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DEVELOPMENT OF HARDWARES AND COMPUTER INTERFACE FOR A TWO-DEGREE-OF-FREEDOM ROBOT

by

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NASA

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SUMMARY

This report presents the research work performed at The Catholic University of America on the research grant entitled "Active Control of Robot Manipulator Compliance," (Grant No. NAG 5-780), supported by NASA/Goddard Space Flight Center. The research was performed from November 16th, 1986 to May 15th, 1987.

In this report we first review the research results that have been obtained through the project. Then the robot actuator, the selection of the data acquisition system and the design of the power amplifier will be discussed. The machine design of the robot manipulator will then be presented. After that, we will discuss the integration of the developed hardwares into the open-loop system. The report is concluded by addressing the current and future research work.

CONTENTS

1.INTRODUCTION AND PREVIOUS RESULTS

Robotics has promising applications in the space station program as pointed out in [1]. Assembly of large space structures can be performed by autonomous robots. Product assembly in space such as mating and fastening of parts requires a very high precision. Because of the enormous difference in tolerance between position and robot manipulators, compliance should be provided to the manipulator so that it can comply with the task-imposed constraint [7]. This can be done by employing the hybrid control scheme that controls position along specified degrees of freedom and independently controls force along the remaining degrees of freedom [4]. We started our analysis of the hybrid control scheme with the two-degree-of-freedom robot. In [7] the dynamics of a robot with two degrees of freedom was modeled. Then by using the system simulation language (SYSL), the complete system including the actuators, the robot dynamics, force and positon feedback was simulated on an IBM PC [Fig.1]. As pointed out in [8], proper adjustments of the controller gains enabled the robot to perform successful operations. Even though good results have been obtained, no clear relationship between the controller gains and the system responses have been identified.

In order to test the performance of the hybrid control scheme on a physical system, it was proposed to actually build the two-degree-of-freedom robot and interface it with an IBM personal computer through a data acquisition system. In the following, we will present the development of the hardwares for the robot implementation and design of the necessary electrical devices and computer interfaces.

2. THE ROBOT ACTUATOR

Two ball screw actuators, manufactured by Motion Systems Corporation were used to implement the robot arms [Fig. 2]. This is an in-line actuator that has a stroke of 16 inches and is driven by a permanent magnet DC motor (24 VDC, 3000 RPM, 3" diameter, 2.5 Amps no-load current) [Fig. 3]. The ball screw actuator 85262 if equipped with heavy duty brake, support bushing, cover tube, rod end and trunnion pins is numbered by 85261.

3. THE DATA ACQUISITION SYSTEM

The interfacing between the outside world consisting of the robot manipulator, drivers, sensors and the IBM computer is done through a data acquisition system. The data acquisition system consists of an IBM data acquisition and control adapter , a distribution panel and a selected software package running the system. We selected the Labtech Notebook software package because open and closed-loop control algorithms are readily implemented and PID (Proportional-Integral-Derivative) controllers can be set up for closed-loop control. The data acquisition and control adapter has 4 analog input channels (12-bit resolution) and 2 analog output channels (12-bit resolution). The voltage of the input and output channels can be selected to be either unipolar (0 to 10 volts) or bipolar (± 5 volts or ± 10 volts). The input current assumes ± 4 milliamps at maximum input voltage. The maximum output load current is ±5 milliamps.

4. THE POWER AMPLIFIER

Since the maximum power that the data acquisition board can deliver is not sufficient (±10 V, ±5 milliamps) to drive the DC motor whose no-load consumption is characterized by +24 volts and 2.5 amps, a power amplifier was designed to amplify the output signal of the data acquisition board. The design employed high-power operational amplifiers OPA501 manufactured by Burr-Brown corporation and compatible heat sinks 0805HS (3° c/watt). The maximum current (7 Amps) delivered by the power amplifiers can be set by selecting a proper resistor R_{sc} .

In order to make the gain of the power amplifier adjustable, the feedback resistor R_2 was set to be of $10K\Omega$ (fixed) and the value of the input resistance could be varied between 0 and $10k\Omega$ potentiometer [Fig. 5].The power amplifier was housed in an Archer instrument case whose front panel provided all necessary connections to power supplies, input from data acquisition board and output to DC motors.

