8
1200 G=USR(7188,P)
1210 P=P+1
1220 H=USR(7188,P)
1250 N=(G*256)+H
1255 PR
1256 PR"THERE ARE ";N;" STEPS TO BE COMP ETED"
1260 O=0
1280 P=P+1
1300 V=USR(7188,S)
1310 S=S+1
1320 IFS=I+4THENS=I
1340 V=V+A
1350 X=USR(7192,32770,V)
1370 O=O+1
1375 PR"STEP POINT # ";O
1380 IFN=OTHENGOTO1050
1400 GOTO1300
1500 REM  Z UP
1505 S=10
1510 Z=2
1600 REM
1610 A=USR(7188,S)
1615 S=S+1
1620 IFS=14THENS=10
1625 A=A+16
1650 X=USR(7192,32770,A)
1700 N=N+1
1800 X=USR(7188,32768)
1810 IFX=1THENGOTO8000
1999 GOTO1600
2000 REM  Z DOWN
2005 S=5
2010 Z=3
2100 REM
2110 A=USR(7188,S)
2115 S=S+1
2120 IFS=9THENS=5
2126 A=A+16
2150 X=USR(7192,32770,A)
2200 N=N+1
2300 X=USR(7188,32768)
2310 IFX=1THENGOTO8000
2450 GOTO2100
2500 REM  BASE CW
2505 S=5
2510 Z=4
2600 A=USR(7188,S)
2610 S=S+1
2620 IFS=9THENS=5
2630 A=A+32
2650 X=USR(7192,32770,A)
2700 N=N+1
2800 X=USR(7188,32768)
2810 IFX=1THENGOTO8000
2950 GOTO2600
3000 REM  BASE CCW
3005 S=10
3010 Z=5
```

```
LIST

1 REM  THREE AXIS PROGRAM FOR RESEARCH ROBOT
2 REM WRITTEN BY GREG WILDER        FEB. 16,1982
30 REM INITILAZATION OF P.I.A.
35 X=USR(7192,32771,0)
40 X=USR(7192,32770,255)
45 X=USR(7192,32771,4)
50 X=USR(7192,32769,0)
55 X=USR(7192,32768,0)
60 X=USR(7192,32769,4)
70 X=USR(7192,35,60)
75 X=USR(7188,32768)
76 PRX
80 REM STORE STEP SEQUENCE
85 X=USR(7192,5,10)
86 X=USR(7192,6,9)
87 X=USR(7192,7,5)
88 X=USR(7192,8,6)
90 X=USR(7192,10,6)
91 X=USR(7192,11,5)
92 X=USR(7192,12,9)
93 X=USR(7192,13,10)
96 P=3500
97 R=1
100 X=1
105 PR
110 X=X+1
115 IFX<5THENGOTO105
120 PR"            THREE AXIS AND HAND TEACH-EXECUTE PROGRAM"
125 PR
126 PR
200 PR"SELECT OPTION FROM MENU:"
220 PR" 1)RECYCLE TO 'HOME' AND EXECUTE"
230 PR" 2)Z AXIS UP (TEACH)"
240 PR" 3)Z AXIS DOWN (TEACH)"
250 PR" 4)BASE CLOCKWISE (TEACH)"
260 PR" 5)BASE COUNTERCLOCKWISE (TEACH)"
270 PR" 6)R AXIS OUT (TEACH)"
280 PR" 7)R AXIS IN (TEACH)"
290 PR" 8)HAND CLOSE (TEACH)"
300 PR" 9)HAND OPEN (TEACH)"
400 PR"YOUR OPTION>>>";
410 INPUT O
450 N=0
460 T=0
470 T=50
500 M=(O*500)+500
510 GOTO M
1000 REM  EXECUTE
1010 X=USR(7192,P,0)
1040 P=3500
1050 X=USR(7188,P)
1055 PR
1056 PR"OPERATION # ";R
1058 R=R 1
1061 PR"TYPE OF SEQUENCE = ";X
1075 IFX=0THENGOTO13000
```

```
2610 S=S+1
2620 IFS=9THENS=5
2630 A=A+32
2650 X=USR(7192,32770,A)
2700 N=N+1
2800 X=USR(7188,32768)
2810 IFX=1THENGOTO8000
2950 GOTO2600
3000 REM  BASE CCW
3005 S=10
3010 Z=5
3100 A=USR(7188,S)
3110 S=S+1
3120 IFS=14THENS=10
3130 A=A+32
3150 X=USR(7192,32770,A)
3200 N=N+1
3300 X=USR(7188,32768)
3310 IFX=1THENGOTO8000
3450 GOTO3100
3500 REM  R OUT
3505 S=10
3510 Z=6
3600 A=USR(7188,S)
3610 A=A+48
3620 S=S+1
3630 IFS=14THENS=10
3650 X=USR(7192,32770,A)
3700 N=N+1
3705 X=USR(7188,32768)
3710 IFX=1THENGOTO8000
3950 GOTO3600
4000 REM  R IN
4005 S=5
4010 Z=7
4100 A=USR(7188,S)
4110 A=A+48
4120 S=S+1
4130 IFS=9THENS=5
4150 X=USR(7192,32770,A)
4200 N=N+1
4300 X=USR(7188,32768)
4310 IFX=1THENGOTO8000
4450 GOTO4100
4500 REM  HAND CLOSE
4510 Z=8
5000 REM  HAND OPEN
5010 Z=9
8000 REM LEARN OVER STORE INFO
8003 PR
8004 PR
8005 PR"# OF COUNTS =  ";N
8010 PR
8100 REM
8115 X=USR(7192,P,Z)
8120 P=P+1
8130 X=USR(7188,P-1)
8150 G=N/256
8160 H=N-(G*256)
8180 X=USR(7192,P,G)
8185 P=P+1
8190 X=USR(7192,P,H)
8195 P=P+1
8500 GOTO100
```

APPENDIX

B. Conference Proceedings

Preface

Industrial Robots Conference

Morehead State University
Morehead, Kentucky

June 14, 15, and 16, 1982

The department of Industrial Education and Technology at Morehead State University, Morehead, KY., sponsored a two and one half-day conference on Industrial Robotics. The sessions were designed to acquaint managers, engineers, technicians, and educators with Industrial Robotics. Emphasis was placed on applications, industrial relations, and the technology involved in Robotic controls and movements. Three actual Robots were displayed by Vendors.

Objectives of the conference were as follows:

1. An understanding of robots and their place in manufacturing.
2. Ability to discriminate between hard automation, low technology, and high technology robots.
3. Hands-on experience with robot programming, teach and execute modes.
4. Basis of developing a curriculum for robotics.
5. Review of current resource materials on robotics.

The conference presenters represented robot manufacturers, application engineers, and managers using Industrial Robots. Presentations also included curriculum development and implementation. The following presents a very brief synopsis of each individual presentation given at the conference.

Industrial Robots Conference

Morehead State University
Morehead, Kentucky
June 14, 15, and 16, 1982

The Department of Industrial Education and Technology at Morehead State University, Morehead, Ky., is sponsoring a two and one half-day conference on industrial robotics. Sessions are designed to acquaint managers, engineers, technicians, and educators with the technology and applications of industrial robots. Industrial robots will be on display.

