

Emulating a robotic manipulator arm with an hybrid motion-control system

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Abstract. A motion control system with four and $\frac{1}{2}$ degrees of freedom, designed to move small objects within a 0.25 m³ space, parallel to a horizontal table, with high speed and performance similar to a robotic manipulator arm was built. The machine employs several actuators and control devices. Its main characteristic is to incorporate a servomotor, stepper motors, electromechanical and fluid power actuators and diverse control resources. A group of actuators arranged on a spherical coordinates system is attached to the servomotor platform. A linear pneumatic actuator with an angular grip provides the radial extension and load clamping capacity. Seven inductive proximity sensors and one encoder provide feedback, for operating the actuators under closed loop conditions. Communication between the sensors and control devices is organized by a PLC. A touch screen allows governing the system remotely, easily and interactively, without knowing the specific programming language of each control component. The graphic environment on the touch screen guides the user to design and store control programs, establishing coordinated automatic routines for moving objects in space, simulation and implementation of industrial positioning or machining processes.

1. Introduction

Many engineering applications need to control the position, speed and acceleration of a tool or an object involved in some manufacturing process. It is frequent to choose a motion control solution based on a robotic manipulator arm, even when it is possible to use other resources to complete the task. But the motion control technologies evolve so quickly that many devices are rejected, under the false assumption that they are obsolete or incompatible [1].

The machine was conceived as training equipment, for engineering students learning how to assemble, communicate and program motion control systems. Even though its hybrid composition, the system allows operating five actuators under closed loop conditions and programing small objects positioning.

2. Power components

A group of actuators arranged on a spherical coordinates system is coupled to the platform of a linear servomotor. The conjugated motion of the actuators can translate a 40 N load, raising it over the table surface and moving it with high precision within a 0.25 m³ space; figure 1.





Figure 1. Actuators arranged on a spherical coordinates system, over the servomotor platform.

The servomotor platform has 1 m horizontal trajectory, with 1 μm resolution and capacity to accelerate up to 5g. The ϕ and ψ angular displacements come from two hybrid biphasic unipolar stepper motors, attached to crown-worm gear 55:1 reductions. Both axes have 0.0327°/motor step resolution; figure 2. The stepper motors are SKC, NEMA 23 size, with 1.8° step angle and 55.6 Nm holding torque.

The ϕ vertical axle protrudes for an enclosure attached to the linear servomotor platform. The second stepper motor is linked to this axle and its worm gear reduction has the ψ axis oriented horizontally. A linear pneumatic actuator is coupled to this second axle and provides 0.1 m radial extension. The linear actuator rod has a pneumatic angular grip, to pick up and hold the load during translation; figure 3 [4].

3. Control components

The linear servomotor is controlled with a Parker Gemini GV6K digital servo drive. The Gemini GV6K offers connectivity to any ASCII-based serial device, including HMI panels and PLC ASCII modules. It has 8 digital inputs and 6 digital outputs onboard I/O capability, expandable up to 256 additional discrete digital I/O points.

Eight digital outputs are needed to feed the stepper motors coils through specific drives for each motor. Four more digital outputs are required for the solenoids, to actuate the two pneumatic directional control valves. To avoid the Gemini I/O expansion unit it was used an Arduino Uno microcontroller board, in order to increase and organize the output signal capability. The Arduino Uno is based on the ATmega328 microcontroller and has 14 digital input/output pins and 6 analog inputs.

The output signals from the Gemini GV6K are + 24 V, while the Arduino Uno receives + 5 V input signals. To solve this incompatibility a converter was designed, based on six optocouplers 4N35 (light emitting diodes optically coupled to photo-transistors). The + 5 V output signals to actuate the directional control valves come out from the Arduino Uno; they energize the coils from



Figure 2. The crown's angular advance is 6.55° for each revolution in the stepper motor.

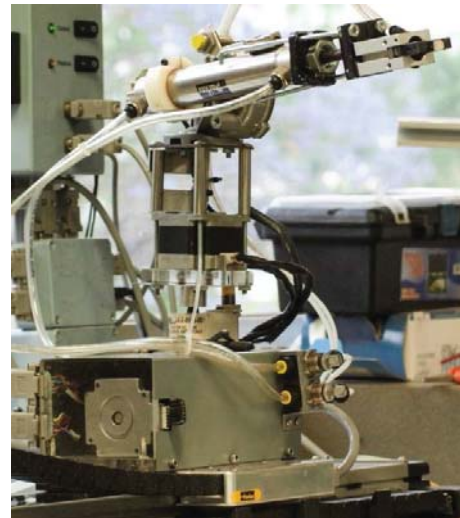


Figure 3. Actuators assembly attached to the servomotor platform.

four Sun Hold, model RAS-0510, SPDT compact relays. As each relay closes one solenoid receives 127 VCA to commute a valve; figure 4.

The servomotor has a linear encoder and one *home* and two *limit* sensors, communicated with the Gemini GV6K through the encoder/hall cable and the limit/home cable. Another four inductive proximity sensors and one encoder provide feedback for operating all the actuators under closed loop conditions; figure 5. Communication between the sensors and control devices is organized with a Mitsubishi PLC, model FX2n-64MR-ES/UL [5].