5. THE ROBOT MANIPULATOR

Fig. 2 illustrates the two-degree-of-freedom robot manipulator that mainly consists of 2 ball screw in-line actuators, a fixed upper platform, motor cover tubes and connecting joints and bearings. The upper platform was made out of a 36x9x1 (inch) solid board that was secured to the concrete wall by 3 steel brackets. To hang the actuators under the upper platform, we made two aluminium tubes and slided them over the two motors. The actuators were then secured to the cover tubes by 2 bolts. Intermediate caps and bearings were used to attach the cover tubes to the upper platform. Each upper joint that allows rotation about the z-axis, consists of a linear pillow block, a shaft hanger and a steel shaft that were all manufactured by Winfred M. Berg Inc and were modified to fit the design of the robot. The essential part of the design was the development of a joint to couple the two end points of the two actuators. Several types of joint were designed, tested and modified to optimize the gripper motion in terms of conversion of rotation to linear motion, vibration and workspace. The finalized joint consists of a shaft hanger, bearing mounting plate and a low friction ball bearing. Some mechanical parts were manufactured by Winfred M. Berg Inc and some were made by In-house machine shop.

The overall dimensions of the robot is described below:

-Width (distance between the attachment points of the arms to the upper platform):	29"
-Length of each arm (fully extended):	51"
-Height (distance between the upper platform and the gripper):	51"

6. THE OPEN-LOOP SYSTEM

Fig. 6 illustrates the overall configuration of the hardwares and computer interface that have been developed up to now. This is mainly an open-loop system in which no sensors for position and force have been integrated. The completion of a closed-loop feedback system will be discussed in the next section.

7. CURRENT AND FUTURE WORK

Currently and in the future we will make all efforts to accomplish the following:

-Troubleshooting the open-loop system and making proper adjustments in the data acquisition board and in the power amplifiers.

-Modifying the robot manipulator hardwares if needed.

-Selecting a proper position sensor (LVDT) and a force sensor and integrating them into the open-loop system.

-Using the Labtech Notebook software package to implement the hybrid control scheme.

-Running the complete closed-loop system and making evaluations.

8. CONCLUSION

This report updated the development of the hardwares and computer interface for a two-degree-of-freedom robot. The robot manipulator was implemented by 2 ball screw actuators and necessary machine designs. A data acquisition system consisting of a data acquisition and control adapter and the Labtech Notebook software package was selected to interface the robot manipulator to the IBM computer. We then discussed the design of a power amplifier that drives the DC motor of the robot actuator. The integration of the developed hardwares into an open-loop system was then presented. The report was finally concluded by discussing all current and future work of the research project.

REFERENCES

1. NASA, "Advancing Automation and Robotics Technology for the Space Station and for the U.S. Economy," vol.II, NASA TM 87566, Advanced Technology Advisory Committtee, March 1985.

2. Paul, Richards P. and Shimano, Bruce, " Compliance and Control," Robot Motion, Planning and Control, Brady, M. et al., eds, MIT Press, Cambridge, Mass., 1983.

3. Whitney, Daniel E., "Force Feedback Control of Manipulator Fine Motions," ASME, Journal of Dynamic Systems, Measurement and Control, June 1977.

4. Raibert, M. H. and Craig, J. J., " Hybrid Position/ Force Control of Manipulators, " ASME, Journal of Dynamic Systems, Measurement and Control, 102, pp. 126-133, June 1981.

5. Premack, Timothy et al., "Design and Implementation of a Compliant Robot with Force Feedback and Strategy Planning Software," NASA TM 86111, GSFC, May 1984.

6. Nguyen, Charles C. and Premack, Timothy, " Active Compliant Control of Robot Manipulators, "NASA Report, NASA/GSFC, July 1985.

7. Nguyen, Charles C. and Pooran, Farhad J., "Active Control of Robot Manipulator Compliance, " Semi-Annual Progress Report, NASA/GSFC, November 1986.

8. Nguyen, Charles C. , Pooran, Farhad J.,and Premack, T. ,"Control of Robot Manipulator Compliance, " in Recent Trends in Robotics: Modeling, Control and Education, Chapter 2, edited by M. Jamshidi, Newyork, pp. 237-242 , 1986.

9. Dieudonne, J. E. et al, " An Actuator Extension Transformation for a Motion Simulator and an Inverse Transformation Applying Newton- Raphson's Method, "NASA Technical Notes, NASA TN D-7067, November 1972.