Conference Topics	Conference Objectives
Industrial Robots "Past—Present—Future"	An understanding of robots and their place in manufacturing
Robots and Industrial Relations "Impact on Labor and Management"	Ability to discriminate between hard automation, low technology, and high technology robots
Robot Applications "Pick and Place, Transfer, Continuous Path"	Hands-on experience with robot programming, teach and execute modes
Micro-Processors and Robots "Interfacing and Programming"	Basis of developing a curriculum for robotics
Academia and Robots "Teaching About Robots"	Review of current resource materials in robotics
Economics of Robots "How to Cost Justify Robots"	

Conference presenters will represent robot manufacturers, application engineers, and managers using industrial robots. Presentations will also include curriculum development and implementation. Morehead State University has integrated robotics into drafting, electricity-electronics, machine tool, time and motion, and welding. Unit classes in robotics are being taught.

Fees
A minimal fee of $5 will be charged for refreshments at the conference.

Credit
1 hr. undergraduate credit is available at $25 for in-state and $35 for out-of-state residents.

For further information contact:

Dr. Robert E. Newton, Head
Department of Industrial
Education and Technology
Morehead State University
UPO Box 774
Morehead, KY 40351
Phone: 606-783-5269

"THE IMPACT OF THE INDUSTRIAL ROBOT IN MANUFACTURING"

Don Andreasson
President
DRT Marketing
433 Elmwood
Troy, MI 48084

Robotics may be the Second Industrial Revolution with Japan leading the way. If America hopes to compete in this International market, the use of robots must be expanded. Robots need to be utilized in industry. Universities have the challenge of training future engineers, and technicians to accept and use robots.

A robot can either be hydraulic or pneumatic or a combination of both. It is a device designed to duplicate human movements. All movements that a robot is expected to follow must be placed in a series of steps and then programmed into the robot. The robot then duplicates the movements in an executive mode. Individuals that are able to program and use robots effectively are in high demand. This responsibility lies heavily on the Colleges and Universities.

Faced with a new situation and a new education, approximately 25 Colleges and Universities across the United States are implementing a Robotics program of some sort, Morehead being such a University. This new technology provides a challenge to students and faculty to attack the broad scope of Robotics.

"INDUSTRIAL RELATIONS, NEW TECHNOLOGY, AND PRODUCTIVITY"

Walter S. Taylor, III
Vice President
Ky. Electric Steel Co.
P.O. Box 3500
Ashland, KY 41101

From the Industrial Relations viewpoint, robotics offer pros and cons. A robot can work 24 hours a day; a robot can perform tedious, repetitive tasks; a robot can perform hazardous jobs; a robot requires no breaks, and is never late. Robots may replace certain classifications of human workers. Anytime workers are replaced, the trade unions perceive this as a problem. The majority of contracts that management has with union, have a clause or provision that allows the introduction of new technology. An Industrial Robot is a new technology. Management and labor must work together to implement new technology and convey the message that increased profits and productivity means more jobs, not less.

The utilization of robots, will necessitate massive retraining. Individuals must be trained in operations and maintenance of robots. The retraining must begin immediately, or a 20th Century Industry will be maintained by 18th Century people. Three types of retraining must be considered and utilized. Industry should be responsible for in-house training, Colleges and Universities should be training individuals to apply and program robots, and Vocational Schools should be training in maintenance of robots.

"THE MICRO-PROCESSOR IN ROBOTS AND MANUFACTURING-INTERFACING, ART OR SCIENCE?"

Doug Rigsby
DRT Research
433 Elmwood
Troy, MI 48084

The interfacing of robots with the micro-processor or other machines has proven to be the most diffficult problem in robotic design and implementation. When considering interfacing, the present method of interfacing must be analyzed and all the alternatives and methods must be flow-charted. To determine which method is most appropriate for the Company, the cost of the alternatives must be determined, and all details must be examined from human as well as technical standpoint. A consultant would be very useful for the above determinations.

The several types of equipment must be considered and a decision as to which will be used, should be determined. Consideration should be given to the computer control-sequencing controls, power requirements, type of sensors, type of signals to be generated, etc. All of these specifications aid in "talking to" the robot as well as simplify the programmers and technicians job.

"ROBOTS IN INDUSTRY"

Jack Lohr
Prab Robots, Inc.
167 Dogwood
Loveland, OH 45140

Robots are playing every role in industry imaginable, and will continue to fill positions uncomprehendible to man. Robots are not R2-D2 or CP-30 devices, but rather a "reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices, through variable programmed motions for the performance of a variety of tasks."

The Prab model 4200 Robot is such a device and is being used extensively in industry. The Prab robot transfers a 90-pound tractor ring gear through several stages of production in a job that would be physically demanding for a human worker. The 4200 handles a motor stator in a solder dripping application--one of the hot jobs now assigned to robots. The robot unloads a red-hot part from a heat treating furnace. The 4200 transfers a transmission case from a belt conveyor to an overhead J-hook monorail. The robot reaches into a die-casting machine to remove a part. These are just a few of the applications of robots in industry and only the beginning. Robots must be implemented in industry in all phases, if Industry in United States hopes to compete with Japan.

"TRANSFER APPLICATIONS WITH UNIMATES & UNMANNED CELLS"

Jim Murray
Rockwell International
708 Rockwell Road
Winchester, KY 40391

To compete with Japan, hard automation is a must. With hard automation, drilling, loading, pick & place, and spot-welding can be achieved. In all applications of robotics, there are four basic principles that must be considered. The four principles are:

1. All parts being presented, must be oriented in a fixed position.
2. All machining chips must be controlled.
3. All robots must be gauge controlled.
4. Drills must be in the proper place, if drilling is to occur.

In the case of utilizing unmanned cells, the following factors must be controlled.

1. Tools to be used.
2. Gauging to be used.
3. Quality of the product is considered.
4. The safety factor must be kept in mind, if the product is to be run unmanned.

If an unmanned machining cell is used or not, depends on the application. In some cases it is difficult to use them, but it can be done, it must be done.

"THE HIGH TECHNOLOGY ROBOT & THE IBM MANUFACTURING SYSTEM"

Robert Heald
IBM Sales Engineer
International Business Machines Corp.
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Of all the high technology robots currently being manufactured, the IBM RS-1 and the 7535, offer the most extensive software capabilities. The RS-1 Manufacturing System is a programmable, multi-functional manupulator. It is suited for light assembly, fabrication, testing, and materials handling. The RS-1 consists of; a manipulator, its own manufacturing language (AML), systems controller with keyboard display station & matrix printer, programmable teach pendant, and hydraulic power supply. The RS-1 is able to travel the X, Y, Z axis, roll, pitch, yaw, & gripper.

The 7535 Manufacturing system was designed for light assembly work and other tasks that require speed and repeatability. It is suited for automatic assembly, feed & insertion of odd-shaped parts, multiple point drilling, tapping, chamfering, multiple point soldering, screw tightening. It is also utilized for assembling & inspecting many parts in process, for packing products into cases, and loading & unloading parts on an automated production line. The 7535 Manufacturing system consists of a jointed arm structure, and a control unit, with an easy-to-use operating panel. It utilizes a kidney shaped workspace.

