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AUTOMATED VACUUM FEEDTHROUGH DRIVE FOR ELECTRIC PROBE IN PLASMA MEASUREMENT

KUSUM P. SONEJI[1], H. K. PATEL[2], SHANTANU KARKARI[3], HASMUKH KABARIYA[4]

1. Institute Of Technology, Nirma University.
2. Institute Of Technology, Nirma University.
3. Institute of Plasma Research.
4. Institute of Plasma Research.

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Abstract: In plasma physics, a large set of data needs to be acquired. In order to measure various plasma parameters-namely plasma potential, temperature, electron density etc., a precise mechanism capable of moving a probe along with feed through is required. In this paper, a Labview based automated vacuum feed through drive system is described which provides axial and radial motion of feed through. Using this mechanism, one can arbitrarily and precisely position feed through within a specific volume in a vacuum chamber. Stepper motor, Linear mechanical slider and DAQ card are the main components of this automated system. The essential feature is the independent motion in each orthogonal direction. Hence separate stepper motors are used for each independent direction of motion and motion in particular direction does not require any correlation motion by another stepper motor. Since, the motion of probe drive is Labview controlled, It has ability to return to any location repeatedly.

Keywords: Stepper motor, DAQ card, Vacuum feed through and Linear slider.

Corresponding Author: MS. KUSUM P. SONEJI

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INTRODUCTION

Spatially determined measurements in vacuum chamber require mechanism which is capable of precisely moving probes in all three direction but, it needs a fraction of chamber volume and are incompatible with high temperature and high density plasma experiments[1]. The necessity for the large volume data sets in plasma physics has forced computer assisted data acquisition for many years[2]. Labview provides the flexibility of integration of data acquisition software/ hardware with the motion control application software to enhance the productivity and reduce cost for automated test and measurement application[3]. Thus, besides data acquisition, DAQ system can also control motion of the probe through vacuum seals. Digital ports of DAQ card provides the digital pulses required for operating the stepper motor. Mostly, stepper motor is the first choice when design specifications require low cost automation with accurate and open loop control. Stepper motor can accept digital signals avoiding the use of digital to analog converters[4], hence computer control of stepper motor is very acceptable. The axial and radial motion of feed through are carried out using stepper motor and mechanical assembly. Axial motion is accomplished by linear mechanical slider while the radial motion is accomplished using a coupler and bracket placed on the carriage of the slider. Thus, diagnostic probe can be moved at any position throughout the plasma volume. Wide range of locations is provided at which data about plasma information is acquired.

I. Axial motion of Feed through

The axial motion of vacuum feed through is required to acquire the data by precisely positioning manipulator with linear displacement as small as 1 mm. This is accomplished using a mechanical linear slider. Mechanical linear slide limits a translating load to a single degree of freedom. The linear slide supports mass of load to be actuated and assures smooth, straight line motion while minimizing the friction. The motor turns the ball screws and its rotary motion is translated into linear motion that moves carriage and load by bolt nut.

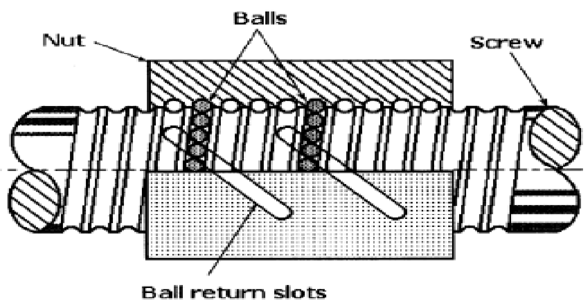

Figure 1. Ball screw drive.

Ball screw drive uses re-circulating balls which provides high level of efficiency, load capacity and position accuracy[5]. A ball screw slide mechanism, used to acquire axial motion is shown in figure1 and Figure2.

a) Ball screw

Most of the force used to rotate screw shaft can be converted to force to move ball nut. Since, friction loss is extremely low the amount of force used to rotate screw shaft is as low as one third of that needed for the acme thread lead screw. Thus, ball screw has high mechanical efficiency.