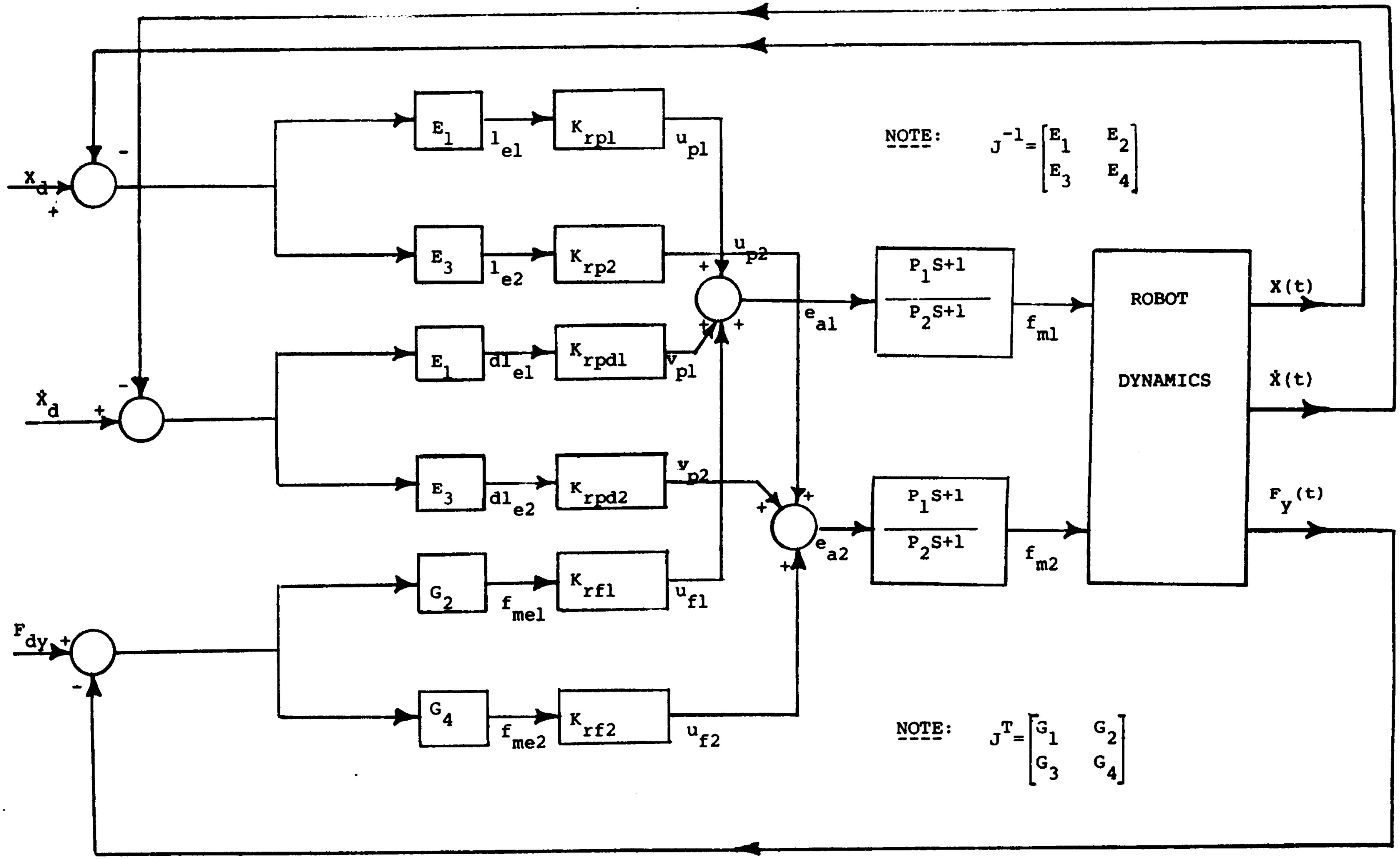


Fig. 1: Implementation of the Hybrid Control Scheme for the 2-Degree-of-Freedom Robot.