"APPLICATIONS"

Jack Brittain
IBM Corporation
Office Products Division Plant
740 New Circle Road
Lexington, KY 40507

The industry of today offers a wide variety of jobs that can easily be handled by robots. The most popular utilization is in the area of welding. Spot and arc welding robots are widely used in the United States and Japan, because of their accuracy, speed, and efficiency.

Another application of the robot is pick-and-place. The robot is used to move parts from one place to another. The parts may be hot or cold. The robot may also be used to palletize and depalletize parts. Parts may be heavy or light and fragile.

Other applications of robots in industry, are as follows. A robot can be used to load and unload parts from production and assembly machines. A robot can spray paint, as well. The spray nozzle is mounted on the robot's wrist. It can be used for machining operations. A robot can be utilized in inspection. This specific area is a relatively new application. Vision sensors can be used to check for missing features or parts in assembly. In the more complete system, actual measurements can be accomplished through the use of vision, lasers, strain gauges, etc.

"INTERFACING"

Dallas Whiting
IBM Corporation
Office Products Division Plant
740 New Circle Road
Lexington, KY 40507

In computer interfacing, there are two considerations. The input; the adapting of the device to the machine to provide data of instruction. The output; result of the input, causes a movement to happen as a result of the current or voltage applied.

When communicating with a robot, it must be done in the computers language with the use of a sensor. This communication is known as human-to-robot commmunication. It is vital if interfacing is to perform its task. Interfacing devices connect the robots to the outside world, and also connect the internal parts of the robot to its other internal parts.

There are three important areas to be considered in robotic design:

1. Robot thinking, or analyzing, processes, & equipment.
2. The robotic mechanical equipment.
3. The interfacing equipment.

Ask three questions before interfacing. What type of sensors are to be used? What types of signals are to be generated? Are they direct interfacing signals?

"THE LOW TECHNOLOGY ROBOT-PICK & PLACE APPLICATION"

Max Vander Graaf
Camco
144 South Wolf Road
Wheeling, IL 60090

The Pick & Place robot is used to move parts, materials, or tools from one place to another. It is one of the most common of the applications for robots. Parts may be heavy, light, fragile, hot or cold. The robot may also employ sensory equipment to identify parts, especially on moving conveyors.

There are several points to consider when utilizing the pick & place robot.

1. The use of the pick & place robot.
2. The orientation of the parts.
3. Will it use magnetic, suction, or clamping?
4. What interlocks are required for the conveyors?
5. What axis movement is required for picking up the objects?

There are several benefits with the pick & place robot. It eliminates the hot, heavy tedious jobs. It is faster than man on lifting heavy objects, and has a longer reach. It reduces damages to fragile parts, and eliminates the need for hoisting devices on heavy items.

"ECONOMIC RATIONALE FOR INDUSTRIAL ROBOTS"

Richard Jinbo
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If a robot is to be utilized in industry, its cost must be justified. A robot need not only be justified to the workers, but also to the cost accountants, and the personnel in the financial department. Before rationalization can take place, the cost of the robot must be considered. Other specifications to be considered are as follows:

*1. purchase price
2. special tooling
3. installation costs
4. maintenance of the robot
5. finance-payback period
6. return-on-investment
7. operating power
8. depreciation

*1. labor displaced
2. quality improvement
3. increase in production

A formula can be used for the analysis of its justification. See attached page for examples and explanation of the formulas.

*Payback formula

$$P= \frac{I}{L--E}$$

Where:

P= the payback period in years
I= the total capital investment required in robot & accessories
L= total annual labor costs replaced by the robot
E= maintenance cost for the robot

In this example:

I= $55,000
L= 24,000
E= 3,000

Period:

Case 1--Single Shift

$$P= \frac{\$55,000}{24,000-3,000}$$

P= 2.62 years

Case 2--two shifts working

L becomes $48,000
E rises to 5,000

$$P= \frac{\$55,000}{48,000-5,000}$$

P= 1.28 years

*Simple payback formula

$$P= \frac{I}{L-E}$$

Where:

P= the payback period in years
I= the total capital investment
L= annual labor costs replaced by the robot
E= annual expense of maintaining the robot

In this example:

I= $55,000
L= is at the rate of $12.00 an hour, including fringe benefits
E= is at the rate of $1.30 hour

There are 250 working days per year, containing either one or two eight hour shifts

Case 1--Single Shift

$$P= \frac{\$55,000}{12(250 \times 8)-1.3(250 \times 8)}$$

P= 2.57 years

Case 2--two shifts working

$$P= \frac{\$55,000}{12(250 \times 16)-1.3(250 \times 16)}$$

P= 1.29 years

*Engelberger, Joseph F., Robotics in Practice, Division of American Management Association, 1980.

"UNIMATION-HIGH TECHNOLOGY ROBOT SYSTEM"

Frank Ryan
Sales Engineer
C.H. Gosiger Machinery Co.
212 Eiler Avenue
P.O. Box 14066
Louisville, KY 40214

Two films were shown on the general, and the specific welding applications of the Unimation robot. The Unimation robot is utilized all over the world. Whether the robot is loading, unloading, stamp pressing, forging, die casting, working with pottery, or welding, it provides service with precision and accuracy.

"CURRICULUM AND TRAINING NEEDS IN INDUSTRIAL ROBOTICS"

Dr. Robert E. Newton
Head, Industrial Tech. & Ed.
UPO 774
Morehead State University
Morehead, KY 40351

Don Andreasson
President
DRT Marketing Group, Inc.
433 Elmwood
Troy, MI 48084

Richard Switzer
Microbot
453-H Ravendale Drive
Mountain View, CA 94043

Jim Murray
Rockwell International
708 Rockwell Road
Winchester, KY 40391

The Second Industrial Revolution, Robotics, has arrived. There is a great need for training and curriculum in the Industrial Robotics field. Companies that desire to hire employees with expertise in robotics are often disappointed when they must turn to robot manufacturers for trained personnel. This dilemma is unnecessary, the robotics field must be persued by the government, colleges, and universities.

The massive training should begin at an early age, to rid society of the R2-D2 image of robots. As the students advance through the school system, exposure to robots and their uses, should be implemented. State-of-the-art techniques and a knowledge of production equipment should be implemented into Vocational-Technical Education.

Areas of specialized training in Robotics is a responsibility that lies heavily on the colleges and universities. Morehead is considering a four-year course of study in robotics. A Bachelors degree, with an Area of Concentration in Industrial Technology, an option in Robotics, and an emphasis in either

Application Engineering or Project Engineering.

The government also shares a responsibility in Robotics. If the United States is to become competitive with Japan, in manufacturing; government, industry, and education must work closely in Robotics and other forms of high technology automation to remain competitive with foreign imports. This is especially true in the automative field.

Rockwell International, truck and axle division, Winchester, Kentucky has used robotics since the plant opened in 1968. Service and maintenance is a major factor in the use of robotics. As industry begins to utilize more robotics, individuals trained in repair, maintenance, and reprogramming will be needed. Industry currently must do their own training. They had much rather the training be done by the educational community.