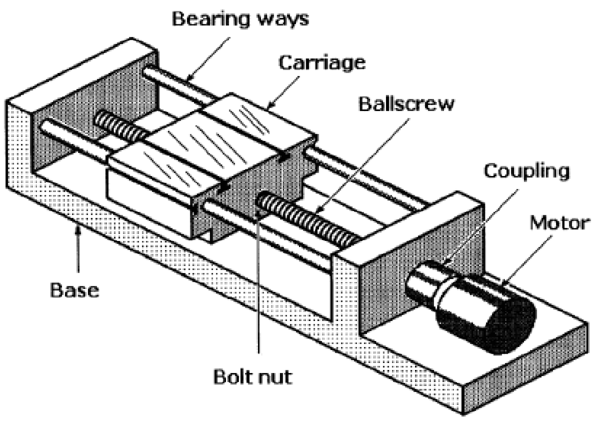

Figure 2. Ball screw slide mechanism

Moreover, because of rolling contact wear is far less then that of sliding contact[5]. Thus, deterioration of accuracy is extremely low. Ball screw moves smoothly enough under very slow speed and load.

b) Motor selection

Widely used motors for motion control systems are stepper motor, permanent magnet DC brush type and brushless DC servomotor. Stepper motors are selected mostly for system because they can be used in open loop without feedback sensors. Stepper motors are also called as pulse motor [4]. These motors can accept digital pulses that turn their rotors a fixed fraction or revolution where they will be clamped securely by their inherent holding torque. Stepper motors are cost effective and reliable choice for many applications that do not require rapid acceleration, high speed and position accuracy of servomotor. Brush and brushless type Permanent Magnet DC servomotors provide high speeds and smoother low sped operation with finer position resolution than stepper motor but both require feedback sensors in closed loops adding to system cost and complexity. Table1 shows the comparison between stepper motor, PM brush type and brushless type DC servomotors.

TABLE 1: COMPARISION OF STEPPER MOTOR, BRUSH AND BRUSHLESS PM DC MOTOR

Parameters	Stepper motor	Brush PM DC	Brushless PM DC
Cost	Low	Medium	High
Smoothness	Low to Good	Good to Excellent	Good to Excellent
Speed range	0-1500 rpm	0-6000 rpm	0-10000 rpm
Torque	High	Medium	High
Feedback required	None	Position or Velocity	Commutation and Position or Velocity
Maintenance	None	Yes	None
Cleanliness	Excellent	Brush Dust	Excellent

Since the shaft of stepper motor moves only the number of degrees that it was designed for when each pulse is delivered, we can control pulses that are sent and hence control the position and speed.

c) Feed through motion

Vacuum feed through can be placed on carriage of slider with the help of perpendicular bracket for axial motion. Linear distance for feed through is user defined with the help of software prepared in Labview. User can enter the distance in mm, set the frequency and direction of the motion. Equation(1) defines the pulse/mm required for stepper motor.

$$pulse/_{mm} = \frac{steps\ per\ revolution}{pitch\ of\ ballscrew} \qquad (1)$$

The speed of hybrid type stepper motor is dependent on step angle and step rate, as define in equation (2).

$$N = \frac{\psi * (s/s)}{6} \qquad (2)$$

Where, ψ= step angle, s/s= step per second and N= speed of motor in RPM.

The mechanism for linear motion of feedthrough is shown in figure3.

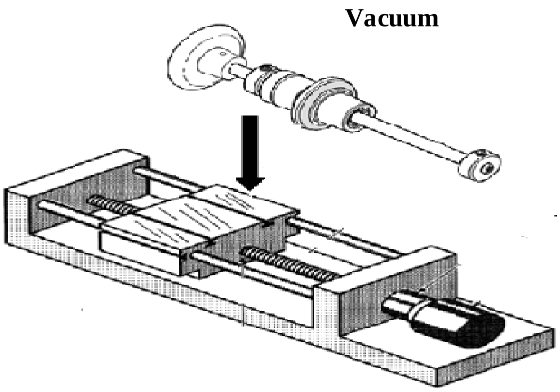

Figure 3. Vacuum feed through placed on carriage of linear slider.

Figure4 shows snap for linear motion, the stepper motor A is coupled with ball screw in a linear motion slider.

