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A Servo-Control-Gripper Design

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[Abstract]
A servo-control gripper is designed to replace a pneumatic-control gripper for a PUMA robot. The two-finger gripper is driven by a DC servo motor and a gear-and-rack mechanism. An E2K-X4M capacitance proximity sensor is mounted to one side of the finger. When an object is sensed by the proximity sensor, a signal is sent to the controller, which will send a signal to the DC servo motor to slow down the closing speed of the finger. In addition, a spring pad and an LVDT- displacement sensor are mounted on the other side of the gripper to control the gripping force. When a specified amount of movement is sensed from the LVDT through an A/D converter, the controller sends a signal through a power amplification system to stop the movement of the gripper. Therefore, the gripper is able to grasp a fragile and brittle object, such as an egg, without cracking it. The design can increase the programming capability of the gripper and is very economical when compared to the purchase of the servo-control board directly from the robot company.

[Introduction]
In a robot, an end effector is a device that attaches to the wrist of the robot arm and enables the general-purpose robot to perform a specific task. It is sometimes referred to as the robot's "hand"[1]. Usually, end effectors must be custom engineered for particular task which is to be performed. This can be accomplished either by designing and fabricating the device from the scratch, or by purchasing a commercially available device and adapting it to the application. Grippers are end effectors used to grasp and hold objects. The objects are generally workparts that are to be moved by the robot. The part-handling applications include machine loading and unloading, picking parts from a conveyor, and arranging parts onto a pallet. Although most of the grippers are mechanical grasping devices, but are alternative ways of holding objects involving the use of magnets, suction caps, or other means[2]. A mechanical gripper is an end effector that uses mechanical fingers actuated by a mechanism to grasp an object. The fingers, sometimes called jaws, are appendages of the gripper that actually make contact with the object. A gripper mechanism is to translate the power input into the grasping action of the fingers against the part. The power input is supplied from the robot and can be pneumatic, electric, mechanical, or hydraulic[3].

The robotic lab at Old Dominion University has a PUMA 762 robot with a pneumatic gripper. Since the robot control system doesn't have the servo-control board for the end effector, the gripper can not grasp a fragile and brittle object. As the cost of adding a servo-control board to the robot system, according to the robot company, is approximately $8,000, a design made by a data-acquisition board is initiated to reduce the cost. In addition to the design of the servo-control system, the project also includes mechanical design, manufacturing, and assembly of a two-finger gripper. Two sensors mounted on each finger are to control the gripping force and speed.

[Gripper Design and Manufacturing]

In this project, a gear-and-rack mechanism is used to generate a parallel force when grasping an object. As given in Figure 1, one finger is fixed on one side and the other finger is mounted on a moving rack, which is driven by a DC motor and a gear chain. The opening distance of the