"ROBOTICS, PAST, PRESENT, AND FUTURE"

Tim Heile
Cincinnati Milicron
Marketing Co.
Lebanon, OH 45036

The concept of Robots slowly changes as their capabilities advance in complexity. Initially, robots were perceived as mechanical creatures to be feared by man; their only goal to destroy and destruct mankind. Later the attitude began to change with "The Tinman" and "I, robot", both created by Isaac Asimov. In the late "70's", and early "80's", concept of robots, changed dramatically with the production of "Star Wars", and "The Empire Strikes Back". Robots were now seen as helpful R2-D2 and CP-30 devices.

Today the emphasis is placed on the Industrial Robot. Based on its many applications in industry, their utilization will continue to grow. Robots are being used in all facets of industry for all types of jobs. They are used for welding, pick & place, machine loading & unloading, spray painting, machine operation, assembly operation, and inspection.

As our technology advances, so will the many uses of robots. Equipment already in production will turn cable television into a two-way commmunication system across the country, enabling customers to pay bills, do shopping or even conduct limited research from the family den. In the future, keeping the shelves stocked with food and other items, may be as easy as a robot's direct computer communication with the supermarkets computerized robot. A robot's capabilities are only hindered by our own technology.

Class Roll
Industrial Robotics
IET 399 - 3 Semester Hours
Spring Semester 1982

C. Class Roll of
Course IET 399,
Industrial Robotics

Adams, William C.

Andreasson, Eric S.

Bankemper, Andrew J.

Beato, Carl S.

Campbell, Teresa G.

Clemons, Ron T.

Conant, Ronald E.

Cooper, Michael D.

Drake, David L.

Early, Jack D.

Emmons, Barbara L.

Imhoff, Bryan D.

Jalil, Omar H.

Johnston, Glenn E.

Kamer, Billy R.

Kendrick, Ronald E.

LaValley, Jeffery D.

LaValley, Joel T.

Macomb, Richard A.

Maloney, Lynn A.

New, Robert L.

Ray, Michael L.

Schmetzer, Paul E.

Seelie, Thomas E.

Sloan, Timmy J.

Smith, Dewayne

Tyree, Breck A.

Wilder, Gregory S.

VIII. SELECTED REFERENCES

Arbuckle, Harvey J., Robots V: "An Overview." Production, SBPE, Vol. 46, No. 10, January 1981.

Brown Chris, "Robotics, The Microcomputing Connection." Microcomputing, September 1981, p. 104.

Engelberger, Joseph F., Robotics in Practice. American Management Association, 1980.

Heath Company, Individual Learning Program - Microprocessor, Benton Harbor: 1977.

Herserman, David L., How to Design and Build Your own Custom Robot. Blue Ridge Summit: Tab Books, 1981.

Holmes, John G., Resnick, Brian J., A Flexible Robot Arc Welding System. Cincinnati, Ohio: Cincinnati Milicron, Publiching No. A-278.

Keebler, Jim, "Robots Load Lather." Tooling and Production. SBPE, Vol. 46, No. 10, January 1981, p. 74-75.

Leonard, Charles C. III. ."The Robot Arm". Programming, Operation and Expansion", Term paper submitted as part requirement in IET 476 Special Problems, 1981.

Lerner, Eric J., "Robots to Crash Assembly Lines". High Technology, November-December 1980. p. 16.

Mandell, Steven L., Computers and Data Processing - Concepts and Applications, St. Paul: West Publishing Co., 1979.

Meacham, John, "TIG Welding with Robots", Robotics Age, Tujunga, Cal.: Robotics Publishing Corporation, March/April, 1981.

Murray, Jimmy, "Industrial Robots and Application", Term paper submitted as part requirement in course IET 395 Special Problems in Voc. Ed. 1981.

Roberts, Meade S., "Automation and its Effect on the Teaching of Industrial Arts and Vocational Education", Unpublished manuscript 1961.

Roberts, Meade S., "Multivibrators, Logic Circuits and Their Use". Unpublished manuscript, 1972.

Roberts, Meade S., "The Design of a Simple, Transistor Audio Frequency Amplifier-theory and Experimentation". Limited publication by the author, 1969.

Safford, Edward L. Jr., The Complete Handbook of Robotics, Blue Ridge Summit: Tab Books, 1978.

Stauffer, Robert N., "An Exercise in Robot Press Loading", Manufacturing Engineering, Vol. 86, No. 2, February 1981, p. 59.

Superior Electric Company, Design Engineers Guide to D.C. Stepping Motors. Bristol connecticut: 1976.

Tanner, William R., Industrial Robots, 2nd ed., 2 Vols.; Dearborn: Society of Manufacturing Engineers, 1981.

Unimation, Inc., Equipment Manual. Danbury, Conn: Unimate Series 4000, Text A398EIA, 25 April 1977,

Unimation, Inc., Unimate Industrial Robots. Danbury Conn: Unimation, Inc., N. 600K1-976, 1987.

Winter, Drew D., "Robot Pays Off Bis for Finishing Operation". Production. Vol. 87, No. 4, April 1981, p. 84.

IX. PRINT SHEET of

JOURNAL ARTICLES - ROBOTICS

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COMPUTERS IN MANUFACTURING.
HUDSON, C. A.
SCIENCE, V215 N4534 P818-25 FEB
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2/3/2
EJ259019
CONSUMPTION ECONOMICS.
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THE SMART MACHINES OF TOMORROW: IMPLICATIONS FOR SOCIETY.
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JOURNAL OF EPSILON PI TAU, V7 N2 P8-14 FALL
1981
AVAILABLE FROM: ^REPRINT: UMI

2/3/4
EJ257440
WILL ROBOTS SAVE DEMOCRACY?
MOORE, DAN T., JR.
JOURNAL OF EPSILON PI TAU, V7 N2 P2-7 FALL
1981
AVAILABLE FROM: REPRINT: UMI

2/3/5
EJ255961
KEEPING UP WITH A REVOLUTION.
BUCKHOLTZ, MARJORIE WEIDENFELD
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1981
AVAILABLE FROM: REPRINT: UMI

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EJ255951
SOUTH CAROLINA'S HIGH TECHNOLOGY [illegible]
DUDLEY, G. [illegible]

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EJ255951
SOUTH CAROLINA'S HIGH TECHNOLOGY BLITZ.
DUDLEY, G. WILLIAM, JR.
VOCED, V57 N1 P32-34 JAN-FEB
1982
AVAILABLE FROM: REPRINT: UMI

2/3/7
EJ254695
MICROPROCESSORS, ROBOTICS, AND WORK.
DEVORE, PAUL W.
MAN/SOCIETY/TECHNOLOGY, V41 N4 P6-9 JAN
1982
AVAILABLE FROM: REPRINT: UMI

2/3/8
EJ254332
FUN AND LEARNING WITH SCIENCE TOYS.
ANGIER, NATALIE
DISCOVER, V2 N12 P46-51 DEC
1981

2/3/9
EJ244002
TRANSLATION: AIDS, ROBOTS, AND AUTOMATION.