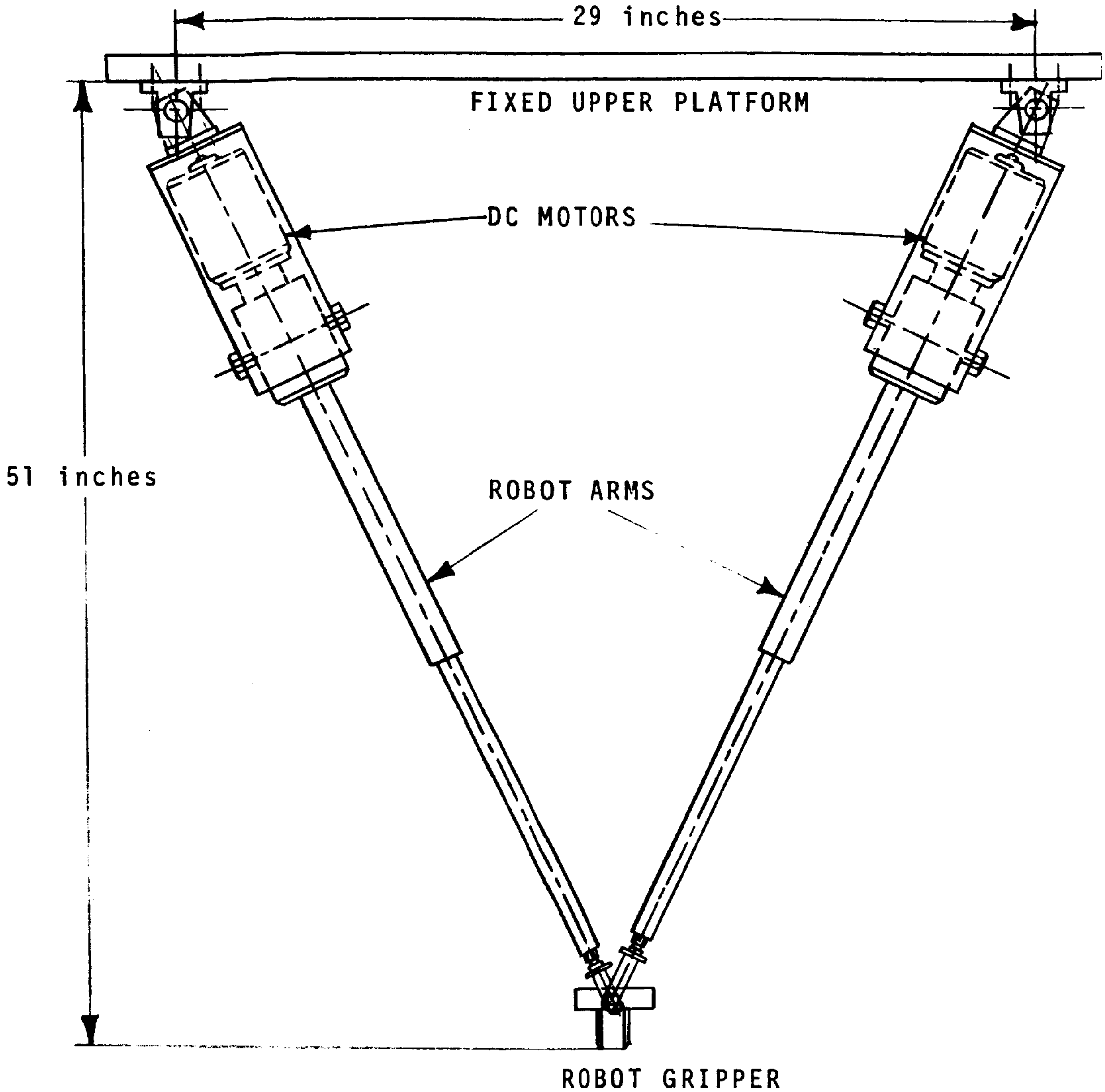
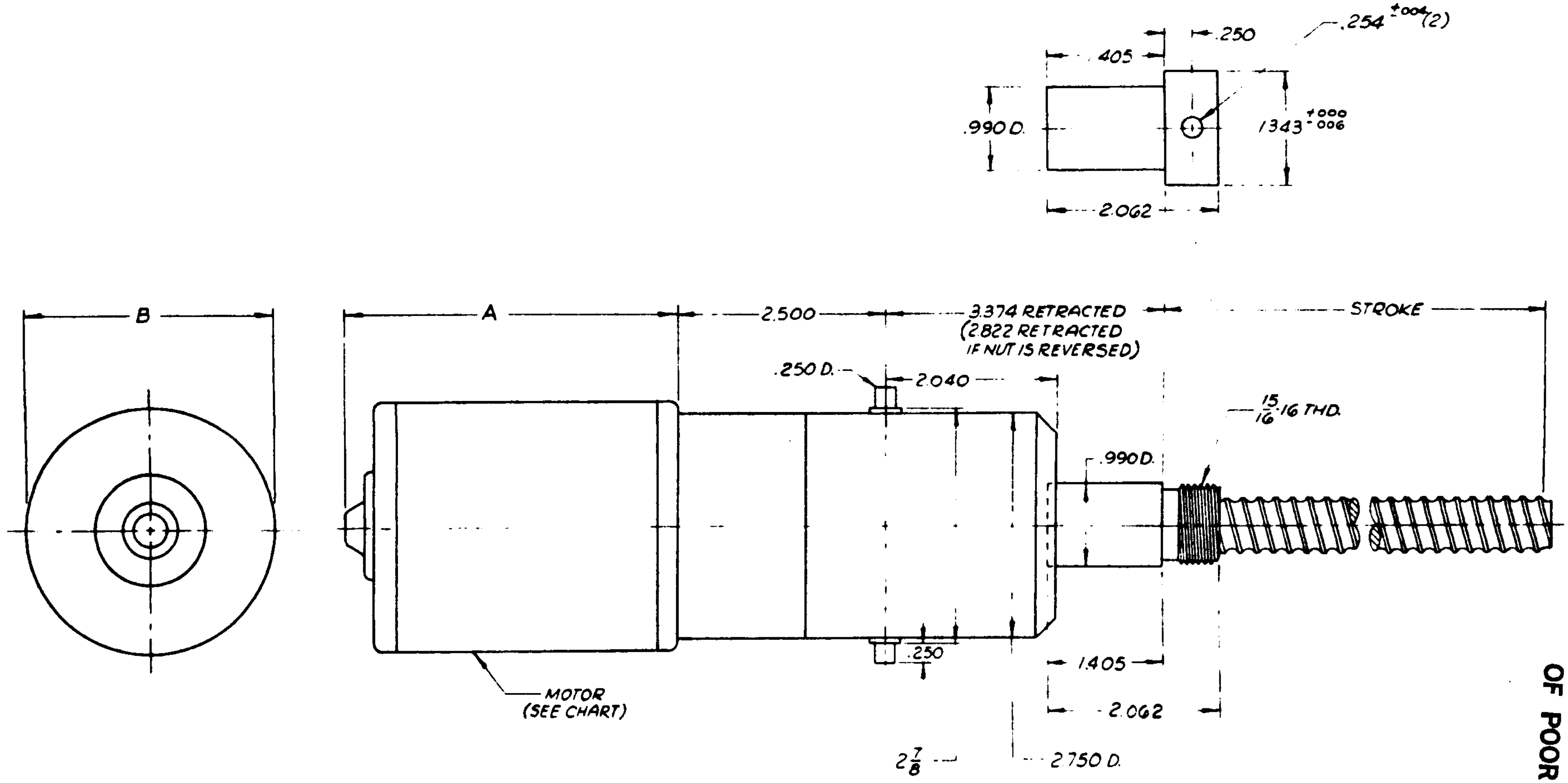


