

FPGA Based Robotic Hoist

SarithaM¹, Kannan S A², Renjith G³, Sangeeth Wilson⁴, Subin Geevarghese⁵, Joel Biju Skaria⁶, Gargi G⁷,
Anju L⁸

Assistant Professors, Department of EEE, College of Engineering, Perumon, Kollam, Kerala, India^{1,2,3}

B. Tech Scholars, Department of EEE, College of Engineering, Perumon, Kollam, Kerala, India^{4,5,6,7,8}

ABSTRACT: A hoist is a device used for lifting or lowering a load by means of some arrangement. The conventional methods of robotic hoist controls including microcontrollers do lack in perfection, speed and accuracy. The inputs given were then sequentially executed hence very lag in the work and also any modifications to the works seem to be difficult. For precisely controlled travel along the major sections of the working area there is need of precise control of hoist. Protection to the devices were also sometimes at risk. In order to tackle such difficulties, we are here adopting an advanced control method using FPGA. It possess the advantageous characteristics like parallel processing and rapid prototype. These properties ensure more perfect motion controls as well as protection to the systems. The control is done over stepper motors and gear motors that in turn controls the movement of a hoist.

KEYWORDS: FPGA-Field Programmable Gate Array.

I. INTRODUCTION

As the human civilization is modernised day by day, the demand of automation is increasing accordingly. It requires control of devices. A hoist is a device used for lifting or lowering a load by means of a drum or lift-wheel or rack and pinion arrangement around which rope or chain wraps. It may be manually operated, electrically or pneumatically driven and may use chain, fiber or wire rope as its lifting medium. A hoist is a sum total of a complex mechanism. The links of the hoist are connected by joints allowing both rotational and translational motion and thus it forms a kinematic chain. The terminus of this is so called an end effector, which is analogous to a human hand.

Control system manages, direct and regulate the mechanism of devices and equipment's. In an ideal control system, clear mathematical relation between input and output must be seen. Here, we design a control system that receive the control signals and calculate the frequency of PWM (Pulse Width Modulation) signal and send it to the motors attached to the links of hoist. For getting high accuracy and quick response, stepper motor is a great choice which has better speed control and will hold a position without application of power. It do not need any feedback sensors and is compatible with modern digital equipment's. High torque is required for the power hoist operation, which is provided by the gear motor assembly. The rack and pinion gear set will convert the gear motor output into accurate linear positioning of power hoist and also provides a gear reduction required.

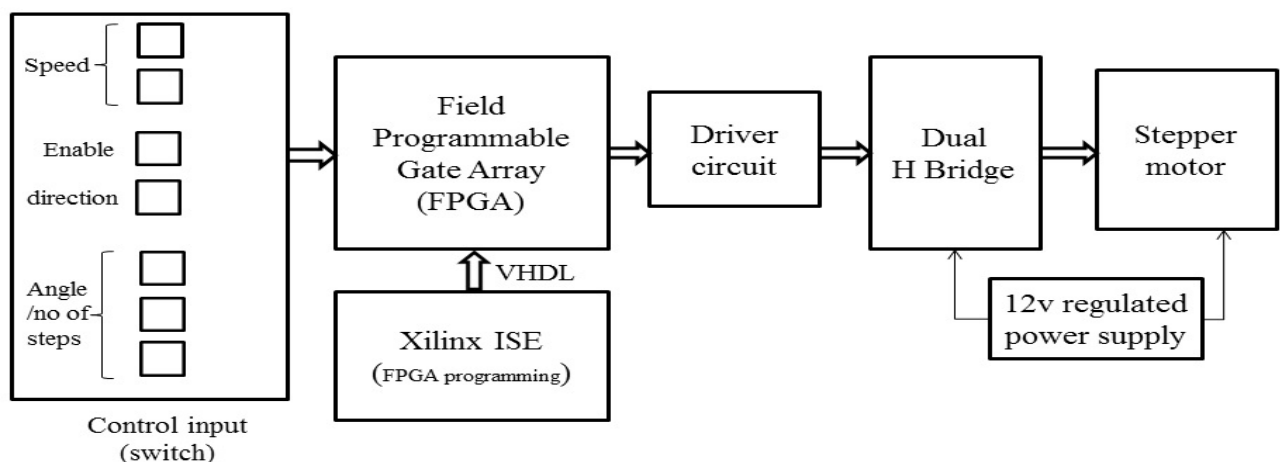
FPGA technology is now preferred by an increasing number of designers due to new degree of freedom in the field of control system. FPGA is an ideal solution because it is a multipurpose controller and is easy to change the function of hoist. Also, it is characterised by high response and is stable than other controllers.

