



**DESIGN AND DEVELOPMENT OF A LASER PROJECTION PLATFORM AS
ASSISTANT FOR MAPPING THE UTILITIES DURING CONSTRUCTION
PROJECTS**

Lappeenranta–Lahti University of Technology LUT

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ABSTRACT

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Design and development of a laser projection platform as assistant for mapping the utilities during construction projects

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Laser-based projection systems have been under active development over the past few years. Due to benefits such as great brightness, extended lifetime, and excellent electric-optic efficiency lasers are considered the next generation light sources for projection.

The purpose of this study is to display a laser image on the position of installation by using Galvanometer scanning system to assist for mapping Utilities during Construction. A dual-axis galvanometer control system based on hardware and software configuration was designed and implemented, as well as the analysis of Galvanometer scanning system components were explained. The analysis section of the thesis work includes the following parts: A description of the galvanometer scanning system and its related parts, such as (mechanical, electrical, and optical), an understanding of operating principles related experimental work, evaluation of laser projecting techniques, and issues related with the target laser projection applications. Design and development of printed controller board (pcb), microcontroller programming for laser projection control algorithms, and interacting with control software having a graphical user interface were the design part of the thesis work. This study concluded with experimental work and evaluation of the result.

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As for me, the experience of M.Sc. studying is like a road trip. The destination is not the only purpose, the people who you met, the things you experienced, the mountains that you conquered, all these together, give the full meaning of this M.Sc. trip. When look back, there are many people and things that I really want to show my gratitude and appreciation. Firstly, I would like to thank my supervisors Professor Heikki Handroos and Postdoctoral researcher Hamid Roozbahani for their positive attitude towards directing to this job and I would like to thank all people took part in the interview. Also, I would like to show special thanks to Naol Belam and Yeabsira Kebede for their support and encouragement.

The most importantly, I would like to express my appreciation for my family, especially for my parents. Thanks to them for their unconditional support and endless.

Lappeenranta, May 2022

Yonas Taye

LIST OF ABBREVIATIONS

CAD	Computer-aided design.
DAC	Digital to analog converter
DC	Direct current
2D	Two dimensional
3D	Three dimensional
HZ	Hertz
PCB	Printed Circuit Board
SPI	Serial Peripheral Interface

Table of contents

Abstract

Acknowledgements

List of abbreviations

1	Introduction	8
1.1	Research Motivation and Objective	9
1.2	The task of the thesis work.....	11
1.3	Overview of Chapters	12
2	Literature review	14
3	Hardware analysis	16
3.1	Principle of Image generation and galvanometric scanning	16
3.2	Steering of Beams	17
3.3	Distortion correction model for 2-D Galvanometer scanning.....	19
3.4	Galvanometer	21
3.4.1	Principle of operation of galvos-scanner.....	22
3.5	Mirrors.....	23
3.6	F-theta	24
3.7	Two types of Scanning Systems	25
3.8	Technical Details:.....	25
3.8.1	515nm 5mw Green Laser Module Diode	25
3.9	Laser Control.....	25
3.10	Servo Driver Board	26
3.11	Power Supply	27
4	Design of hardware & software.....	29
4.1	Electronic Parts for the circuit.....	29
4.2	The Theory of the Controller	29
4.2.1	Controller for motion.....	30
4.2.2	ATmega328P Microcontroller.....	30
4.2.3	DAC.....	31
4.2.4	GALVO	32
4.3.	Design of PCB Control board	32

4.4	Software Design for Controller Board	32
4.5	GUI Design	33
4.6	Design Method	33
4.7	Mechanical Design	34
5	Experiments & conclusion	35
5.1	Laser Pointer	35
5.2	Method	35
5.3	Experimental Setup.....	35
5.4	Experimental Results	37
6	Conclusion.....	41
	References.....	42

List of Figures

Figure 1. Laser projection on the wall	9
Figure 2. Laser projection System	10
Figure 3. Galvanometer scanning	11
Figure 4. Laser projection step	17
Figure 5. Typical Beam Steering System	18
Figure 6. Cartesian System for Scanning.....	18
Figure 7. 2D Galvanometer Scan Coordinates.	20
Figure 8. Galvos-scanner layout	22
Figure 9. Principle of operation of the galvos-scanner.....	22
Figure 10. Dual-axis Galvo Modules.....	23
Figure 11. Servo Driver Board	26
Figure 12. Servo Driver Board Schematic Diagram.....	27
Figure 13. Control of laser projection.....	29
Figure 14. Compute the signals	30
Figure 15. Control board PCB	32
Figure 16. Projix	34
Figure 17. Experimental Setup	36
Figure 18. MCP4822 device	37
Figure 19. Circle laser projection on the wall.....	37
Figure 20. Rectangle laser projection on the wall	38
Figure 21. Triangle laser projection on the wall.....	39
Figure 22. Crossline laser projection on the wall	40

List of tables

Table 1. Electrical Characteristics of Galvos Modules.....	26
Table 2. Parts for the circuit.....	29

1 Introduction

Laser technology are widely used today in a variety of fields such as Aircraft industry, automotive manufacturing, military and other applications. Technological advancements over the past few decades have resulted in significant advances in laser technology. Laser projector has received a lot of attention and is most rapidly developing in digital manufacturing industry in the world. It has several applications in which it may be used to increase production and improving quality.

Laser projector is the techniques that create an image on workspace by rotating the laser beam on the screen with high speed. The laser beam can show in different two ways. The first is the laser beam that patterns are created on space and the people can see the image on the air. The other one is through graphics which laser beam are generated on the workspace by moving the laser beam to display a graphical image on the screen. It possible to project the graphics onto big surfaces area if the power of the laser is enough.

The Galvanometer scanning system is used in laser display systems to show CAD image on work space. Two orthogonal mirrors are connected to each other to reflect the location of the laser in the operating areas. The high-speed motion of the galvanometer gives the appearance of complex forms such as lines, arcs, and circles.

E. D. Ledbetter et al analysed Computer Design and Analysis creates a wide range of electronic product description of the product. Improved viewing, copying and precision of 3-D images improve quality and reduce design costs. Laser Projection appears as an effective way to clearly and accurately display computer model data for employee instructions. Some systems adapt to the sensors found in the tools thus avoiding costly setup.