Fig. 2: The Robot Manipulator

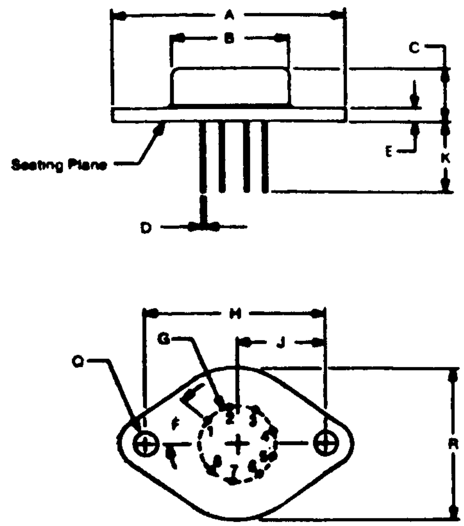


MOTOR	A	B
115VAC INDUCTION 1700 RPM	4.625	3.310
115VAC INDUCTION 3400 RPM	4.625	3.310
12VDC UNIVERSAL 6000 RPM	3.875	3.000
12VDC PM 6000 RPM	4.437	2.750
12VDC PM 3000 RPM	4.750	3.000

NOTE -
1. MAT'L - HEAT TREATED STEEL WITH BEARING RACES ROCKWELL 56C MIN.
2. STROKE PER CUSTOMER REQUIREMENT.
3. LIMIT SWITCHES NOT REQUIRED.

Fig. 3: The Robot Actuator

TOLERANCES	MOTION SYSTEMS CORPORATION		
DECIMAL ± .005		SCALE FULL	DRAWN BY FGW
FRACTIONAL ± 1/64	TITLE BALL SCREW ACTUATOR		
ANGULAR ± 1/2°	DATE 1-29-79	DRAWING NUMBER 85262	



NOTE
Leads in true position within .010"
.25mm R @ MMC at seating plane

Pin numbers shown for reference only
Numbers may not be marked on package

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	1.510	1.550	38.35	39.37
B	.745	.770	18.92	19.56
C	.300	.400	7.62	10.16
D	.038	.042	0.97	1.07
E	.080	.105	2.03	2.67
F	40° BASIC		40° BASIC	
G	.500 BASIC		12.7 BASIC	
H	1.186 BASIC		30.12 BASIC	
J	.593 BASIC		15.06 BASIC	
K	.400	.500	10.16	12.70
Q	.151	.161	3.84	4.09
R	.980	1.020	24.89	25.91

a)