ANDREYEWSKY, ALEXANDER
META, V26 N1 P57-66 MAR
1981

2/3/10
EJ243530
ROBOTS: CARRYING A (WELDING) TORCH FOR AMERICA.
JARREAU, JOSEPH A.
FLORIDA VOCATIONAL JOURNAL, V6 N7 P10-14 APR
1981

2/3/11
EJ235033
PROGRAMMED TO THINK.
EDELSON, EDWARD
MOSAIC, V11 N5 P19-23 SEP-OCT
1980
AVAILABLE FROM: REPRINT: UMI

2/3/12
EJ215037
PLANETARY ENCOUNTERS.
DAVID, LEONARD
AVIATION/SPACE, V6 N5 P20-26 NOV-DEC
1979
AVAILABLE FROM: REPRINT: UMI

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3/3/1
EJ260355
COMPUTERS IN MANUFACTURING.
HUDSON, C. A.
SCIENCE, V215 N4534 P818-25 FEB
1982

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3/3/7
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MICROPROCESSORS, ROBOTICS, AND WORK.
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MAN/SOCIETY/TECHNOLOGY, V41 N4 P6-9 JAN
1982
AVAILABLE FROM: REPRINT: UMI

3/3/8
EJ24~4002
TRANSLATION: AIDS, ROBOTS, AND AUTOMATION.
ANDREYEWSKY, ALEXANDER.
META, V26 N1 P57-66 MAR
1981

3/3/9
EJ235033
PROGRAMMED TO THINK.
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MOSAIC, V11 N5 P19-23 SEP-OCT
1980
AVAILABLE FROM: REPRINT: UMI

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VOCATIONAL EDUCATION AND PRODUCTIVITY.
WATSON, ROBERT, JR.
13P.; PA^PER PRESENTED AT THE ANNUAL CONVENTION OF THE NATI[
ASSOCIATION OF STATE DIRECTORS OF VOCATIONAL EDUCATION (63RD, ATLANTA, (
DECEMBER 4, 1981). 4 DEC 1981
EDRS PRICE - MF01/PC01 PLUS POSTAGE.

3/3/11
ED210150
AUTOMATION AND ENGINEERING PSYCHOLOGY: A LOOK TO THE FUTURE.
PARSONS, H. MCILVAINE
HUMAN RESOURCES RESEARCH ORGANIZATION, ALEXANDRIA, VA.
20P.; PAPER PRESENTED AT THE ANNUAL MEETING OF THE AMERICAN PSYCHOLOGIC
ASSOCIATION (89TH, LOS ANGELES, CA, AUGUST, 1981). 1981
EDRS PRICE - MF01/PC01 PLUS POSTAGE.

3/3/12
ED206915
TECHNOLOGY EDUCATION SYMPOSIUM II. PROGRAM THEME: "TECHNOLOGICA
LITERACY" (MENOMONIE, WISCONSIN, MAY 1-2, 1981).
SMALLEY, LEE, ED.
WISCONSIN UNIV. - STOUT, MENOMONIE.
70P. MAY 1981
AVAILABLE FROM: LEE SMALLEY, UNIVERSITY OF WISCONSIN--STOUT, MENOMONIE
WI 54751 (SEND 9" X 12" STAMPED, SELF-ADDRESSED ENVELOPE).
EDRS PRICE - MF01/PC03 PLUS POSTAGE.

3/3/13
ED206911
HUMAN FACTORS AND ROBOTICS: CURRENT STATUS AND FUTURE PROSPECTS.
PARSONS, H. MCILVAINE; KEARSLEY, GREG P.
HUMAN RESOURCES RESEARCH ORGANIZATION, ALEXANDRIA, VA.
27P. OCT 1981
EDRS PRICE - MF01/PC02 PLUS POSTAGE.

3/3/14
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3/3/14
ED193689
ON THE NECESSITY OF BEING HUMAN.
MYERS, RENEY
7P.; PAPER PRESENTED AT THE ANNUAL MEETING OF THE NORTHEAST REGIONA
CONFERENCE ON ENGLISH IN THE T~WO-YEAR COLLEGE (15TH, NEW YORK, NY, OCTOB
16-18, 1980). OCT 1980
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AMERICAN EDUCATION, V17 N9 P10-14 NOV
1981
AVAILABLE FROM: REPRINT: UMI

9/3/2
EJ255951
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DUDLEY, G. WILLIAM, JR.
VOCED, V57 N1 P32-34 JAN-FEB
1982
AVAILABLE FROM: REPRINT: UMI

9/3/3
EJ254695
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EJ244002
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1981

15/3/4
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FROM TINKER TOYS TO ROBOTS
DUFFY, JOSEPH W.
INDUSTRIAL ARTS AND VOCATIONAL EDUCATION, 60, 2, 28-30
FEB 1971

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ED211693
VOCATIONAL EDUCATION AND PRODUCTIVITY.
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COMPUTERS IN MANUFACTURING.
HUDSON, C. A.
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AVAILABLE FROM: REPRINT: UMI

17/3/2
EJ259019
CONSUMPTION ECONOMICS.
PARRISH, JOHN B.
ILLINOIS VOCATIONAL EDUCATION JOURNAL, V37 N3 P18-19 SPR
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17/3/3
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TECHNOLOGY EDUCATION SYMPOSIUM II. PROGRAM THEME: "TECHNOLOGIC
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18/6/3
ED206911
HUMAN FACTORS AND ROBOTICS: CURRENT STATUS AND FUTURE PROSPECTS.

18/6/4
ED194003
PHDS IN NONACADEMIC CAREERS: ARE THERE GOOD JOBS? ROBOTS OR REINSMEN:
OPPORTUNITIES AND PROFESSIONAL STANDING FOR COLLEGIATE ADMINISTRATORS
~~THE 1980S. CURRENT ISSUES IN HIGHER EDUCATION, NO. 7, 1979.

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IX. REPORT OF GRANT FUNDED BY THE FACULTY RESEARCH COMMITTEE

Name of grant recipient: Meade Stanley Roberts

Department: Industrial Education and Technology, School of Applied Sciences and Technology

Title of research: Design, Construction, and Operation of an Industrial Type Robot

Date of final report: September 1982. Date grant was funded: October 1981

Amount for which grant was funded: $2,888.00

Objectives of the research:

Determine if a facsimile of an industrial robot can be designed and constructed in an instructional setting using available "off the shelf" technological devices.

Research summary:

A robot like device was constructed using three stepping motors to manipulate a mechanical "arm" and "hand". This Research Robot is complete with a microswitch teach box, it operates in both the teach and execute mode and is controlled by a Heath/Zenith microcomputer. Industrial Technology students, in a special class IET 399 Industrial Robotics, aided in the design and construction. The robot, useful for teaching purposes, cannot be considered an industrial robot, it has slow speed, lacks yaw and roll capacity, and has low weight capacity. Its maximum motor speed is 247 steps per second. This compared with several hundred to several thousand steps per second typical of industrial robots.

The building of an industrial robot required highly advanced knowledge and skills in programming, mechanical design, digital electronics, and computer architecture. Its design and construction requires a team approach.

