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A GRAPHICAL USER INTERFACE FOR XY LINEAR ACTUATOR USING LEAD SCREW MECHANISM

[1]Prajna, [1]Prathvi P Shetty, [1]Ramya, [1]Sanjay S, [2]Dr. Sukesh Rao M

[1]UG Students, Department of Electronics & Communication, NMAM Institute of Technology, Nitte, Karkala, India
[2]Associate Professor, Department of Electronics & Communication, NMAM Institute of Technology, Nitte, Karkala, India

Abstract: A linear actuator is a device which converts rotational motion into push or pull linear motion, which can be used for lifting, dropping, sliding, or tilting of machines or materials. Linear actuators work by moving an object or piece of equipment in a straight line, moving an object accurately and repeatably if required. The project is intended to design XY linear actuator which can carry the payload in X and Y direction. Lead screw mechanism is used to provide the linear actuator in XY direction using two stepper motors. The drive signals for the stepper motor is provided using CC3200 MCU (microcontroller unit). CC3200 is enabled with IEEE802.11 for wireless connectivity and a Graphical User Interface is provided through a web page with HTTP protocol for controlling XY linear actuator. Additionally, a webpage is developed for controlling a XY linear actuator. The experimental results shows 0.1062 mm and 0.1437 mm of error for X and Y axis respectively.

I. INTRODUCTION

A linear actuator is a device that changes the rotational motion of a motor into a straight line. The linear actuator is very stable when operated, even at low speed [1]. It also offers smooth acceleration and deceleration operation. Position and speed of the linear actuator can be adjusted precisely with the help of stepper motor [2].
XY linear actuator is a mechanical assembly usually constructed with a lead screw mechanism [3–9]. XY linear actuator can make linear movement in X and Y axis. Linear actuators utilize an oriental stepper motor [10] with an integrated lead screw and mounting table in an all-in-one linear motion product to enable XY motion control [11]. XY linear stage is created by precisely joining two single-axis stages, mounted perpendicular to one another, the top of the lower axis serves as the upper axis base [12]. In each individual stage, a hybrid stepper motor linear actuator is combined with a precision lead screw and nut to move the carriage to a precise destination point in the linear motion system.
The proposed project is on a XY linear actuator through which the user can precisely control the position of the object in straight line using a graphical user interface. The values taken from the GUI fields are obtained and are transmitted to a remote MCU using wireless communication protocol. The MCU enumerates the values provided from the GUI and provides control signals to the motor driver which provides a required drive in X and Y axis.

II. SYSTEM OVERVIEW

CC3200 MCU is used to provide the control signal for the two-stepper motors and communicates the command sequences from the GUI. The user interface is provided from the GUI developed using C programming language, which consists of fields to control the X and Y movements in mm scale. The values entered by the user to move the XY linear actuator to a particular position is transmitted to the CC3200 MCU using wireless communication protocol. The CC3200 MCU provides control signals to the motor driver based on the values obtained from the user. The application code for controlling the stepper motor using CC3200 MCU is developed using Energia tool. The system uses ST330-V3 stepper motor driver to provide the required drive for the two NEMA 23 stepper motors in X and Y axis. Figure 2.1 depicts the block diagram of XY linear actuator using lead screw mechanism along with GUI.

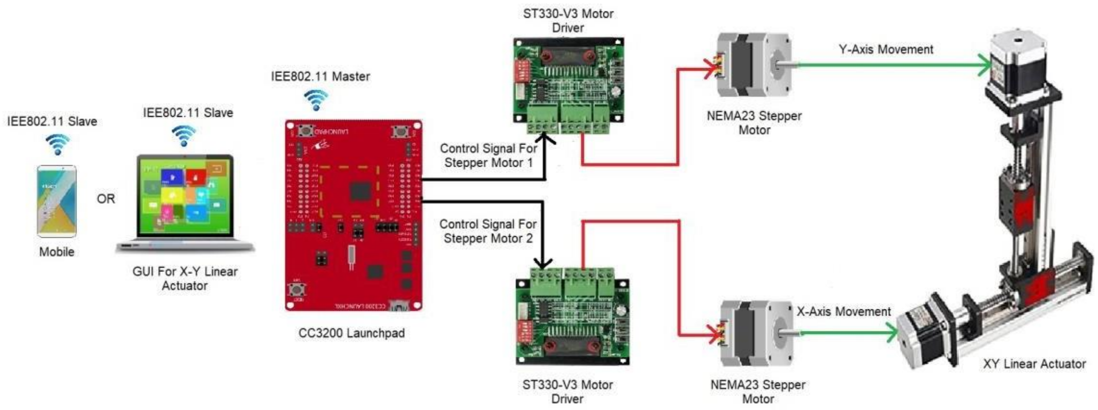

Figure 2.1: Block diagram of GUI for XY linear actuator using lead screw mechanism