Laser technology is also being used in the construction industry for positioning and measurement purposes. Laser Projection for Mapping in construction is rarely used, as the technology is not yet fully developed. The object of this study was enable without physical templates in any construction processes by showing the laser beam for mapping Utilities in the construction site. The 2D laser projection positioning technology can realize the projection positioning in right place, reduce costs, and improve accuracy of the construction.

1.1 Research Motivation and Objective

This thesis mainly focused on the realization of a Laser Projection by using the galvanometer scanning system to assistant for mapping the utilities during construction that includes laser source, two-axis galvos commercially available and electronics. The hardware and a advanced software interface is used to control the system using an electronic design controller. In addition to improve the quality of the laser beam focusing on the material being processed f-theta has been evaluated. The laser projection principle is visualized in the figure 1.

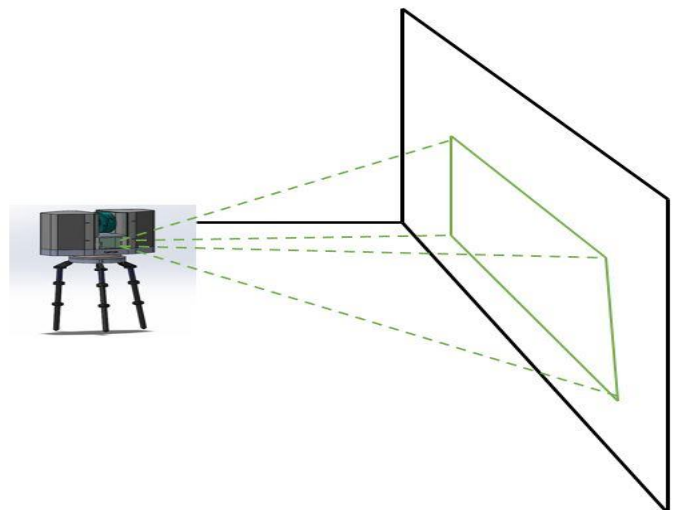


Figure 1. Laser projection on the wall

The laser beam strikes the x- mirror, then vertically strikes the y- mirror, which is then focused and projected onto the workstation using an F-Theta lens for this thesis. The rotation angle of the mirror is between -25 and 25 degrees, and movement of the mirror is controlled by voltage. When a laser ray is incident, it is direct to the X axis. As the mirrors are rotated, the deflection of the x and y axis angles is vary. The limitations of the conducted research were considered: laser projection area is taking into consideration because of the rotation angle of the mirror is limited. Inertia effect is not taken to account when investigating laser projectors to ensure high- quality laser picture projection.

The objective of this study, based on the limitations outlined above, are:

- Analysis of Galvanometer Laser Scanner as a laser projection for coordinate measuring instrument.
- Designed and development of printed controller board(pcb) to control the source of laser radiation; Reception of information from the rotation angle, Tool mechatronics control, the sensor; Management of galvanometric scanners;
- Development of program for laser projection control algorithms based on hardware and software.
- Analytical review of existing devices for laser projector.

Following figure 2 shows general view of laser projection system.

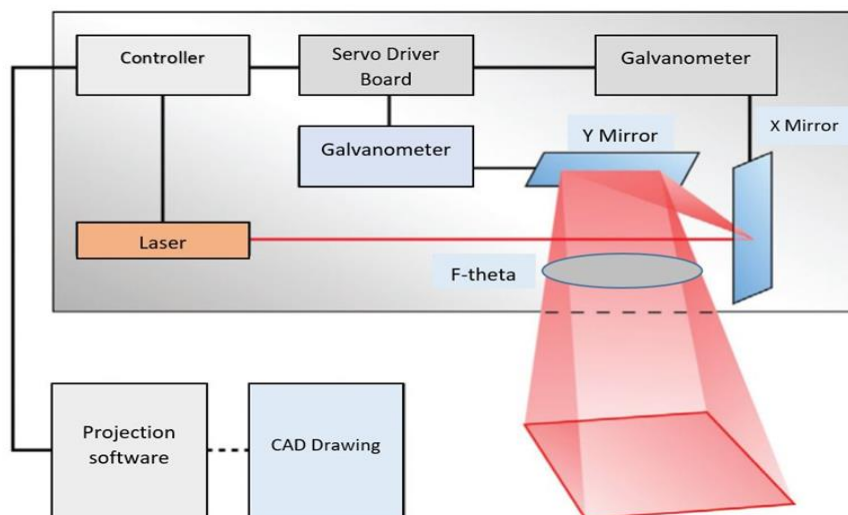


Figure 2. Laser projection System

If the project area is x - y coordinate and laser ray value on the operating bench is $(0, 0)$. When turn on the laser ray on the operating bench, the scan trajectory can be defined. Scanning of the x - y coordinate of galvanometer is shown in figure 3.

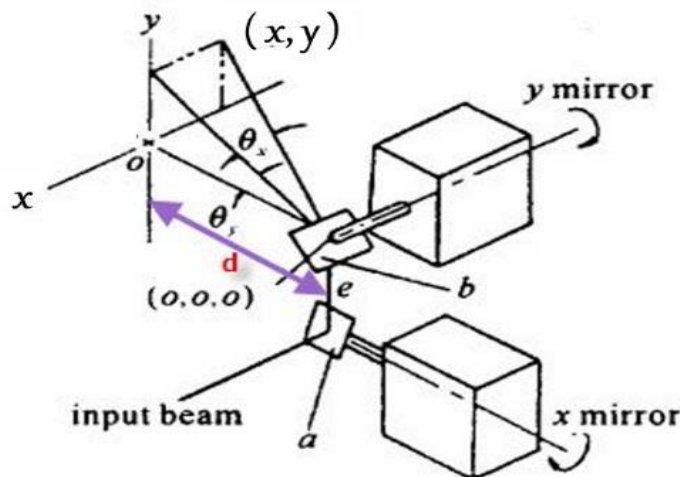


Figure 3. Galvanometer scanning (Jigang et al., 2018)

1.2 The task of the thesis work

This thesis project is divided into four parts, as follows:

Phase I – Design

In the design phase, all the necessary components that would be required, in order to Design and develop laser projection was discussed. The primary goal for the laser projector will be decided and its maximum capabilities were established. The galvanometer for the laser projectors would be chosen and, mathematical model of a galvanometric scanner for controlling a laser beam were done.