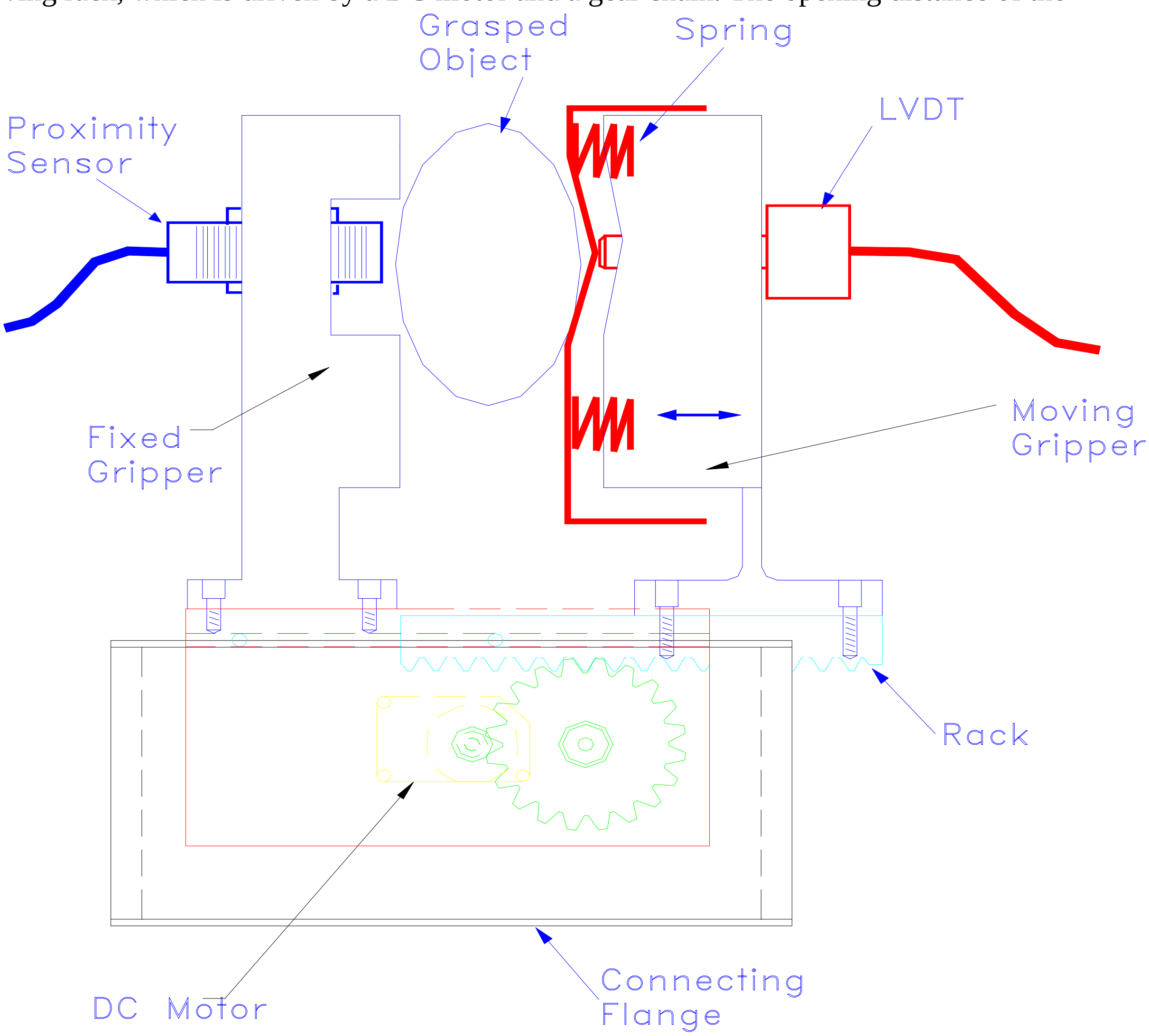


Figure 1. A Gear-And-Rack Gripper With a Sensor On Each Finger.

two fingers can be controlled by either adding a mechanical stop on the rack or using software control. A proximity sensor mounted on the fixed gripper is to reduce the moving speed of the gripper when an object is sensed. The springs combined with the Linear Voltage Differential Transformer (LVDT)[2] located on the moving gripper are to control the griping force. So when a specified voltage has been sensed, the moving gripper will stop and complete the gripping procedure. All the mechanical parts of the gripper except transmission gears and rack are made by using a CNC machine currently available at Old Dominion University. The CNC tool paths are generated by using the EZ-CAM system[4], which can directly read the "dxf" files from the design drawings. With a suitable hardware connection, the CNC controller can download the programs from its supervisor computer, which is usually an IBM PC.

[Electrical Control Design]
The hardware of the controller is a 5525MF (ADAC)[5] Data Acquisition Board, which has 16 high level (± 10V) analog inputs multiplexed to a 12 bit A/D converter, three programmable timers, and four analog (± 10V) outputs. The board can be inserted into an IBM PC and the grasping procedures can be controlled by a software program written in C language.