III. RESULTS AND DISCUSSION

3.1 Hardware Implementation

The hardware part of the project consists of CC3200 Launchpad, lead screw mechanism, ST330-V3 motor driver, NEMA23 stepper motor and power supply. This section talks about the necessary implementation done in order to meet the objectives.

3.2 Microcontroller Interface

Once the hardware components are assembled, the microcontroller is programmed to implement a web server. The web server can be accessed through a browser on a computer or mobile device. When the user enters the value in the webpage to move the XY linear actuator to a desired position, the webpage sends HTTP requests to the microcontroller, which interprets the request. The microcontroller then powers up the stepper motor. The power delivered to the stepper motor is regulated by the motor driver ST330-V3. The stepper motor rotates the lead screw in X and Y directions based on the command sent by the microcontroller. Figure 3.2 shows the microcontroller interface with the ST330-V3 stepper motor and NEMA23 motor driver. The operations happening is over a local network and does not require any internet. CC3200 act as remote local webserver and facilitates the user to acccess webpage. With the help of CC3200 Launchpad we can create a WiFi access point which will act as a WiFi gateway. A firmware is developed for CC3200 to connect to a known WiFi hotspot with the help of SSID and password. An IP address will be assigned to the connected device and user can access the webpage through the IP address.

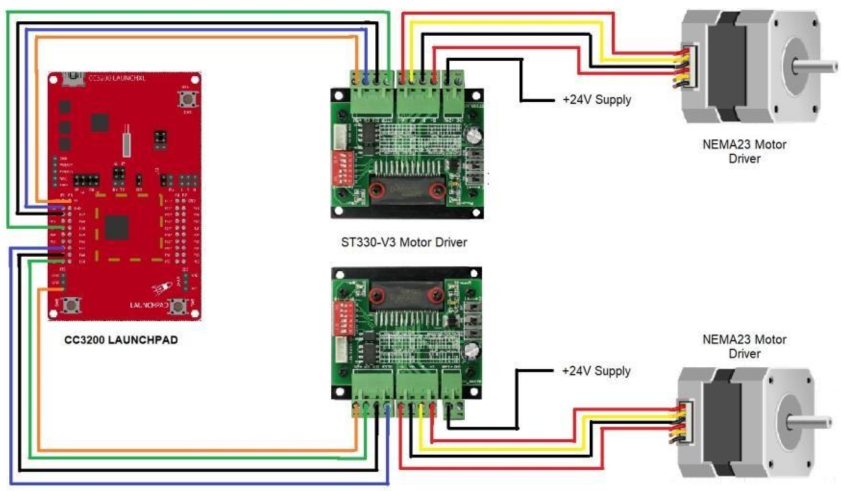

Figure 3.2: Microcontroller interface with ST330-V3 motor driver and NEMA23 motor

3.3 Firmware Development

The software part of the system consists of the user interface and the local server. The user interface is a web application. The local server is set up on a personal computer.

Initially, the GPIO pins on the microcontroller are declared and configured for the motors that drive the linear actuator. The pins are typically configured as output pins, and each pin corresponds to a specific motor. In order to move the XY linear actuator along the X axis or Y axis, the direction pin is made high. The for loop executes based on the values given by the user. Inside the for loop, the step pin is set to high, which makes the motor take a step. After a short delay, the step pin is set to low.