Phase II – Build and Program

In this phase, all the components will be mounted to make a laser projector. The initial all wires are connected with a control board, servo driver, and galvos to test all the laser

projector will be completed, along with the laser pointer. Further, initial tests will be done on the power supply and galvos mirror.

Phase III – Test

After the laser projectors is assembled, it will be tested by a completely wired system. The projector would be tested extensively to verify that the galvos mirror rotate consequently move through the predetermined locations. Troubleshooting and tweaking of the laser projector will be done.

Phase V – Experimentation

After establishing communication between the Arduino UNO, control board and the processing GUI will be tested then the experiment shows the laser beam circle on the wall. After the galvo and control board worked, the angle of projection will be modified to be bigger, for this research, a rotation angle ranges between -25 and 25 degrees would be designed. The first test directed the laser projection to project directly to the wall. As a result, this phase would bring the project's goal to a close.

1.3 Overview of Chapters

This thesis is composed of five chapters, each of them deals with a different aspect. The first part is an introduction. This chapter is divided into three sections. Part 1 describes the Laser Projector and describes the Laser Projection Platform using a galvanometer scanning system that allows to show CAD-based laser images into geometric objects to assist in mapping during construction projects. Part 2 discusses a brief presentation of important findings from previous research, and the third explains that previous research has not been considered or evaluated.

Chapter two Provides information on reviews of scientific research done on laser projector and topic related to galvanometer scanning.

The third chapter is the analysis of hardware components (Laser, Focusing optic, galvos controller, and PCB control board) with an imaginary PCB base and performance simulation. The idea of creating a specific image by the galvanometer scanning principle on the basis of integrated the laser beam's movement into two axes as well as simple control ON / off or laser beam switching, Laser control, and the power supply for the system was explained in this chapter.

Chapter four is a summary of software and hardware design. The software development environment that would be utilized for coding, Electronic Parts for the circuit for pcb board, the theory of the Controller and Controller Board for the galvanometer scanner was discussed. Mechanical Design used for Testing laser projection require correct alignment of optics and their proper connection to electrical systems included in this chapter.

The experimental and conclusions are presented in Chapter five. The main purpose of the graduation thesis has been achieved.

2 Literature review

On the development and research of laser projection systems, interest in the scientific community does not stop at the present time. The main reason is the continuous improvement of the design and characteristics of beam positioning units in equipment for additive manufacturing, as well as in laser measuring systems. Both directions fit into the strategy for the development of digital production. Some researchers have been done on the practical applications of laser projection.

Purkhet et al. (2008) studied precise and efficient approach for creating graphics using a laser projection. According to this research the first section tries to overcome the problem of unexpected laser trails by putting a basic pattern to the test. Discuss a strategy to adjust for the mistake induced via the inertia factor for various mirror degrees of rotation introduce in the second part.

Kobiela et al. (2021) have investigated a projection head, which is in charge of projecting necessary characteristics, including a head for capturing images, which permits placement of the complete system in reference to the examined item and easy measurements. Following a review of available standards, their study was agreed that the accuracy of the system tested would be carried out utilizing a ball-bar standard. Prior to measurements, the system's capacity to acquire and identify reference sphere pictures was validated.

Meng et al. (2019) In this study a two-dimensional plane transformation probe's underlying error is being discussed. Their investigations show that this approach does not introduce a computer rotation system operating in real-time error, which may considerably enhance the accuracy of System scanning using a laser and yield sufficient results for correction of both pincushion distortion and normal line distortion.

Xi Luo et al. (2017) studied to bring the laser density similar to the tool to be processed, two methods of control were discussed: the first was a control algorithm to improve the scanning path based on changing scanner features and precision requirements, and the second was a method to adjust depending on laser changing scanning rate.

Speed up position allows to display templates on workspaces through the use of virtual methods and certain procedures for controlling. Chellappan et al. (2010) studied the purpose of marking it is possible to eliminate or greatly reduce the use of manual measurement instruments and tools. Physical templates are no longer necessary, and the time required for operational and performance positioning is reduced. There are disadvantages to employing this strategy over the usual way due to its high degree of complexity. It necessitates a strong understanding of coordinate metrology and CAD procedures, with skilled operator. Virtual positioning systems must also be handled correctly because they are more in danger of being damaged under industrial conditions than traditional templates.

Kobiela et al. (2021) According to their study in the process of preparing a task for processing, a CAD model previously prepared, and data on the position of the processed objects on the printed circuit board are extracted from k. Then the data is grouped by processing sectors, sorted, and optical distortion correction is applied to each of the formed groups. System path according to previously known tabular data. At the final stage, the prepared data is transferred to the executive devices. Shows the algorithm of the device when drilling holes. At the beginning of XY processing, the drive moves the object to be processed to the first position (sector) and punches all holes that fall into the processing field of the scanning module. When the processing in the first sector is completed, the XY drive moves to the next processing sectors. The disadvantage of using this control algorithm is the loss of the overall processing performance due to the long (comparable to the processing time in a small field) time of changing the position of the "high-inertia" scanner.

3 Hardware analysis

The analysis of the hardware components were discussed in this chapter. The characteristics of their main components, steps of laser projection, Distortion correction, technical Details and optical system are considered.

3.1 Principle of Image generation and galvanometric scanning

The idea of creating a specific graphic shape by galvanometric scan is depending on the laser beam's combination movement into two axes and simple control on / off or a laser switch. The incoming laser first strikes a shiny surface - called an “X-axis mirror” – That connected on a galvos rotor shaft, and as a result, the reflected pole is able to move along only one axis as a result of the rotation of the axis -X. mirror.

The light of the laser is transferred to a Y-axis mirror and provides additional directional guidance on the second axis so that the beam shown at the end is a joint, a dual-axis scanning area can move on both the X and Y- direction at the same time. In contrast to the Mirror enclosure with X-axis; the Y-axis beam working there is no single point formed by the mirror. Instead, we generate a line on the longitudinal on the Y-axis mirror as a result of the rotation of the X-axis mirror. This is why Y-shape glasses (mirror) are often larger in size when compared to X-axis mirrors in height. By turning it ON AND OFF the intensity of the laser beam is controlled then the result of controlling the laser beam the desirable images and patterns can be found in the target area. The step of laser projection shown in figure 4.