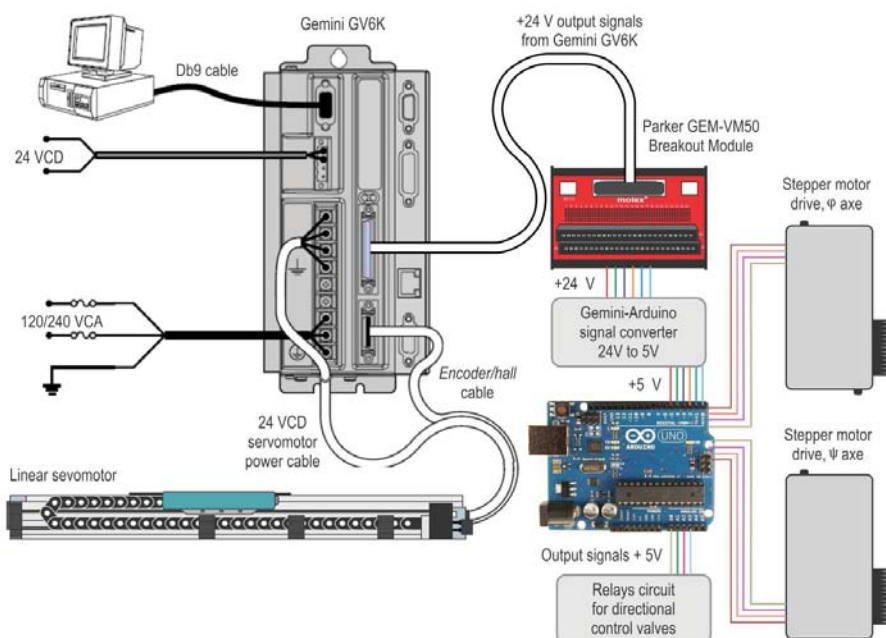


Figure 4. Control signals communication between three drives, the Arduino Uno and relays circuit.

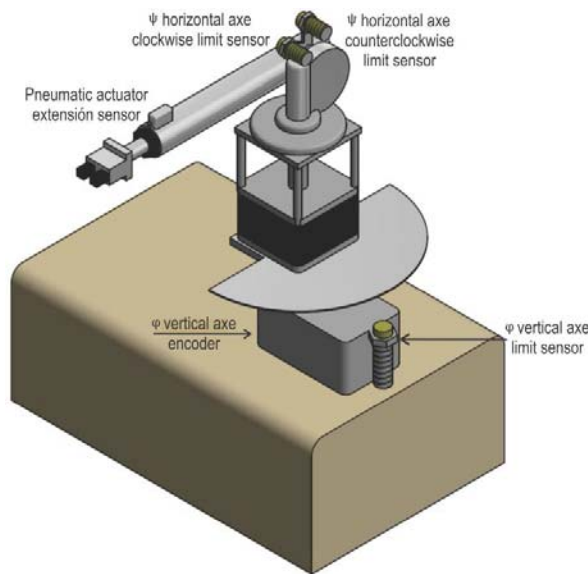


Figure 5. Limit sensors and encoder in the φ , ψ and r axes.

The two limit sensors for the ψ horizontal axis allow a maximum 300° angular displacement. Only one sensor is installed for the φ vertical axis, but it works with a half circle metallic surface and allows only 180° angular displacement (enough to move the load from the front to the rear of the servomotor and vice versa). The optical encoder in the φ axis is an Avago Technologies model HEDS-9700, with a 500 CPR code wheel.

The PLC receives the sensors signals and sends them off to the Gemini GV6K drive, through the Parker GEM-VM50 I/O breakout module; figure 6. The PLC also provides the 24 VCD sensors feeding. Two inductive sensors are PNP Lanbao model LR08BF02DPOY; another one is NPN Lanbao model LR08BF02DNOY. One 4N35 optocoupler was needed to conciliate the 5 V encoder output signal with the necessary 24 V PLC input signal [6].

The master control governing the drives and the PLC is a CTC-Parker power station, model PA10T-133. This touch screen power station is linked with the Gemini GV6K drive through a RS232 port; it allows real time tracing for the whole system and establish graphic communication with the users. Programs with motion control routines are stored in an external 32 Mb compact flash memory.

4. Conclusions

The motion control system performs very similar to a robotic manipulator arm, even though it is constructed with highly dissimilar actuators and diverse control resources, some of them far from being the most modern components. Its design intentionally shows how to overcome apparent incompatibility problems and take advantage of simple but efficient power and control solutions. Several routines have been designed to prove the flexibility and reliability of the system.

The touch screen is a key control component, because it communicates flawlessly the subordinated control drives. It also allows governing the system remotely, easily and interactively, without knowing the specific programming language of each control component.

The capacities of the system can be improved with the addition of free software control and programming platforms, like the Arduino or Raspberry microcontroller boards.

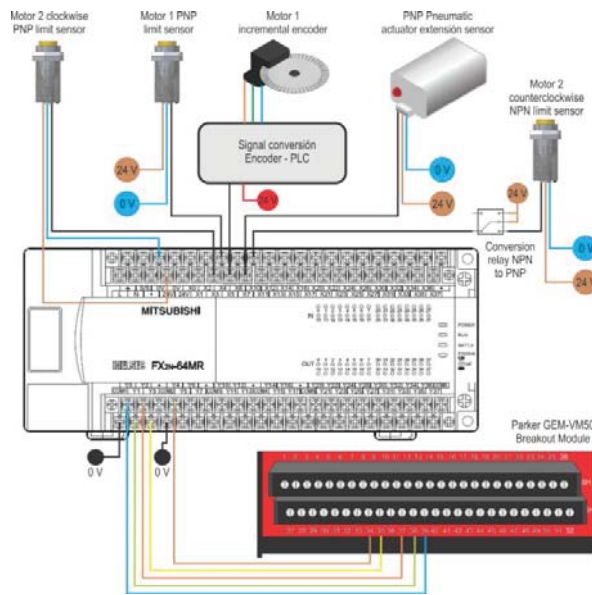


Figure 6. Sensors and encoder signals managed with the PLC.

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