Improved robots are now being constructed using concepts developed in this research specificly a Welding Robot and an Assembler Robot. Industry has expressed an interest in commercially producing the Assembler Robot.

Final use of project results:

The Research Robot will be used as a teaching aid and it will be operated and displayed at schools and conventions.

The Research Robot was demonstrated at the Industrial Robotics Conference held at Morehead State University June 14, 15, and 16, 1982.

Research results will be submitted to "Robotics Age" and "School Shop" for publication consideration.

REPORT OF GRANT FUNDED
BY THE FACULTY RESEARCH COMMITTEE

Name of grant recipient: Meade Stanley Roberts

Department: Ind. Educ. and Technology School: Applied Sciences & Technology

Title of research: Design, Construction, and Operation of an Industrial Type Robot

Date of final report: September, 1982 (Mo./Yr.) Date grant was funded: October, 1981 (Mo./Yr.)

Amount for which grant was funded: $2,888.00

Use the space below for a single-spaced abstract of approximately 100 words. This should be a narrative summary of the final report of your grant.

Objectives of the Research: Determine if a facsimile of an industrial robot can be designed and constructed in an instructional setting using available "off the shelf" technological devices.

Research Summary: A robot like device was constructed using three stepping motors to manipulate a mechanical "arm" and "hand". This Research Robot is complete with a microswitch teach box, it operates in both the teach and execute mode and is controlled by a Heath/Zenith microcomputer. Industrial Technology students, in a special class IET 399 Industrial Robotics, aided in the design and construction. The robot, useful for teaching purposes, cannot be considered an industrial robot, it has slow speed, lacks yaw and roll capacity, and has low weight capacity. Its maximum motor speed is 247 steps per second. This compared with several hundred to several thousand steps per second typical of industrial robots. The building of an industrial robot required highly advanced knowledge and skills in programming, mechanical design, digital electronics, and computer architecture. Its design and

...see back...