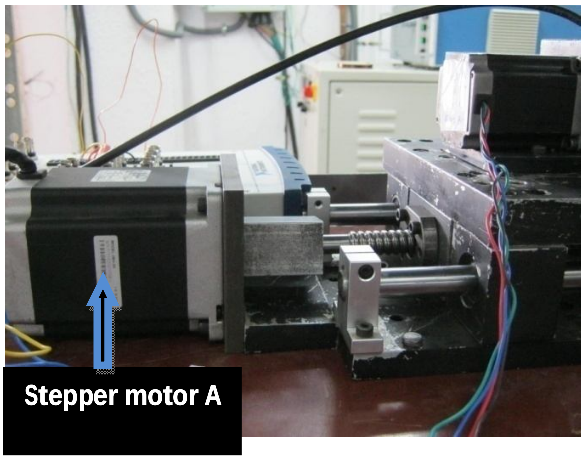

Figure 4 For linear motion stepper motor A coupled with ball screw

II. Radial motion of Feed through

For basic analysis of plasma, density of electrons, plasma temperature, ion saturation current and plasma potential are required to be measured. Thus, it is necessary to move diagnostic probe in the entire plasma volume [6].

For rotational motion of feed through another stepper motor is used. Vacuum feed through is coupled with stepper motor B using a coupler designed and placed on carriage of slider with help of orthogonal bracket as shown in figure5. The relation between the pulse per degree and the step per revolution is given in equation (3):

$$degree/_{pulse} = \frac{360}{steps\ per\ revolution} \qquad (3)$$

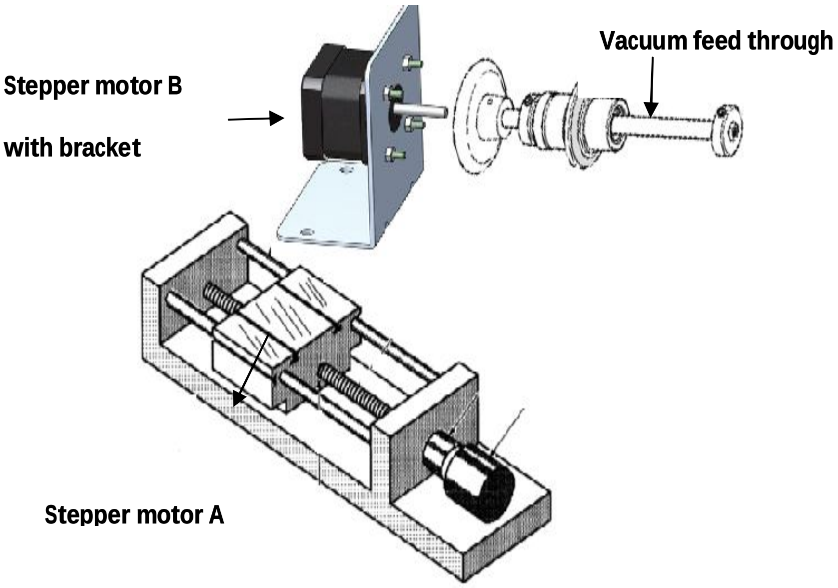

Figure 5 Feed through couple with orthogonal bracket for radial motion.

Figure4 shows snap for linear motion, the stepper motor A is coupled with ball screw in a linear motion slider.

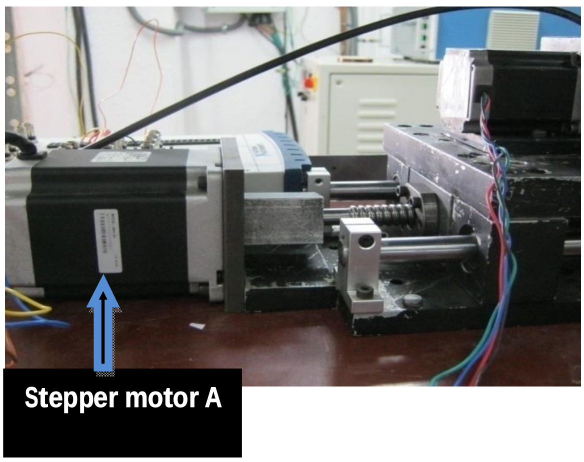

Figure 4 For linear motion stepper motor A coupled with ball screw

I. Radial motion of Feed through

For basic analysis of plasma, density of electrons, plasma temperature, ion saturation current and plasma potential are required to be measured. Thus, it is necessary to move diagnostic probe in the entire plasma volume [6].