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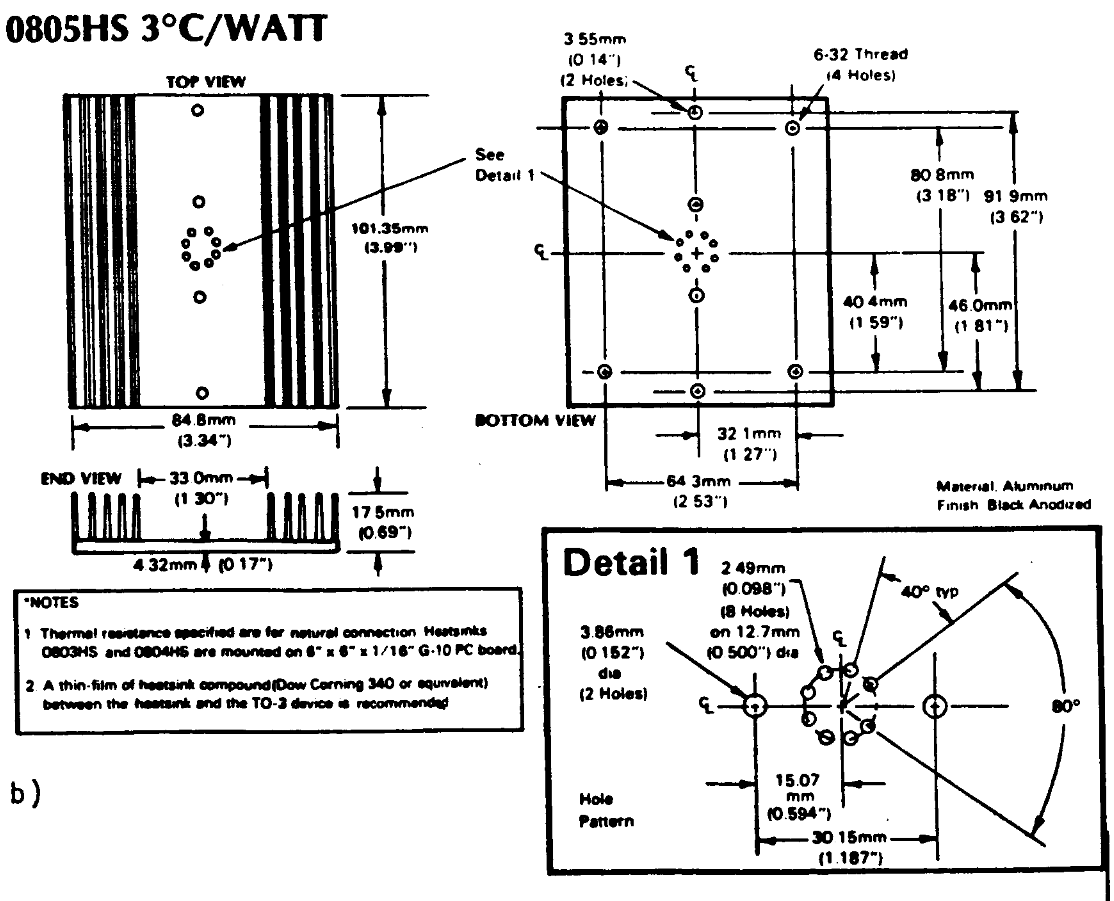


b)

Fig. 4: Elements of the Power Amplifier: a) Operational Amplifier, b) Heat Sink.