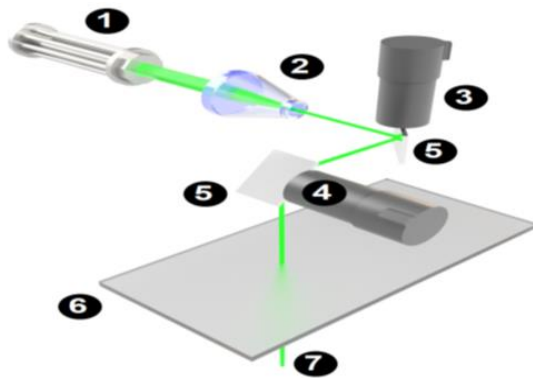


Figure 4. Laser projection step (Kobiela, 2021)

Fast moving of galvanometers create complicated projection that the human eye interprets a laser beam on the workspace.

1. Laser beam
2. Optical focus
3. X-Galvanometer
4. Y- galvanometer
5. The Mirrors
6. Safety glass
7. Laser Beam output

3.2 Steering of Beams

The laser beam is fixed and strikes two mirrors mounted on vertical galvo at axes X and Y. The beam then exits the device through a safety glass and appears in the work area. Beam Steering System for laser projection is presented in figure 5.

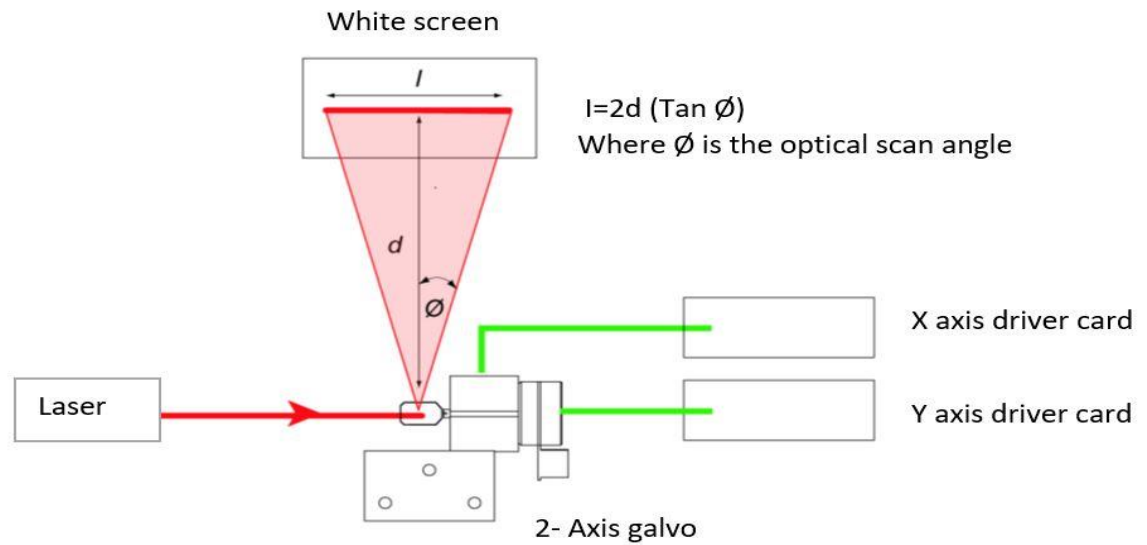


Figure 5. Typical Beam Steering System

For a dual axis directional system, without using an additional focus method or simply using a standard lens; the movement on each axis of a laser beam described. The scanning system for Cartesian System presented in figure 6.

$I = 2d \tan \phi$. Ex: Let the optical- angle $\phi = \pm 25^\circ$

$= 2d * \tan 25^\circ$ so the galvos angle is that scanned $\pm 12.5^\circ$

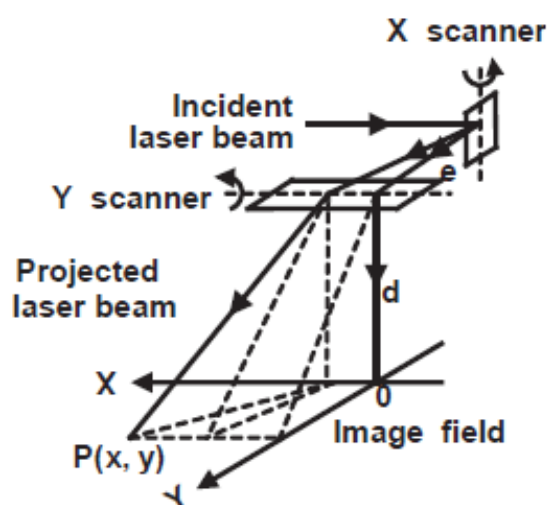


Figure 6. Cartesian System for Scanning (Jigang et al., 2018)

Suppose the X-axis of the fold-over angle(deflection angel) galvanometer is θ_x , the Y-axis of the fold-over angle(deflection angel) galvos is θ_y , the gap between the X-direction of the galvo and the Y-direction of the galvanometer is e in the vertical direction, and d is the area distance galvo -Measurement axis Y in a straight line . Then coordinates of point P can be stated in terms of the ratio of the deflection degree of the X-axis galvo to that along the Y-axis galvos, Δfr -defocus error and mechanical scanning angle of the X scanner.

$$\begin{aligned}
 x &= e \tan \theta_x + \sqrt{d^2 + y^2} \tan \theta_x = \left(e + \frac{d}{\cos \theta_y} \right) \tan \theta_x \\
 y &= d \tan \theta_y \\
 fr &= \sqrt{x^2 + (e + \sqrt{d^2 + y^2})^2} \\
 \Delta fr &= \sqrt{x^2 + (e + \sqrt{d^2 + y^2})^2} - (e + d) \\
 \alpha_x &= \frac{1}{2} \theta_x = \frac{1}{2} \arctan \left(\frac{x}{e + \sqrt{d^2 + y^2}} \right) \\
 \alpha_y &= \frac{1}{2} \theta_y = \frac{1}{2} \arctan \left(\frac{y}{d} \right) \\
 y &= d \tan \theta_y
 \end{aligned} \tag{1}$$