The electrical portion of the project consists of the analog and digital interface between the computer, robotic controller, actuator motor, and sensors. A TB5525 I/O board is used in the desktop computer to facilitate all analog and digital communication between the computer and external devices. Due to some voltage and current level considerations, buffering of the computer and sensor signals was necessary.

Due to a combination of the high current requirements of the actuator motor and the low current capability of the analog board output, a power amplifier was inserted between the analog I/O board and the motor. Figure 2 shows this circuitry. An LM675 power operational amplifier is connected as a simple voltage follower. This gives the analog board capability to provide ±10 volts to the motor at a much higher current compliance as required by the motor.

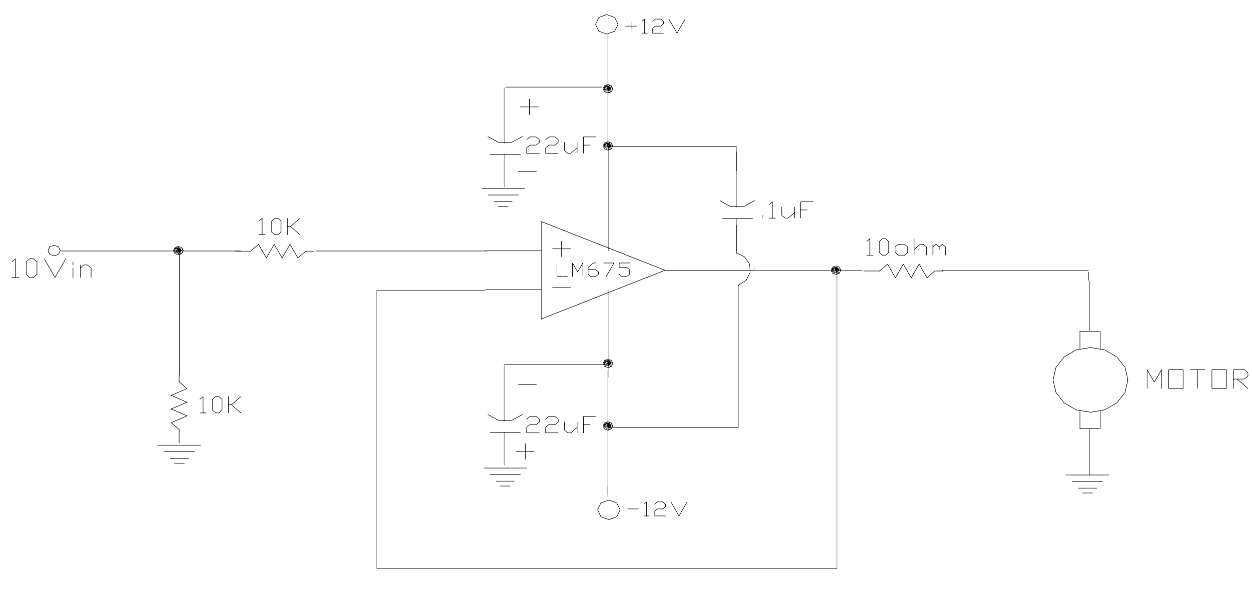


Figure 2. Amplification for the DC Motor.

In order to sense “end of travel” for the actuator, a proximity sensor is provided. The wiring of this sensor is shown in Figure 3. Note that since the output of the sensor is a digital signal with 0 and +12 volt logic levels, a zener diode has been added in series with the output to lower the logic level to 0 and 5 volts.