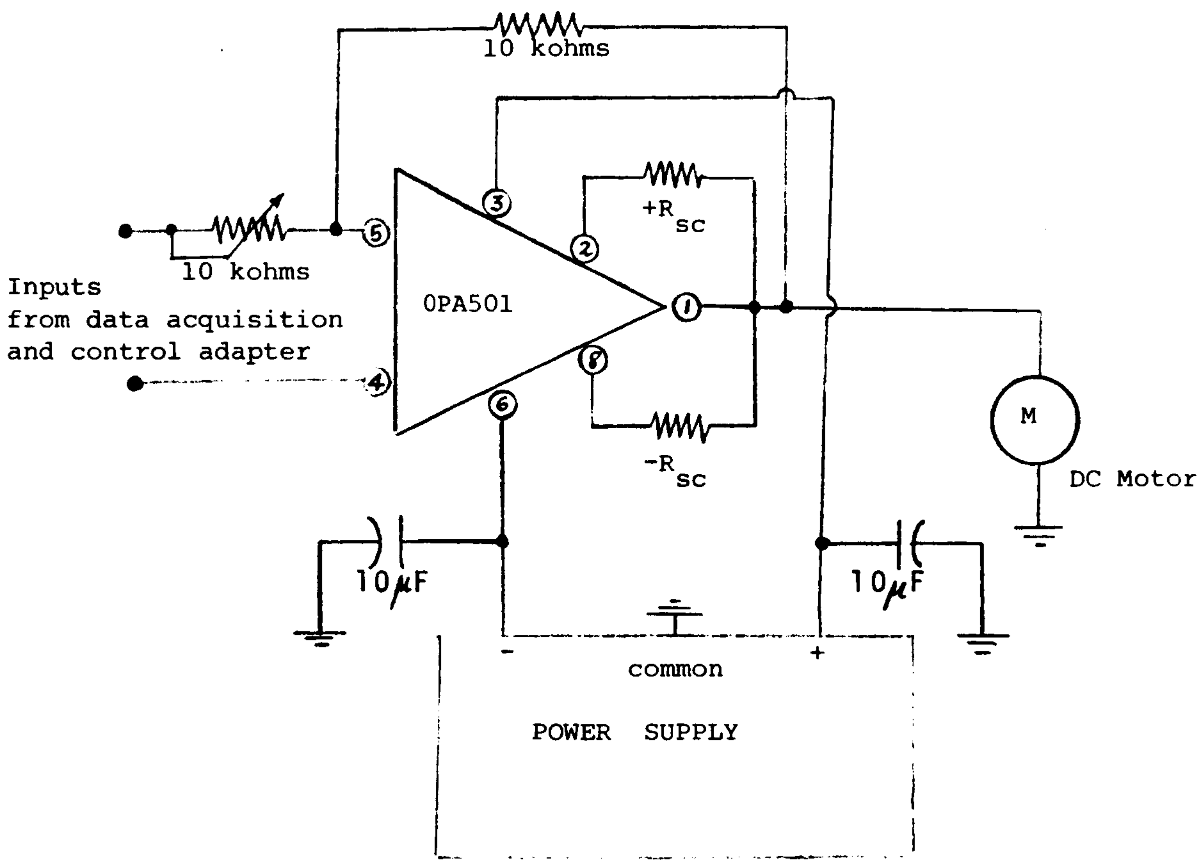


Fig. 5: The Power Amplifier

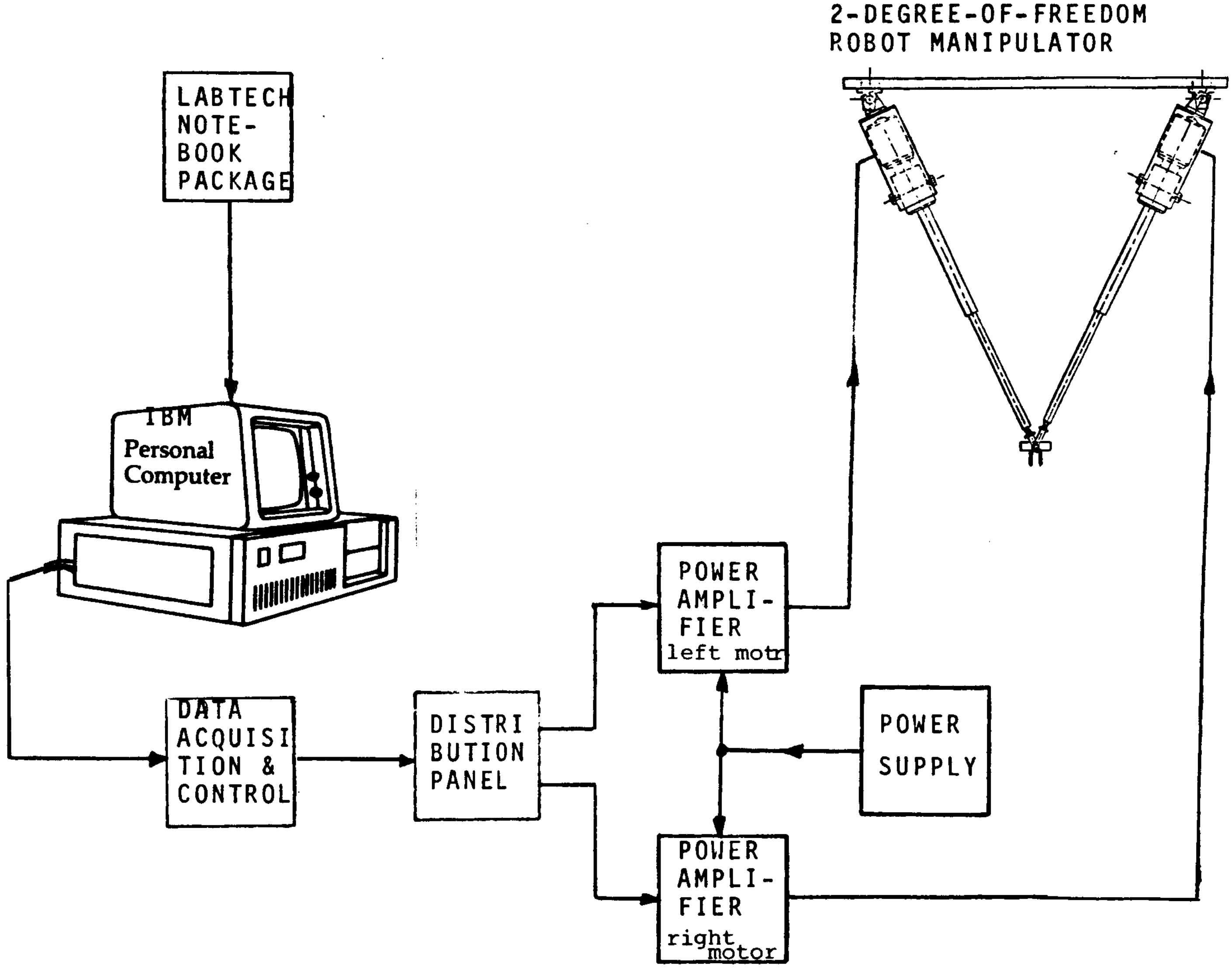
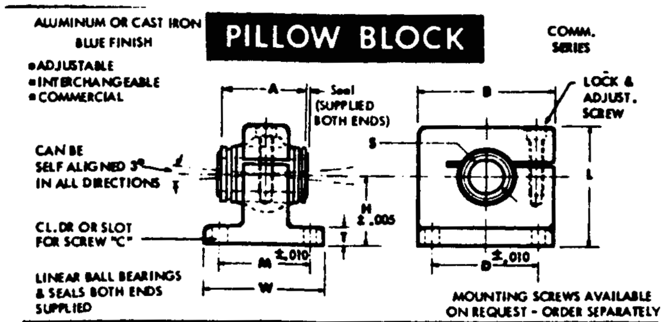
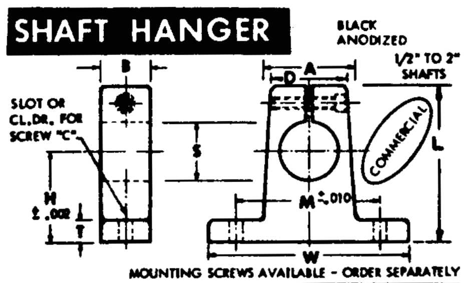