3.3 Distortion correction model for 2-D Galvanometer scanning

The distortion map of the scan point (x', y') . The coordinate of the actual graph corresponding point (x, y) and the relationship between (x', y') and (x, y) . The Galvanometer Scan Coordinates are shown in figure 7.

$$\begin{aligned}
 x' &= f(x, y) \\
 y' &= g(x, y)
 \end{aligned} \tag{2}$$

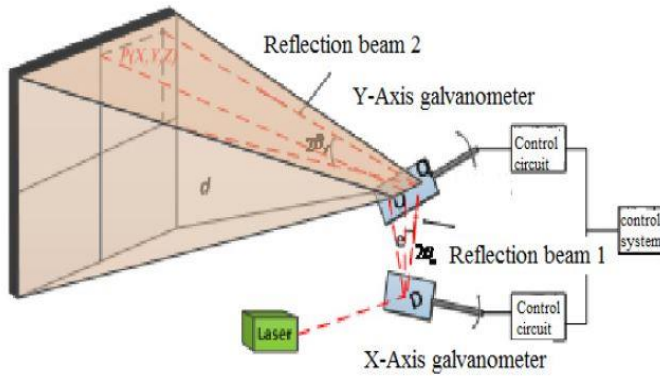


Figure 7. 2D Galvanometer Scan Coordinates (Meng et al., 2019).

This relation, the real point, determines the true point and the distorting point. The distortion points and the actual points have an active link to check that we have real n points (x_1, y_1) , $(x_2, y_2) \dots$ find (x_n, y_n) and these are known as constraint points for associated points of distortion points. On the a distorted map (x_1', y_1') , (x_2', y_2') ... (x_n', y_n') beam shift spot in direction of x may be calculated using on the optical reflectance ratio (Meng et al., 2019), which

$$x = \left(e + \sqrt{d^2 + y^2} \right) \tan 2\theta_y \quad (3)$$

$$\text{Let } k = e + \sqrt{d^2 + y^2}$$

$$X = K. \tan 2\theta_y$$

In Y direction, the reflected light is not distorted and the correction can be obtained from the equ (8) and (10)

$$x' = \left(\frac{x}{k} \right) (e + \sqrt{d^2 + y^2}) \quad (4)$$

$$y' = y$$

Correction of the linear error, a linear transformation technique straight line function can be used to implement it $y = \alpha_1 x + \alpha_2$ and $y' = \alpha_3 + \alpha_4$ this after the distortion line is parallel to the ideal straight line and distortion that is distorted. After that it translated $n_1 y + n_2 = \alpha_3 x (m_1 + m_2) + \alpha_4$

Conclude that the relation between the distortion position (distortion point) x', y' and the ideal point (x, y)

$$\begin{aligned} x' &= m_1 x + m_2 \\ y' &= n_1 y + n_2 \end{aligned} \tag{5}$$

For the above equation the relation between actual point linear distortion and the distortion point is obtained

$$\begin{aligned} x' &= \left(\frac{x}{k}\right)(e + \sqrt{d^2 + y^2}) + m_1 x + m_2 \\ y' &= (n_3 + 1)y + n_4 \end{aligned} \tag{6}$$

$$\text{Where } k = e - \sqrt{d^2 + y^2}$$

3.4 Galvanometer

It appeared in the late 1970s, and began to be widely used in the 1980s, in view of the boom in electronics, as well as laser technology. There is a certain set of implementations of the galvo-scanator principle, which consists in creating an electric field and using it to remove an object from a basic, potential state that is maintained by a constant magnetic field. The return to the basic state is also carried out by the torsion, which is made in the form of either a metal rod or a spring.

A motor moves the mirror in a galvanometer, and a detector feeds the system with mirror position information. Closed loop circuits are also used in commercial galvanometers to reach the required position with great precision. The layout of Galvos-scanner presented in figure 8.

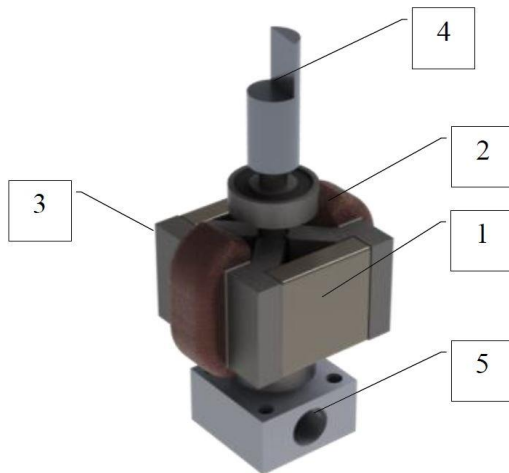


Figure 8. Galvos-scanner layout (Gilyazov, 2018)

The galvanometric scanner proposed in this paper belongs to the class of resonant scanners with feedback (closed loop).

3.4.1 Principle of operation of galvos-scanner

Consider the principle of operation of galvo-scanner in more detail are presented in figure 9.

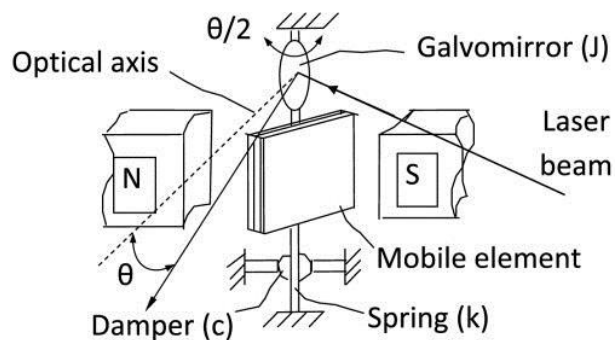


Figure 9. Principle of operation of the galvos-scanner (Gilyazov, 2018)

Let us define the criteria for the required characteristics of such sensors:

1. Fast response - Galvo scan rate is from 20 Hz to 1.5 kHz for the most advanced samples;
2. Angular resolution - the galvo scanner is capable of positioning up to 25 thousand points in space, which, with a working area of and a working distance from the scanner to the object. The dual galvanometers are shown in figure 10.