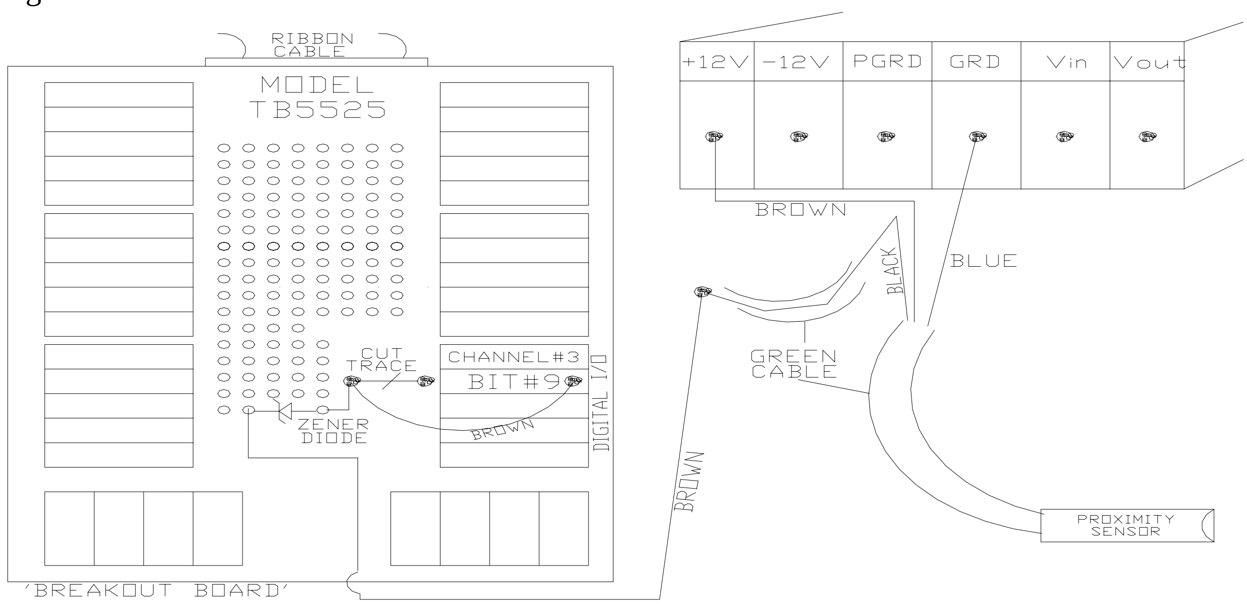


Figure 3. Circuit Design for the Proximity Sensor.

Figure 4 illustrates the wiring of the linear variable differential transformer (LVDT). The LVDT is used for sensing the position of the actuator. It operates from a single +12 volt DC power supply and provides a linear 0 to 10 VDC output relative to its position. Figure 5 shows the digital “handshake” wiring between the computer and robot controller. This simply provides the robot controller with “start/stop” information. Digital level shifting (5 volts to 12 volts) is provided by a transistor amplifier. Detailed wiring schematics of the LVDT, proximity sensor, and motor amplifier and motor are shown in Figure 6.

Figure 4. Circuit Design for LVDT.