Fig. 6: The Organization of the Open-Loop System



PART NO.	RETAIL PRICE	"S" SHAFT DIA.	"H"	"T"	"W"	"B"	"A"	"M"	"D"	"L"	"C" SCREW
LMP-A 8	$ 20.16	1/2"	.875	1/4"	1-1/2"	2"	1-1/4"	1"	1-1/2"	1-5/8"	# 8
LMP-A12	23.52	3/4"	1.125	5/16"	2"	2-3/4"	1-5/8"	1-3/8"	2"	2-1/8"	#10
LMP-A16	33.79	1"	1.375	3/8"	2-1/4"	3-1/4"	2-1/4"	1-1/2"	2-1/2"	2-9/16"	1/4"
LMP-A20	50.52	1-1/4"	1.750	7/16"	2-3/4"	4"	2-5/8"	1-7/8"	3"	3-1/4"	5/16"
LMP-A24	63.72	1-1/2"	2.000	1/2"	3"	4-3/4"	3"	2"	3-1/2"	3-3/4"	5/16"
LMP-A32	97.08	2"	2.500	5/8"	3-1/2"	6"	4"	2-1/2"	4-1/2"	4-3/4"	3/8"



STOCK NUMBER	RETAIL PRICE	"S" SHAFT DIA.	"H"	"T"	"W"	"B"	"A"	"C" SCREW	"L"	"M"	"D"
LMH-13	$ 5.86	1/2"	1.000"	1/4"	2"	5/8"	1"	#8	1-11/16"	1-1/2"	3/4"
LMH-15	6.26	3/4"	1.250"	5/16"	2-3/4"	3/4"	1-1/4"	#10	2-1/8"	2"	1-5/16"
LMH-16	7.82	1"	1.500"	3/8"	3-1/4"	1"	1-3/4"	1/4	2-9/16"	2-1/2"	1-3/8"
LMH-17	11.50	1-1/4"	1.750"	7/16"	4"	1-1/8"	2-1/8"	5/16	3"	3"	1-5/8"
LMH-18	13.12	1-1/2"	2.000"	1/2"	4-3/4"	1-1/4"	2-1/2"	5/16	3-1/2"	3-1/2"	2"
•LMH-20	17.39	2"	2.500"	5/8"	6"	1-1/2"	3-3/8"	3/8	4-1/2"	4-1/2"	2-5/8"

Fig. 7: Bearings and Joints for the Robot