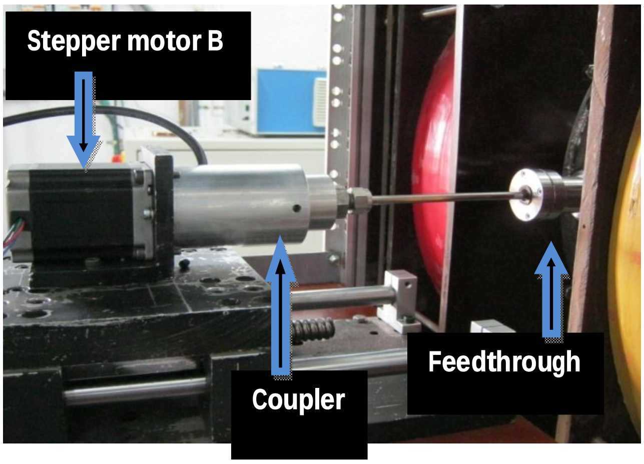

Figure 6 For rotational motion Stepper motor B coupled with feed through

Figure6 shows the snap for the rotational motion, the stepper motor B mounted on orthogonal bracket is coupled with feed through. The NI USB 6008 DAQ is used to generate pulses for both the stepper motors. Direction and the number of pulses for stepper motors are controllable by application software prepared in Labview. USB 6008 DAQ device has 12 digital lines on two ports. Port 0 has eight lines (p0.0.-p0.7) and port1 has four lines (p1.0-p1.3). GND is ground reference signal for digital I/O ports. All lines of ports are individually programmable. Total four digital lines are used to generate pulse and controlling direction for both stepper motors. Also using PFI 0 of DAQ 6008 as an event counter. PFI 0 counts falling – edge events using a 32-bit counter. The pulse generated by the lines are given as input to PFI 0 and hence, number of pulse can be count and controlled using application.

I. Software implementation

Axial and radial motion of feed through are controlled individually using Labview. Initially, feed through is placed linearly to some distance in plasma volume and then radial motion of feed through can be obtained. Figure7 and figure8 shows flowchart for the linear and angular motion of feed through respectively.

In linear motion of feed through user define the distance(mm). Direction and frequency of pulses are also user defined. In angular motion of feed through user defines desired angle for probe rotation, direction and frequency. Figure9 and figure10 shows the front panel for linear and axial motion of feed through respectively.