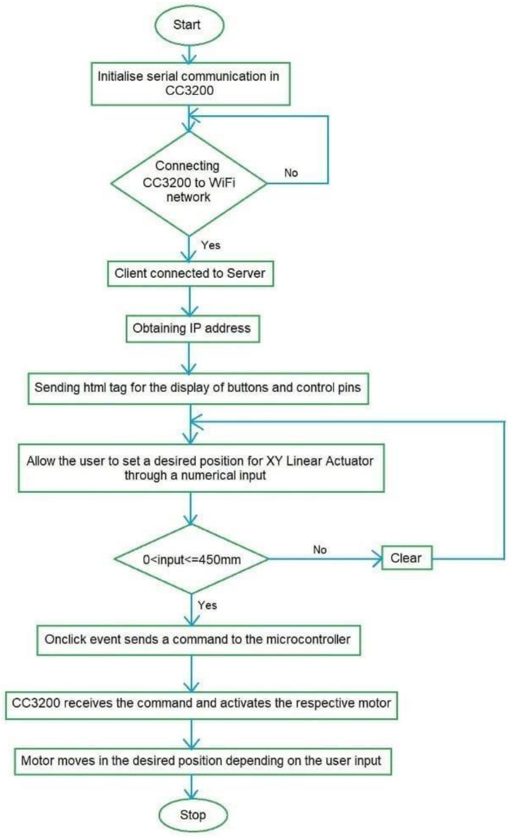

Figure 3.3.1: Flow chart of GUI for XY linear actuator using lead screw mechanism

The firmware developed for webserver includes WiFi.h library which provides functions for connecting to WiFi networks and creating servers. The server object is created on port 80, which is a default port for HTTP traffic. In the setup() function, the serial communication is initialized and CC3200 Launchpad connects to a WiFi network with a given SSID and password. The while loop waits until the connection is established. The server is started with the server.begin() function, the loop() and the server.available() function checks if a client has connected to the server. If a client is available, the function returns WiFiClient object representing the client and the code sends an HTTP response to the client. The response is sent to the client with the client.print() function. The firmware waits for a short delay and then closes the connection.

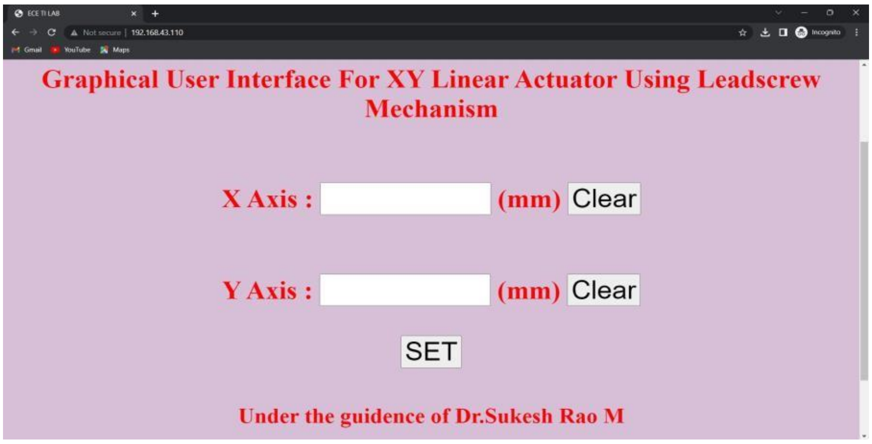

Figure 3.3.2: Webpage for XY linear actuator

A web page interface displays buttons that the user can click as shown in the Figure 3.3.2 to initiate the movement of the XY linear actuator. The webpage has a field that allows the user to set a desired position of XY linear actuator through numerical input. The graphical user interface will check whether the input is within the valid range or not. If the input is not within the valid range, then GUI will display invalid input and ask the user to clear the previous value using the clear button and to reenter the valid number. If the user enters a valid input, then onclick event sends a command to the microcontroller that controls the XY linear actuator to move it to the specified position. The microcontroller receives the command and sends signals to the XY linear actuator's motors to move it to the desired position.