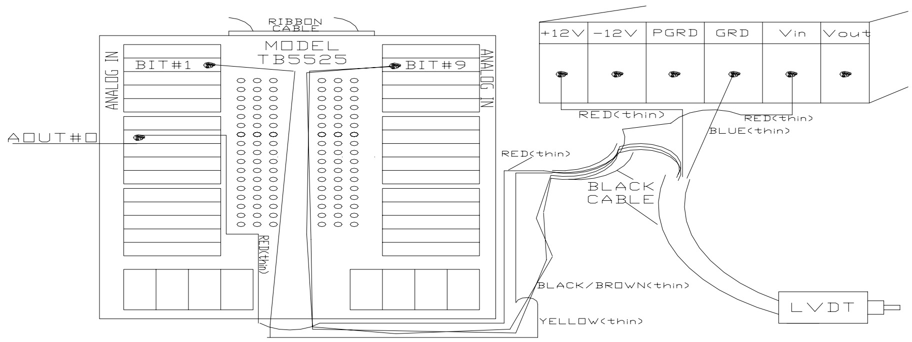
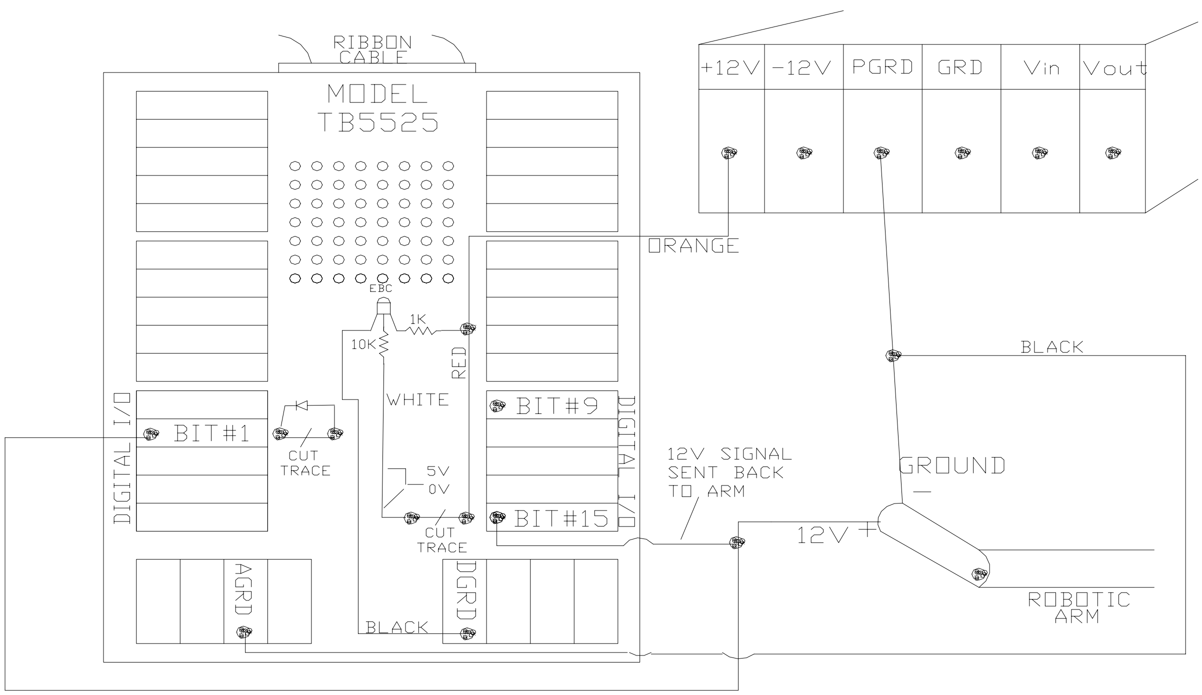


Figure 5. Circuit Design for the Handshake Signal.