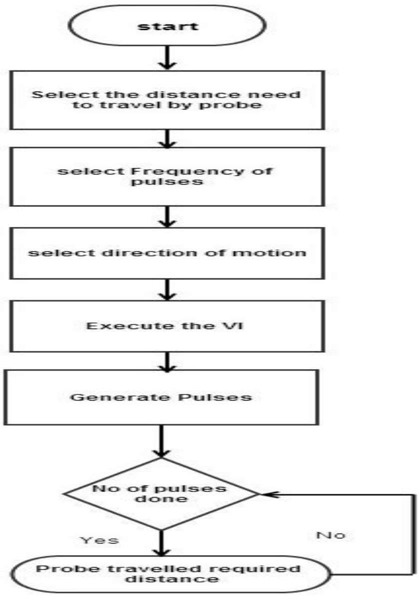

Figure 7 Flowchart for linear motion of probe

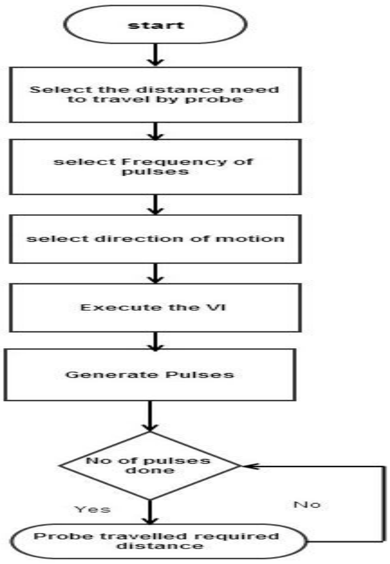

Figure 8 Flowchart for angular motion

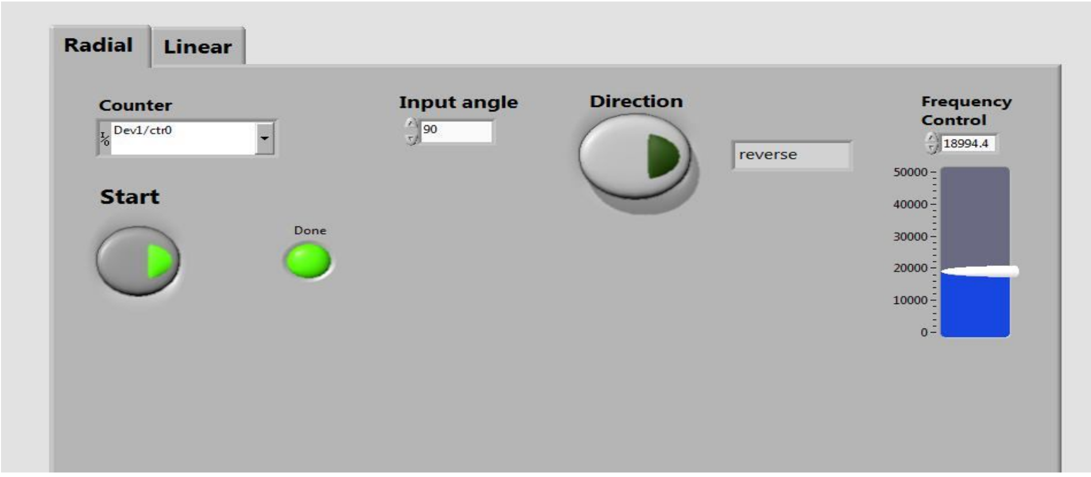

Figure 9 Front panel for linear motion of the Probe

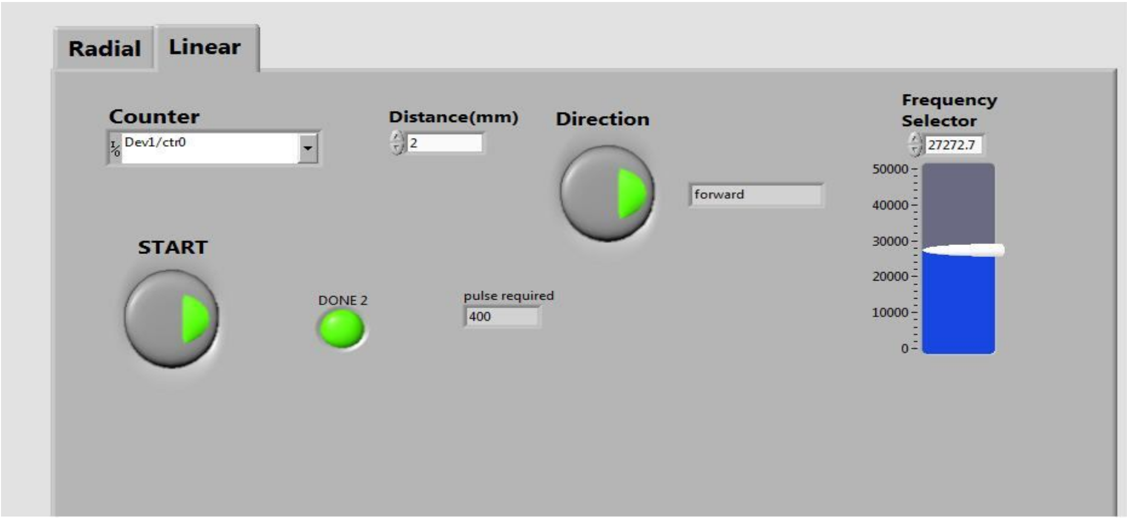

Figure 10 Front panel for angular motion probe.

III. Conclusion

An automated system is developed for vacuum feed through using DAQ 6008, stepper motors and Linear slider accomplished with ball screw. Ball screw mechanism gives a precise and accurate positioning of feed through. Moreover, radial motion of feed through increases the credibility of data acquisition in plasma physics. Thus, data acquisition of plasma parameters will be more reliable and accurate. Controlling of stepper motor using Labview makes it simple, avoiding the programming codes and provide graphical user interface. In plasma experiments, DAQ card can be used to acquire the data as well as to control stepper motors. Thus, an additional circuitry to control stepper motors are being avoided. This system is cost effective and user friendly.

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