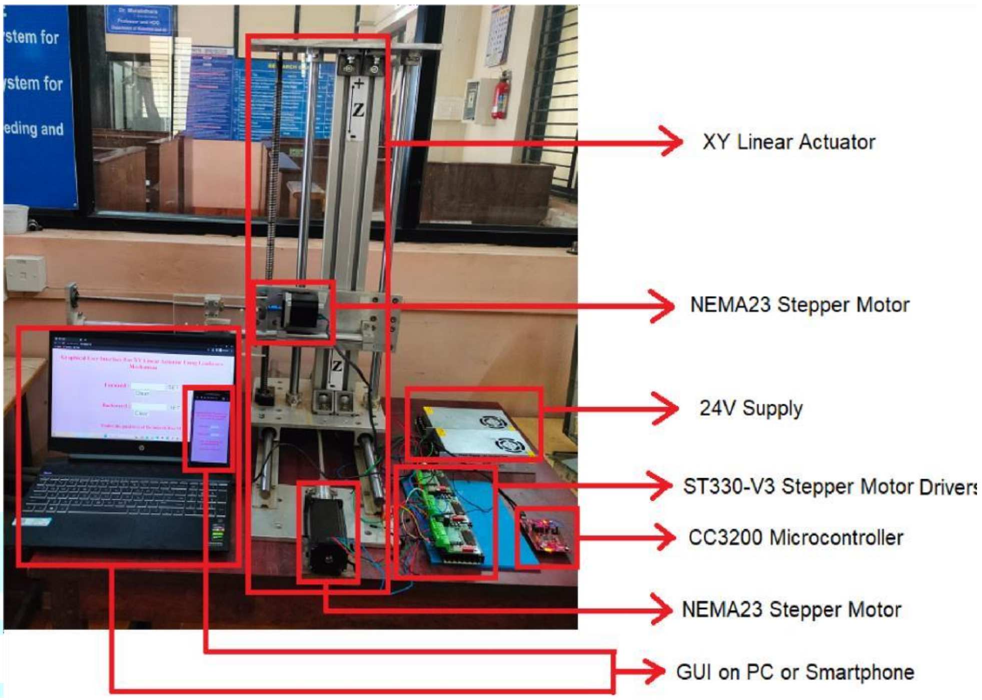

Figure 3.3.3: Setup of XY linear actuator

The equations for calculating the expected distance covered by a linear actuator in the x axis and y axis is given by

$$Expecteddistance(mm) = \frac{Numsteps}{stepsperrevolution} x \frac{pitchoftheleadscrew}{sin(stepangle)} \quad (3.1)$$

where,

Expected distance is the distance travelled by the linear actuator in the x or y directionNumsteps is the number of steps taken by the stepper motor in the x or y direction 200 is the number of steps per revolution of the stepper motor

1.25 is the distance traveled by the linear actuator for one revolution of the lead screw in millimeters

1.8 is the step angle of the stepper motor in degrees

The sin(1.8) term is used to convert the linear distance traveled by one step of the motor into the linear distance traveled by the actuator, taking into account the angle of the step.

$$Expecteddistance(mm) = \frac{Numsteps}{200} x \frac{1.25}{sin(1.8)} \quad (3.2)$$

Table 3.1: Readings of X axis movement

Numsteps	Expected distance (mm)	Practical distance (mm)	Error (mm)
200	1.28	1.20	0.08
400	2.56	2.50	0.06
600	3.85	3.70	0.15
800	5.13	5.00	0.13
3200	20.53	20.50	0.03
6400	41.07	40.90	0.17
12800	82.14	82.00	0.14
25600	164.29	164.20	0.09

Table 3.2: Readings of Y axis movement

Numsteps	Expected distance (mm)	Practical distance (mm)	Error (mm)
200	1.28	1.20	0.08
400	2.56	2.40	0.16
600	3.85	3.80	0.05
800	5.13	5.10	0.03
3200	20.53	20.40	0.13
6400	41.07	40.80	0.27
12800	82.14	81.90	0.24
25600	164.29	164.10	0.19

From the table 3.1 and 3.2 it is observed that the error increases with the distance travelled by the XY linear actuator. The average error for the readings of X axis movement is 0.1062 mm and the average error for the readings of Y axis movement is 0.14373 mm.

IV. CONCLUSION AND FUTURE SCOPE

4.1 Conclusion

This project concentrates on development of a GUI through a webserver for controlling XY linear actuators using lead screw mechanism. The lead screw mechanism provides accurate and repeatable motion in two dimensions, making it ideal for applications that require precise positioning. A system has been built using CC3200 microcontroller to control the movement of XY linear actuator in X and Y direction. A webserver has been developed using Energia IDE where the user can enter the values for X and Y fields. Based on the values entered by the user the CC3200 microcontroller will send the control signal to ST330-V3 motor driver which will give the required drive to the motor to move the XY linear actuator in the desired position. Based on the distance travelled by the XY linear actuator, the error is calculated by comparing it with the theoretically calculated expected distance and it is observed that the average error is 0.1062 mm and 0.1437 mm for X and Y axis respectively.

4.1 Future Scope

With the advancement of technology, GUIs have become more intuitive and efficient, allowing users to easily interact with complex systems. In the future, GUIs can incorporate features like real time position feedback, automatic calibration, and predictive maintenance, making them even more valuable for controlling linear actuators. Additionally, GUIs can also be integrated with other advanced technologies like artificial intelligence and machine learning, enabling them to learn from user behaviour and optimize the performance of the actuators.

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