II. MODEL AND DESCRIPTION



The design includes a stepper motor, a rack and pinion arrangement, a pulley set up and two gear motors. It's an advanced design for the weight lifting application. The stepper motor at the bottom of the arrangement helps in the 360° rotational motion of the whole system. The rack and pinion arrangement converts the rotational motion into linear motion along with a pulley set up for the control of extension and contraction of the rope rounded over it for the various levels of lifting of objects. The rack and pinion movement and the motion of rope over the pulley are controlled by the two gear motors separately. The control for the gear motors as well as the stepper motors are done using the advanced FPGA programming. The parallel processing capability of FPGA is adopted as the main advantage of this work because we can simultaneously or at the same time all motors are in action that is at the time of translational motion we can use the pulley arrangement by another motor. This makes the task too easy.

III. BLOCK DIAGRAM AND DESCRIPTION



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The block diagram the main part is, an advanced FPGA (Field Programmable Gate Array) based control system is placed. FPGA doesn't have a fixed hardware structure, on the contrary it is programmable according to user applications. we can have the processes done using FPGA according to the written HDL code "in parallel" which means simultaneously. Ability of parallel processing is one of the most important features that separate FPGA from processor and make it superior in many areas. Since the user can determine the hardware structure of the FPGAs, we can program FPGA to process larger data with few clock cycle.

It is also possible to define and use processor and user specific hardware functions on only one chip by using FPGA. This gives the opportunity to control the hardware because of its great flexibility. We can modify and update whole design (FPGA on the processor and other logic circuits) by only changing the code on FPGA, without any change on circuit board layout. In this way, we can add different functions, improve performance and make design resistant of time without having to redesign the cards.

Here stepper motors and gear motors are used. By using the stepper motor micro stepping action we can rotate the whole system 360° precisely with a stepping angle of about 1.8°. The gear motors used is Johnson gear motor which is a high efficient motor that can deliver high torque and can easily lift high weight.

The Stepper motor are controlled using PWM (Pulse Width Modulation) technique. The signals produce by FPGA is a PWM signal but is too weak to drive a stepper motor hence there is a need of H Bridge circuitry as a Driver for the motor. The dual H Bridge action for the stepper motor we can use a L298 motor driver IC. Another L298 motor driver can be used to control two gear motors. Because the gear motor has two input hence this driver can be used for the control of two gear motors. The complete movement of the motor can be controlled by regulating the pulse width of the signal produced using FPGA.

IV. COMPONENTS USED

1. FPGA



FPGA or Field Programmable Gate Arrays can be programmed or configured by the user or designer after manufacturing and during implementation. Its configuration is generally specified using a Hardware Description Language (HDL). FPGAs are truly parallel in nature so different processing operations do not have to compete for the same resources. Multiple control loops can run on a single FPGA device at different rates. In this project we use Numato Labs Elbert v2 FPGA development Board featuring Xilinx Spartan-3A FPGA.

Board features

- FPGA: Spartan XC3S50A in TQG144 package
- Flash memory: 16 Mb SPI flash memory (M25P16)
- USB 2.0 interface for On-board flash programming
- FPGA configuration via JTAG and USB
- 8 LEDs, Six Push Buttons and 8 way DIP switch for user defined purposes

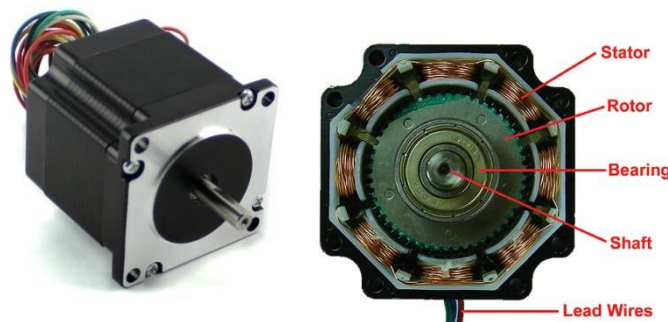
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- One VGA Connector
- One Stereo Jack
- One Micro SD Card Adapter
- Three Seven Segment Displays
- 39 IOs for user defined purposes
- On-board voltage regulators for single power rail operation

Advantages of FPGA

1. Long time availability
2. Can be updated and upgraded at your customer's site
3. Real time applications
4. Massively parallel data processing
5. Performance gain for software applications
6. Fast and efficient systems
7. Extremely short time to market

2. Stepper Motor

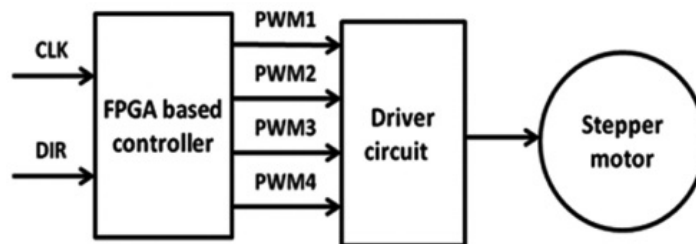


The stepper motor is an electromagnetic device that converts digital pulses into mechanical shaft position. They have stable open loop operation to any step position and consequently no feedback is needed to control them. Stepper motors are extensively used now in many industries all over the world. Basically, a stepper motor is a synchronous motor with the magnetic field electrically switched to rotate the rotor. In theory, a stepper motor is similar to a permanent magnet synchronous motor. The motor rotation not only has a direct relation to the number of input pulses, but also its speed is related to the frequency of the pulses. Due to ease of use, simple and precise control, stepper motors are commonly used in measurement and control applications. Some applications include printers, disk drives, robots, and machine tools.