Figure 10. Dual-axis Galvo Modules (Thorlabs, 2011)

An optical mirror is attached to the shaft of the galvo along with the motor, resulting in a completely scanning galvanometer with function remarks arriving to the controller via a detector. So as to offer faster reaction times and a higher resonant frequency, the GVS collection makes use of a moving magnet layout in place of a desk bound magnet and rotating coil design. An optical sensing gadget placed inside the motor housing is used to encode the location of reflection. The fast rotation shaft angular acceleration reasons length, form, and inertia of the mirrors to play a critical position inside the layout of excessive overall performance galvo device.

3.5 Mirrors

At the end of the motor shaft there is a mirror assembly that redirects the light beams according to the width of the motor angular shaft. At high speed galvos scanning applications and high frequencies are required, so the actuator's and mirror assembly's inertia might cause greatly affect the performance of the device.

The mirrors utilized are suited for usage from 400nm to near infrared (2000nm), have a protective silver coating, and can tolerate a power of 100 to 150W / cm².

3.6 F-theta

To improve the quality of the laser beam focusing on the material being processed, an optical system was discussed that consisted of several lenses and implemented a flat focal surface. Such a system is known as a flat field scanning lens, and the height of the object image in it can be described as:

1. Changing the f-theta of the lens, so that the area where the focal spot has a minimum value (for example, from 20 to 60 microns) is maximum, while distortion is minimal. The achievement of this goal is possible, in our opinion, only through the construction of a lens f-theta model, with the use of appropriate software packages, since the variability of changes and the complexity of calculations cannot be solved in an analytical form.
2. Modification of the galvanometric scanner in terms of the scanning angle. Galvo-scanner is a complex multi physics object, in which there is mechanics in dynamics, electrical action and magnetic. The currents in the windings can reach tens of amperes and flow in milliseconds. All this affects geometry, the strength of magnets, currents, even the choice of material for the torsion bar.

To obtain the highest scanning frequency, a galvanometric scanner model and the associated software package must be built.

3. Improvement of the rotation angle sensor. Changes in the objective and galvanometric scanner, expansion of the scanning range will immediately require improvement of the feedback angle sensor, in particular, a change in its design to obtain a linear response section corresponding to the new scanning angle;

3. Production of the installation and verification of characteristics. Verification of the obtained models should be carried out by developing solid models of these devices, drawing up a methodology for their manufacture and implementation in glass and metal. Performance verification will also require the development of an appropriate methodology and its implementation.

3.7 Two types of Scanning Systems

There are two types of position of X and Y scanner in dual galvanometer scan system for practical application. The first is the pre-pose scanning technique, which involves placing the Scanners, both X and Y in front of the field scanning lens (f-Theta lens). Another system is called the post-objective scanning technique, which involves placing behind the scanners are the x and y-laser beam. the normal lens (Figure 12). The field scanning lens focuses in the pre-target scanning mechanism on the building associated with the viewing field without blurring the errors near the viewing links. The disadvantages of scanning the lens in the first place.

3.8 Technical Details:

During the experimental studies green laser Module Diode 515nm Laser Beam are used. .

3.8.1 515nm 5mw Green Laser Module Diode

- Green Laser Module 5mw 3V 515nm Direct Diode
- Working Temperature Range: -20 °C ~ + 50 °C
- Glass Laser 510nm Dot Laser Beam
- 515nm DC3V Laser
- Green Diode Laser Module with Fixed Focus

3.9 Laser Control

Instead of using the same communication methods, often involving multiple lines of data as well as many other problems that may arise due to the high number of wiring connections, the main philosophy behind the design control board was to identify the most efficient but integrated design make the system connection easier; using consecutive communication channels to communicate with the SIP; instead of using compatible communication methods, which often include multiple lines of data as well as many other problems that may arise due to the high number of cable connections; In this work, the Laser can be controlled by means of a software communication.

3.10 Servo Driver Board

Galvo has its own servo drive architecture-based specialized driving and control parts.

The servo circuit convert signals from the local detector and then drives the actuator to the required place in the output controller using the local error, speed, and the combination of current words. Board scanners employ non-compliant, Class 0 servos, which allow for faster system speeds than servo integration systems and can be termed vector configuration applications. The electrical characteristics of galvanometer modules are listed in table 1.

Table 1. Electrical Characteristics of Galvos Modules

	X- Galvo	Y- Galvo
Rc (coil Resistance)	2.49 Ohm	2.50 Ohm
Le (Coil Inductance)	166uH	168uH

It can be expected that drivers can vary from one to another. However, due to the difference in size, shape and rotor mounted inertial mirrors are installed, and each Galvo must be operated with the matching driver. The setting of the galvos is used with default settings from factory without any modifications or other settings. In addition, a built-in filter at the power amplifier stage's input is built-in and eliminates advanced sound. Each driving card requires the use of an electrical splitter. The output voltage has a signal connected to the driver $\pm 15V \pm 18V$ (eg: current sensor A, current sensor B, car coil signal). The control panel supports multiple modes. The first way makes it easier to use, and the second increases the bias level in standards mode. The Servo Driver Board are visualised in figures 11.



Figure 11. Servo Driver Board (Thorlabs, 2011)

Figure 14 represents an overall view of a driver board for galvanometer. The servo drivers for the X-axis and Y-axis galvos are separate. Both of them they have their own dedicated servo drivers. The electrical properties of the X and Y galvos are almost similar, depending on the measurements done on them: The driver board activated by a control signal from the outside, but the ability to disable or replace the on board controller cannot be considered an operating system problem. 15V output low impedance output 15V on the board cannot be considered a malfunction of the operating system. Low output impedance +15V output 15V. Schematic Diagram Servo Driver Board are presented in figure12.