Final use of project results, e.g., Where was it published? At what professional meeting was it presented? How was it disseminated to the academic or regional community?

The Research Robot will be used as a teaching aid and it will be operated and displayed at schools and conventions.

The Research Robot was demonstrated at the Industrial Robotics Conference held at Morehead State University, June 14, 15, and 16, 1982. Research results will be submitted to "Robotics Age" and "School Shop" for publication consideration.

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Improved robots are now being constructed using concepts developed in this research specifically a Welding Robot and an Assembler Robot. Industry has expressed an interest in commercially producing the Assembler Robot.

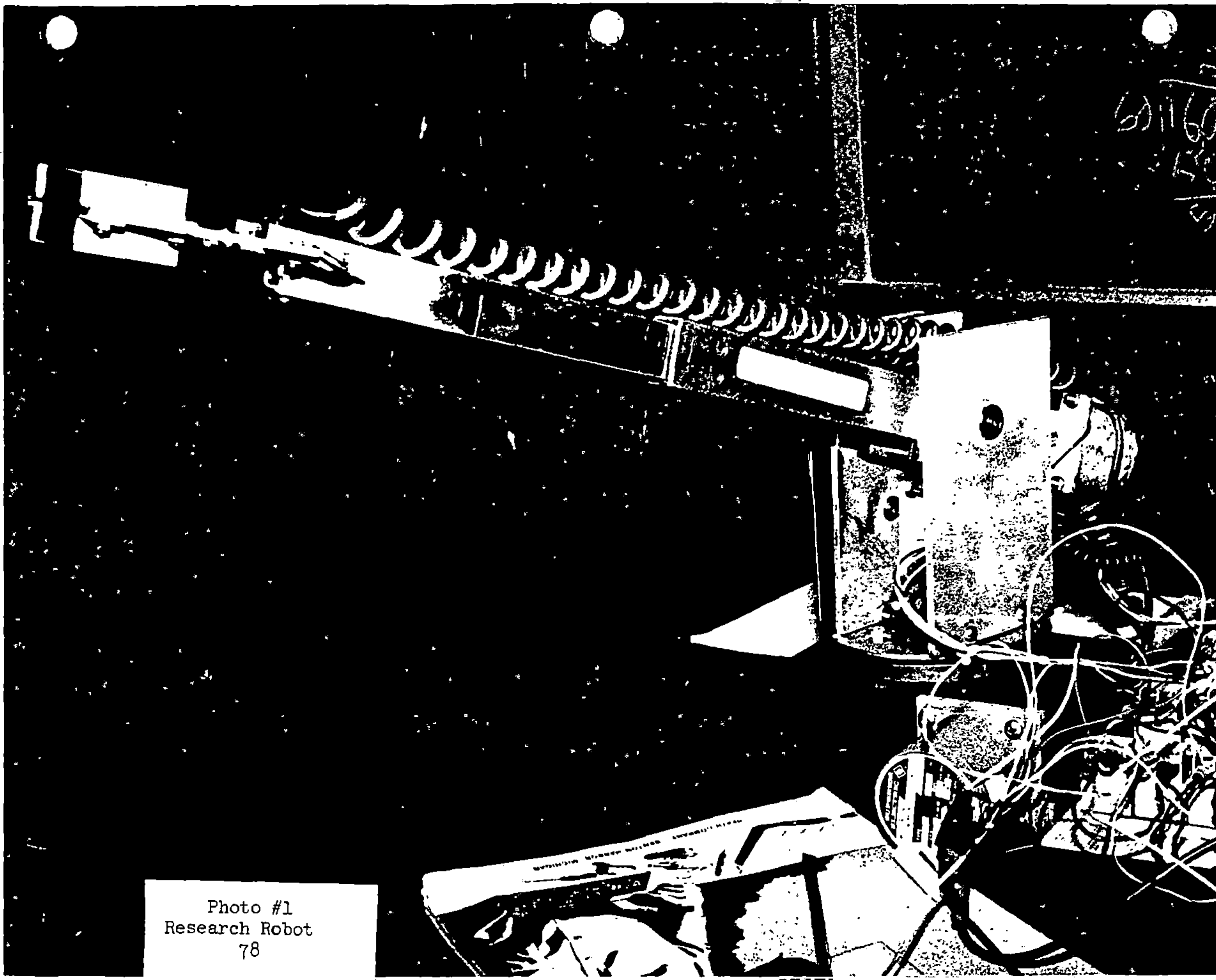

Photo #1
Research Robot
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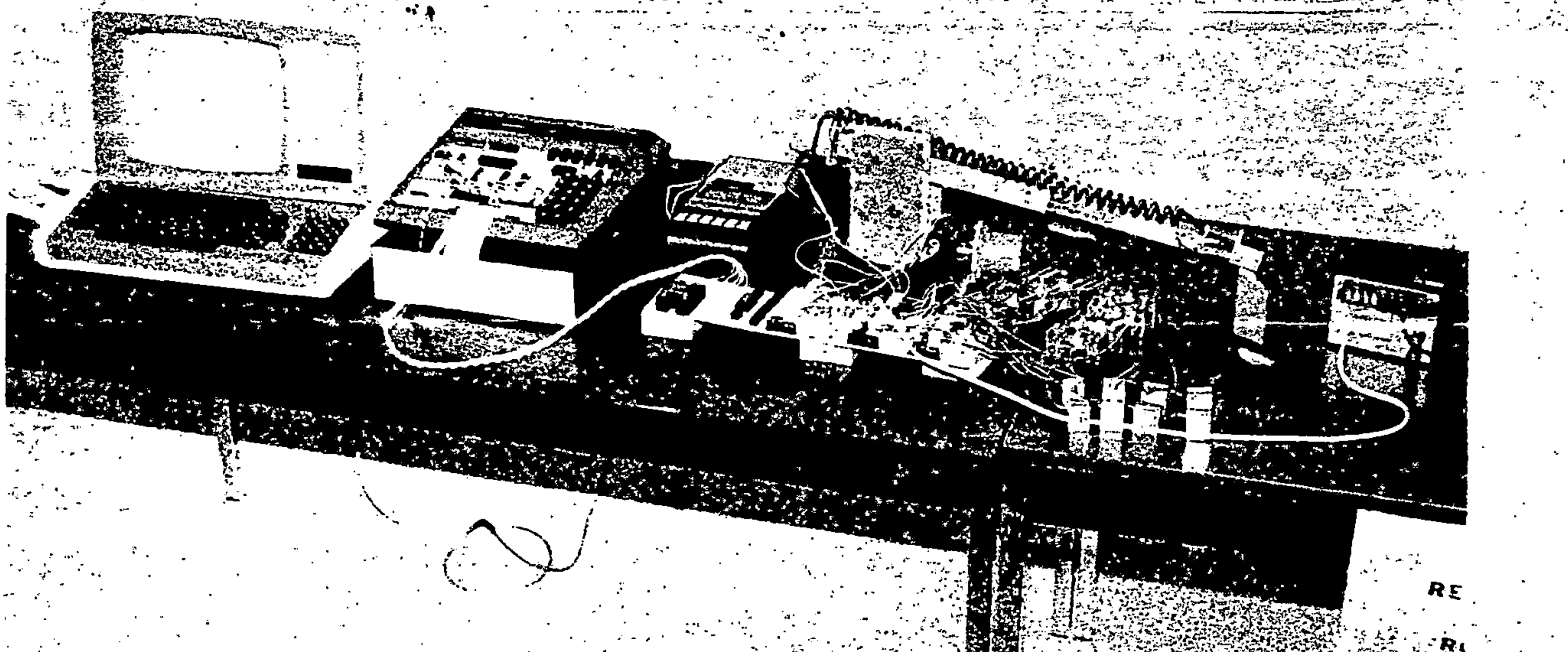

Photo #2
Research Robot and
Peripheral Equipment

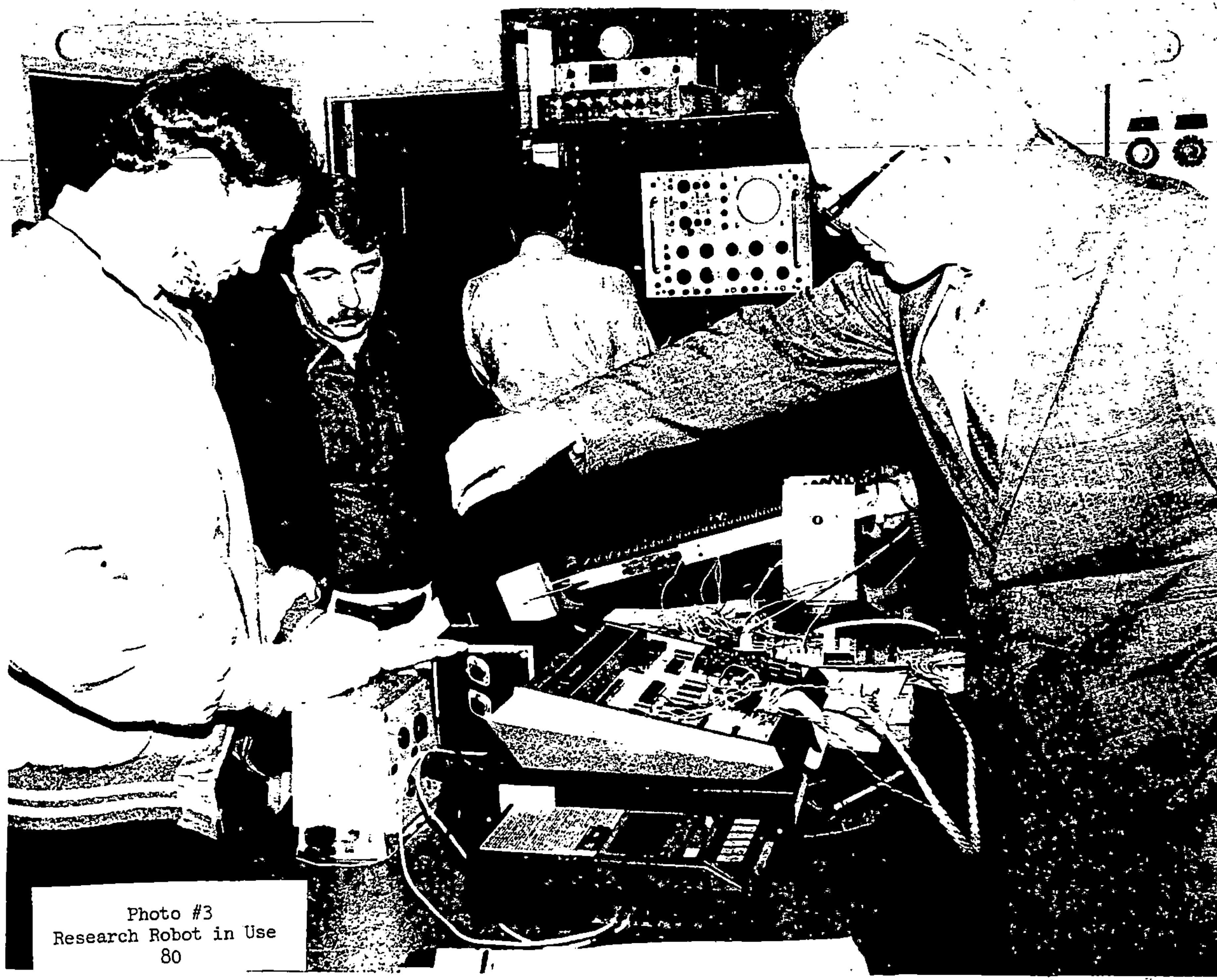

Photo #3
Research Robot in Use

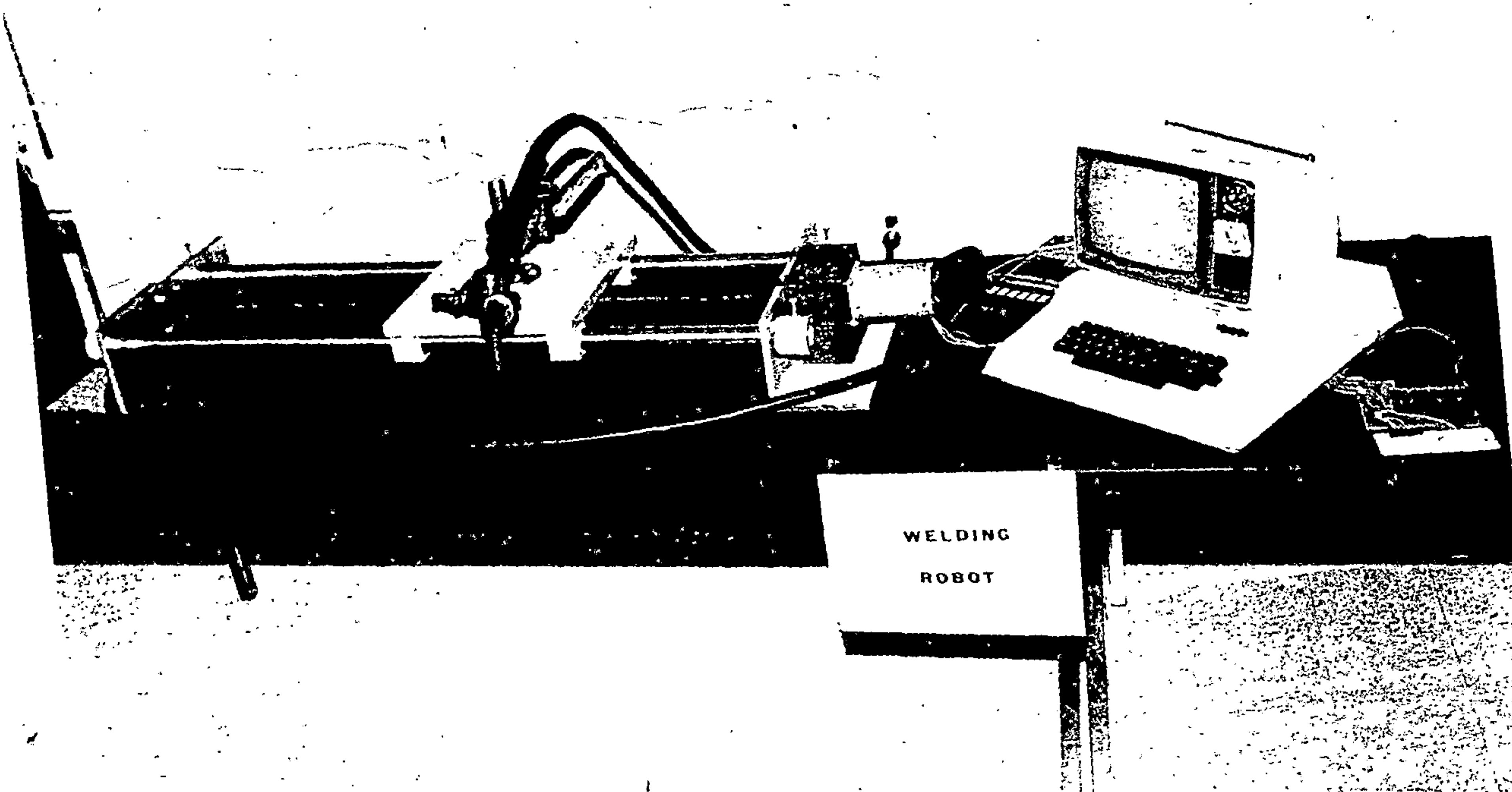

Photo #4
Welding Robot

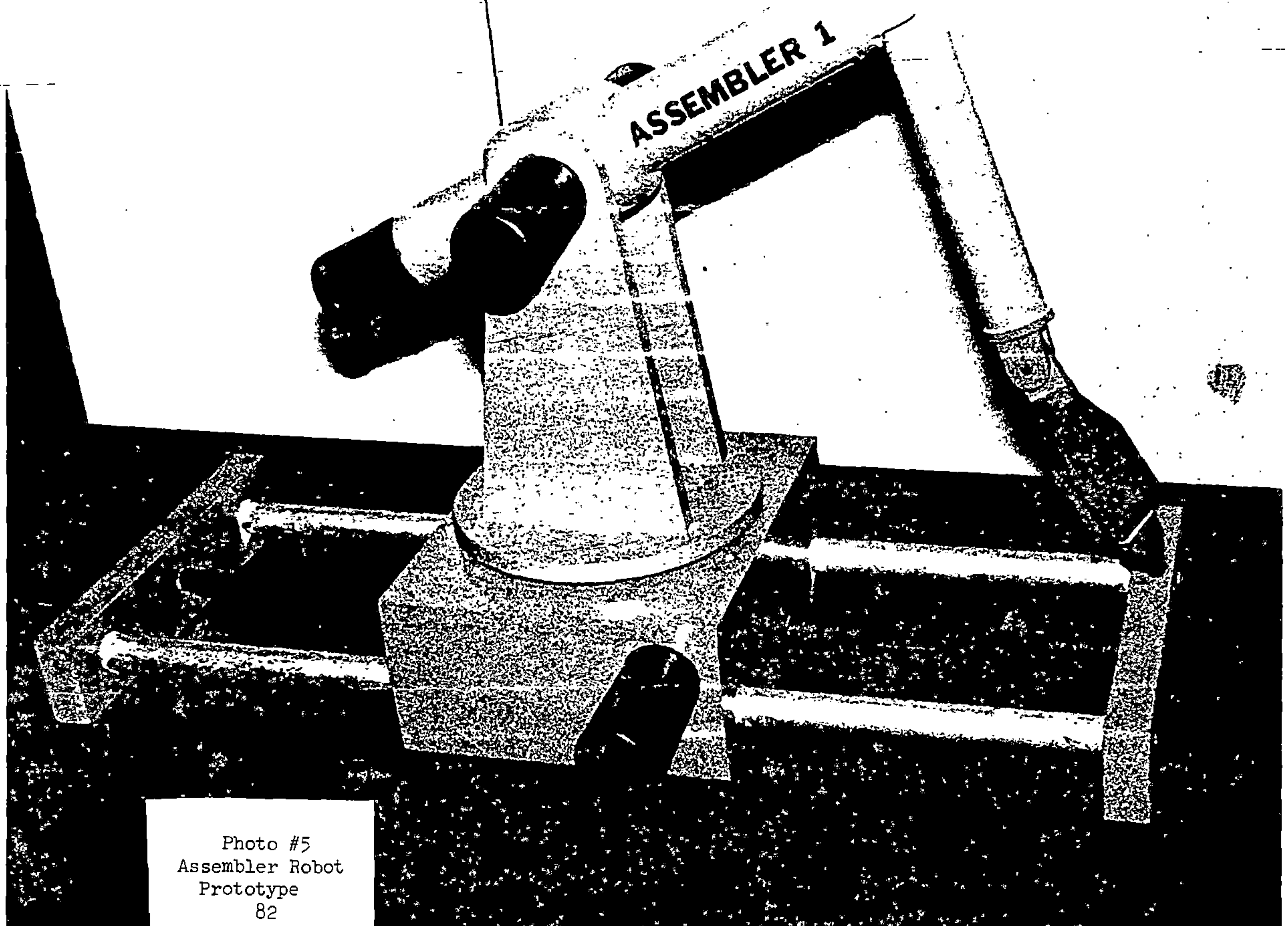

Photo #5
Assembler Robot
Prototype