Steppermotors rotate when voltage is applied to their terminals. Stepper motors, on the other hand, effectively have multiple "toothed" electromagnets arranged around a central gear-shaped piece of iron. The electromagnets are energized by an external control circuit, such as a microcontroller. To make the motor shaft turn, first one electromagnet is given power, which makes the gear's teeth magnetically attracted to the electromagnet's teeth. When the gear's teeth are thus aligned to the first electromagnet, they are slightly offset from the next electromagnet. So when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one, and from there the process is repeated. Each of those slight rotations is called a "step", with an integer number of steps making a full rotation. In that way, the motor can be turned by a precise angle. Stepper motors provide means for precise positioning and speed control without the use of feedback sensors. The basic operation of the stepper motor allows the shaft to move a precise number of degrees each time a pulse of electricity is sent to the motor. The shaft of the motor moves only the number of degrees that it was designed for when each pulse is delivered. We can control these pulses that are sent and control the positioning and speed. The rotor of the motor produces torque from the

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interaction between the magnetic field in the stator and rotor. The strength of the magnetic field is proportional to the amount of the current sent to the stator and number of turns in the winding.



Block Diagram Representation of Stepper Motor System

3. Gear Motor



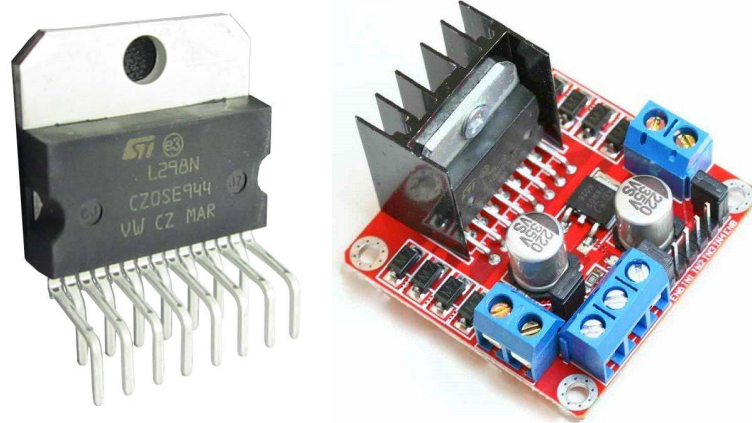
A gear motor is a specific type of electrical motor that is designed to produce high torque while maintaining a low horsepower, or low speed, motor output. Gear motors can be found in many different applications, and are probably used in many devices in your home.

Gear motors are commonly used in devices such as can openers, garage door openers, washing machine time control knobs and even electric alarm clocks. Common commercial applications of a gear motor include hospital beds, commercial jacks, cranes and many other applications that are too many to list.

Gear motors are primarily used to reduce speed in a series of gears, which in turn creates more torque. This is accomplished by an integrated series of gears or a gear box being attached to the main motor rotor and shaft via a second reduction shaft. The second shaft is then connected to the series of gears or gearbox to create what is known as a series of reduction gears. Generally speaking, the longer the train of reduction gears, the lower the output of the end, or final, gear will be.

In this project we use Johnson Geared Motor. The Johnson Geared motor is famous for its compact size and massive torque. The Johnson Geared motor is famous for its compact size and massive torque. A torque as much as x3 as compared to center shaft or side shaft geared motor, with an affordable price tag. The motor comes with a metal gearbox and off centered shaft, also shaft has a metal bushing for wear resistance. Apart from robotic application they are also used in industrial applications, vending system, hygiene and cleaning industry, and household electric appliance. Specifications - RPM - 100 Shaft Diameter - 6mm (with internal hole) Shaft Length - 15 mm Dimensions : Gearbox diameter - 37mm; Motor Diameter - 28.5 mm; Length (body only) - 63mm Weight - 300 gms Torque - 12 kgcm Voltage - 6 to 24 (Nominal Voltage - 12v) No-load current = 800 mA(Max), Load current = 9 A(Max).

4. L298 Motor driver



The L298 is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

V. CONCLUSION

The values of control signals are determined and then generated required PWM signals for the configuration of motor control. The VHDL code using ISE Xilinx software environment was programmed and generated. Then tested and found system running with faster response. FPGA based design of power hoist control is very efficient and proved success in meeting future challenges in this field.

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