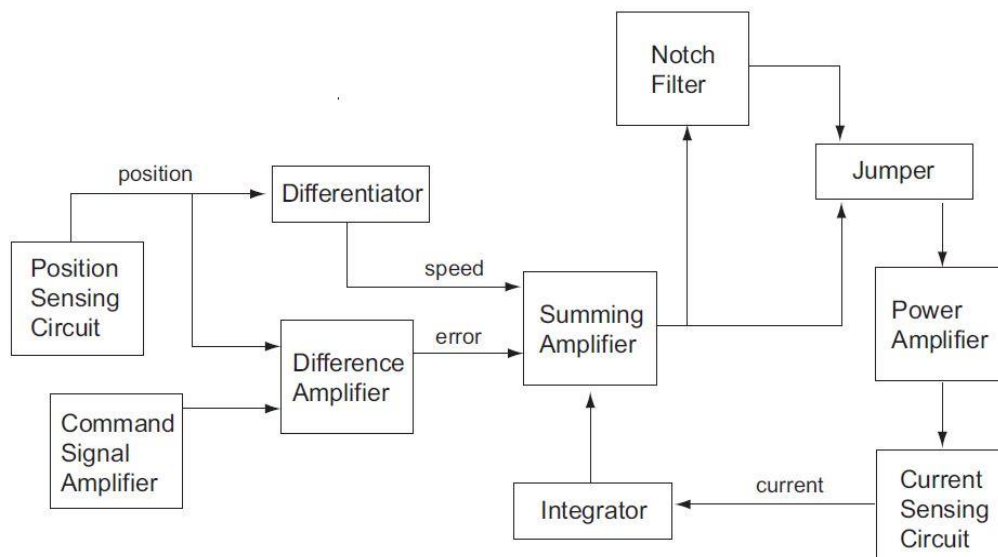


Figure 12. Servo Driver Board Schematic Diagram (Thorlabs, 2011)

3.11 Power Supply

It has been especially designed for galvo controller boards, Thor labs recommends the use of it to strength the controller boards. All cables which might be required to connect to the motive force playing cards are protected with the GPS011 in order that it is able to strength up to two driving force playing cards below any pressure situations. Further, customers have the option of incorporating the boards into current systems with the aid of the usage of a 3rd party electricity supply.

It is vital to know that energy voltage source and cutting-edge scores are in the acceptable range. With the help of power electronics, cut up rail DC components ranging from 15V to 18V are required. Because the forums itself have regulators, the playing cards no longer require a strictly controlled supply. On each rail of the motive force cards, there could be no modern-day draw more than 1.2 A. Furthermore, for the best overall performance, the supply must be capable of delivering height currents of up to 5A on each rail.

4 Design of hardware & Software

Microcontrollers and other embedded hardware solutions are widely used in the majority of today's applications. When evaluating the electrical hardware requirements for laser projector systems, a somewhat modest control platform with a computer interface becomes necessary (such as galvo scanner & control). A supervisory board based on a digital signal controller was devised and installed to suit these needs. The electronic parts used for developing pcb are listed in table 2.

4.1 Electronic Parts for the circuit

Table 2. Parts for the circuit

Description	Name on circuit	Quantity
MCP4822 12 bit dual channel DAC	MCP4822	1
TL082 dual OpAmp	IC1, IC2	2
1k Resistor	R1-R6	6
10k trim-potentiometer	R7-R10	4

4.2 The Theory of the Controller

Control of laser projection was implemented during the development. The way to control the system presented in figure 13.

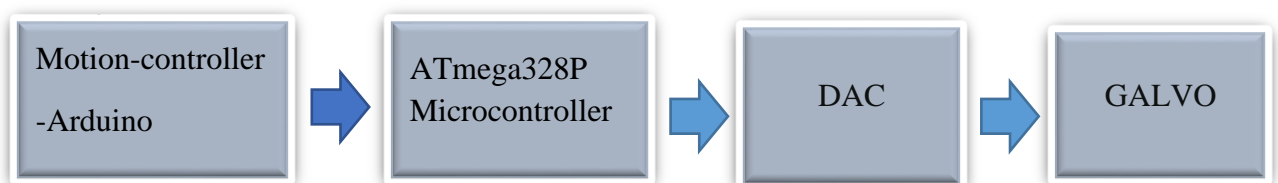


Figure 13. Control of laser projection

4.2.1 Controller for motion

The step and direction signals are generated by the motion controller.

4.2.2 ATmega328P Microcontroller

The Arduino UNO microcontroller is the heart of this controller. This microcontroller has several tasks to do. These tasks are:

- a) Measure the signals

First, the input signals must be measured. In this situation, step and direction signals will be measured.

- b) Compute the signals

The controller calculates the signals the correct value for the digital to analog converter. The reason is the galvos generates a nonlinear polar coordinate system, a modest computation is required to provide a linear relationship between step and the actual moving laser. Here's a rough sketch of calculation shown in figure 14.

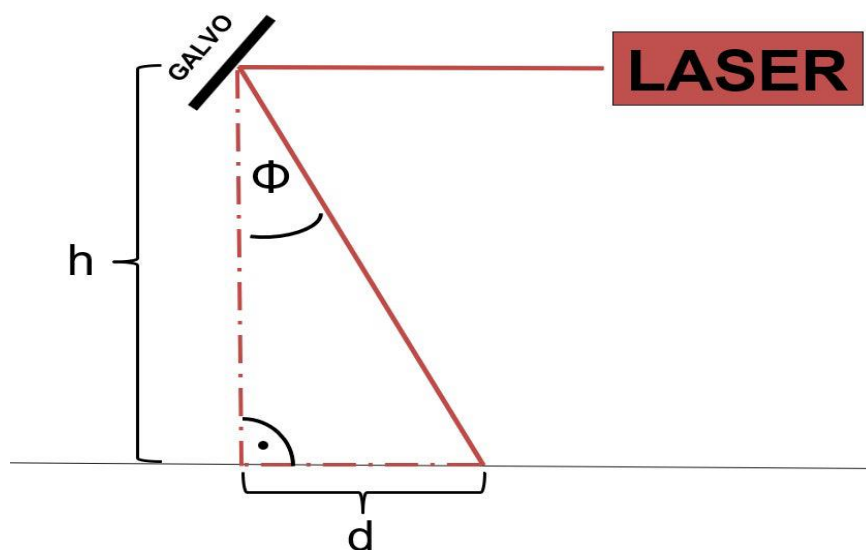


Figure 14. Compute the signals

The next step is to figure out the calculation. From 12bit Digital to analog converter, output a voltage between - 5 and +5 in steps of 0 to 4096. With the galvanometer the totally scanner angle is 25 at -5 - +5V. To consider the angle of phi -12.50 to +12.5, to determine how far the angle should be used to scan in the range of the scan filed of 100mmx100mm. Based on the values of phi and d=50, the h value is 225,5mm. With a little formula brought d in relation to phi using tangents, in order to change the angles into "DAC-values," using the tangents.

$$\theta(d) = \tan\left(\frac{d}{225.5}\right) \cdot \frac{4096 * 14.4}{2\pi}$$

c) Send the following values to the DAC

The DAC and Arduino UNO communicate through SPI, USB communication with a PC and laser, and control.