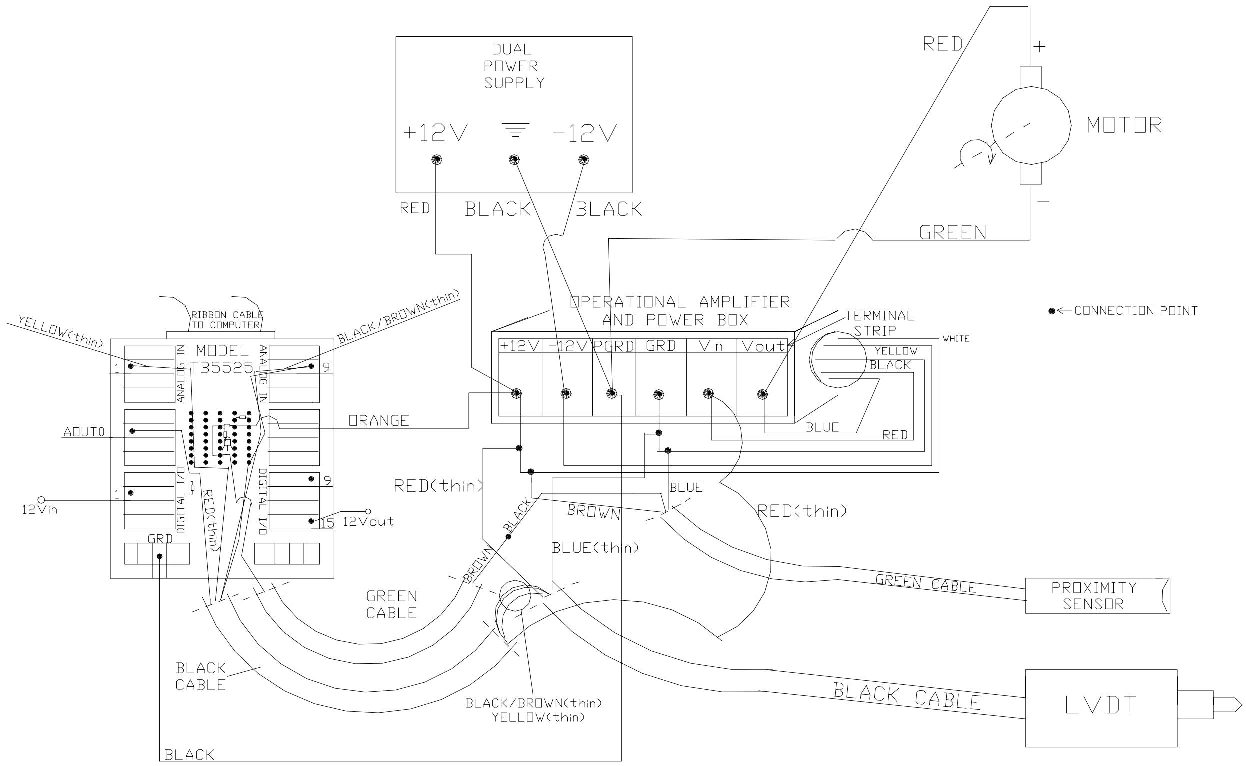


Figure 6. Integrated Circuit Design Between the DAC Board, Sensors, and the DC Motor.

[Control Scheme]

As shown in Figure 7, a Data Acquisition Board 5525MF[5] is inserted in an IBM PC. The B5525 provides screw terminal connections to the 5525MF data acquisition board when interconnected with a G50 cable. The screw terminals are positioned to facilitate separate grouping of connections to the analog inputs (Ain), analog outputs (Aout), clock and digital I/O. In the software control, the ADLIB[6] is a set of data acquisition subroutines for programmers involved indeveloping process control and/or data acquisition applications. The functions supplied with ADLIB provide an easy to use interface to the 5525 MF board. The library software has been compiled to machine code so that it has the capability of supporting many of the popular programming languages for the IBM-PC. These languages include C, C++, Fortran, and Basic. In this project, a Turbo-C program is written to control the following procedures:

1. When the robot guides the gripper in a position to grasp an object (through a robot program using a vision system or manual teach mode), the robot controller sends a hand-shake signal (Ain) to the PC.
2. The Ain signal triggers the software program written in the PC to control the following gripping strategies:

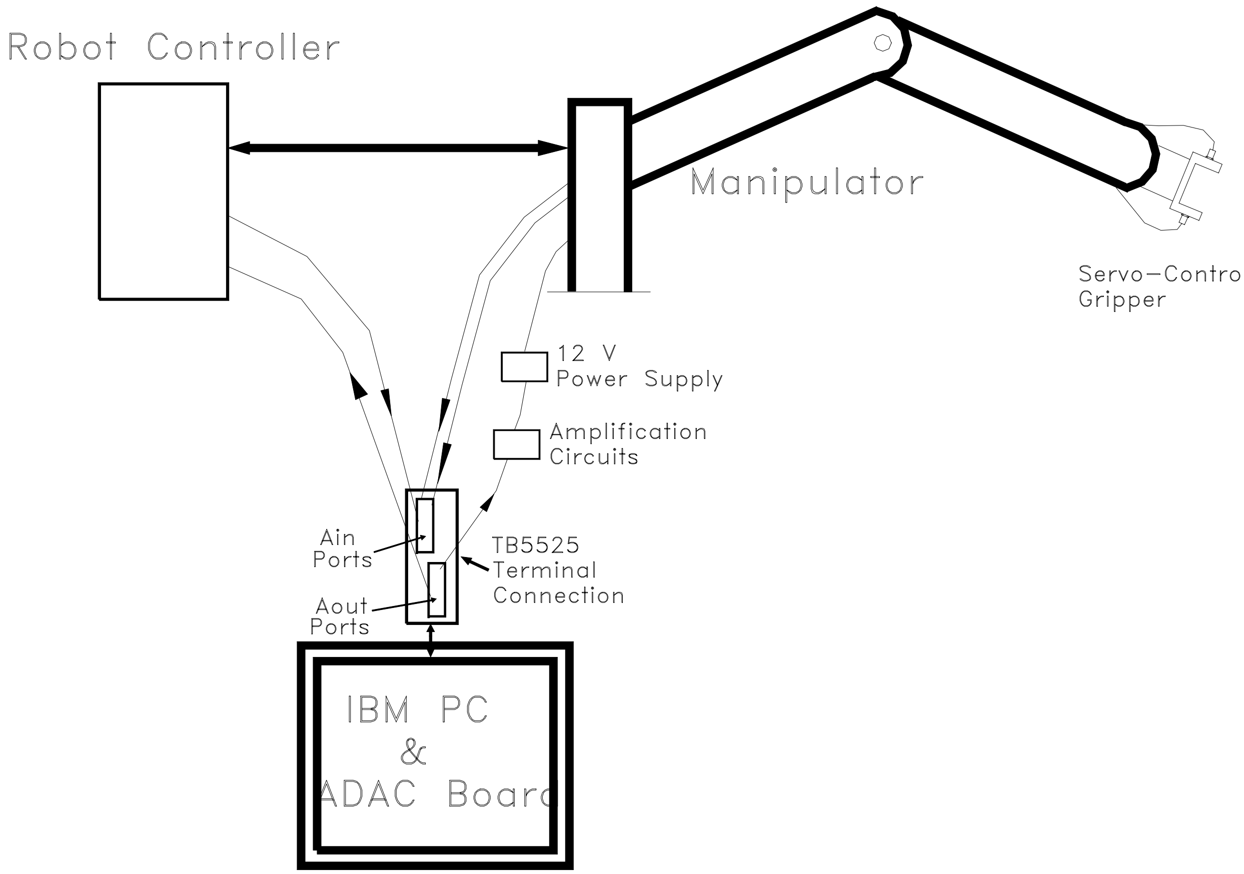


Figure 7. Schematic Diagram for the Control Scheme

a. For each specified increment of movement (Aout and a 12-v power supply system), a proximity sensor (Ain) is to check if the object is within the sensible range.
b. If the object is within the sensible range, the moving speed of the gripper will slow down.
c. Check if the other sensor (Ain) from the LVDT has reached a specified amount, then the gripper stops and completes the gripping action.

3. When the gripper grasps the object, the PC sends another hand-shake signal (Aout) to notify the robot controller.
4. When the robot guides the gripper to the target to place the object, it sends a hand-shake signal to the PC. The PC then sends a signal (Aout) to the gripper to release the object.
5. The gripper calibrates itself by moving the movable gripper to a calibrated position and is ready to wait for another grasping cycle.

[Conclusion]

The project includes mechanical design, part procurement, CC programming for the parts, electrical design, mechanical and electrical assembly, software program development, and final test. Result shows that the grippers can grasp an egg very tightly and without cracking it. The cost of the design including mechanical gripper and control system is only approximately $1200.00. As the cost of a servo-control board provided by the robot company is about $8,000.00, design of the control scheme in this project is very economical while providing a good learning experience to the students.

[References]

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