4.2.3 DAC

To properly set the laser beam on the piece of work in the desired location, the drive platform and controller of galvanometric signals require signals, low noise, clean, reasonably large bandwidth control signals. Selected 12bit DAC "MCP4822 modules have a low glitch impulse of 0.5nV • sec and SPI connectivity up to 50MHz. The developed PCB employs low-frequency audio op-amps as output buffers for a low-required impedance generation, resulting in bi-polar power. Onboard generates DAC supply bias voltage is divided (i.e. V 5V) Outlet two driver. -jumper voltage selection, with the possibility to choose between 4.096V and 5V reference voltage settings.

Because the DAC is unipolar 0- 4,2V and you need +-5V bipolar for the ILDA standard, you need to build a circuit with some OpAmps. Using TL082 OpAmps. To build this amplifier-circuit twice, because control two galvos. The two OpAmps are connected to -15 and +15V as their supply voltage. Because the Arduino UNO used has no build in DAC, an external DAC was used.

4.2.4 GALVO

The last part is rather simple. The Output voltage of the two OPAmps will be connected to the ILDA Galvos drivers. Then the galvos should be able to control with step and direction signals.

4.3. Design of PCB Control board

The control board was designed during development, it was decided to design in a pcb board. When designing, the possible influence of the power unit on information signals was taken into account, and therefore they are separated. The developed pcb are presented in figure 15.

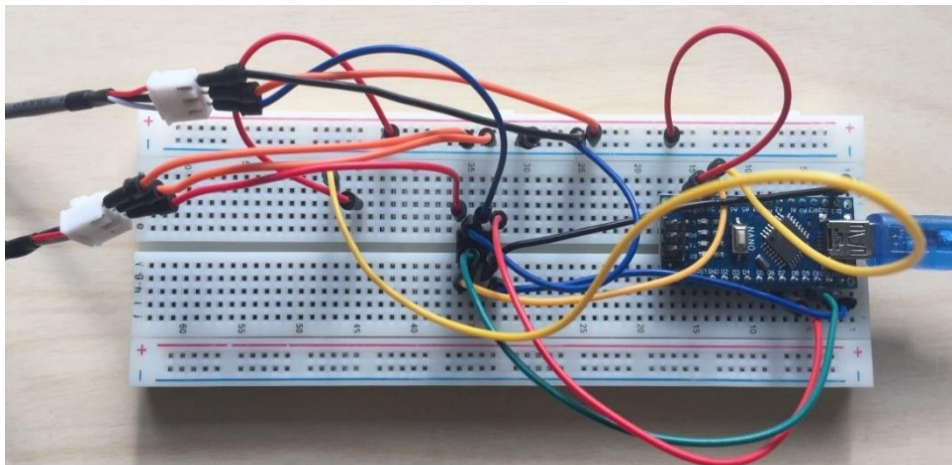


Figure 15. Control board PCB

4.4 Software Design for Controller Board

Following the design of the controller board, the next stage was to choose the software development environment that would be utilized for coding. Because the Arduino programming environment device language, as compared to other language-based technologies, often delivers faster code development. The microcontroller platform code is used in such a way that its operating algorithm is based primarily on interference; that means, it is carried out in an event-driven fashion, resulting in seamless performance, and time

efficiency, especially when considering a variety of tasks such as information collection, transfers location data to Digital to analog converter via Serial Peripheral Interface bus, USB. PC and laser communication, external user interaction and control.

4.5. GUI Design

Embedded technology, which might necessitate for the transferring of operating instructions or data from a digital control area to the system are primarily concern in Industry or scientific researcher, so that "intermediate step" software can be both easy to control, Device and data transfer between digital control, as well as simplifying system integration. Most of the professional laser projection systems today use controls based on user-friendly images known as GUIs (graphical user interfaces); the windows form-based python GUI application is designed to meet the same criteria.

4.6 Design Method

The preferred strategy was to use part of the available python software.NET. The application can send usable output extensions, eliminating the need for further software installation, allowing the system to be used on any USB-enabled computer. Other benefits include: serial port communication can be easily utilizing Windows in an object-based manner; many of the essential advantages of the respondent's time can be added to affect the system function, such as downsizing, and having limited time operation.

4.7. Mechanical Design

Testing laser projection require correct alignment of optics and their proper connection to electrical systems. Additional mechanical components were developed in the Solid Works area, mechanically engineered, and used for future experimental studies for this purpose.

Projix is way to measure digital and shows by laser-beams the exact places where dividing walls, holes for drain and water pipes, electrical systems are to be constructed. For the alignment of optics developed mechanical component in the Solid Works shown in figure 16.



Figure 16. Projix

5 Experiments & conclusion

Experimental studies of the thesis work in laser display, especially focusing on the laser projection are discussed. The achievements of this research are described in this Chapter and the main results are summarized here.

5.1 Laser Pointer

5mWatt optical laser with 515nm wavelength and modulation input that uses a level 20 kHz modulation signal to allow for beam intensity adjustment. The laser's built-in collimator was used to alter the focusing.

5.2 Method

The image data to be executed on a project in the workplace is stored in a developed control board memory. Analog drive signals for galvanometer servo driver boards are manufactured using a specially designed DAC board controlled by data from the control board via a 20MHz Serial Peripheral Interface communication connector. Galvos was a project to direct the laser into a targeted area. There was no additional focus device used. Photographs with continuous lines: (laser is permanently turned on). Experimental Setup of the laser projection are presented in figure17.

5.3 Experimental Setup

- 25Kpps galvos with driver cards and power supply
- Arduino UNO + USB Cable
- a 220V or 110V power cord
- MCP4822 DAC (a cheap dual channel 12 bit DAC)
- Green Diode Laser pointer Module
- a few crocodile/alligator clips (to easier connect the laser pointer)

- a breadboard or PCB prototyping
- jumper cables

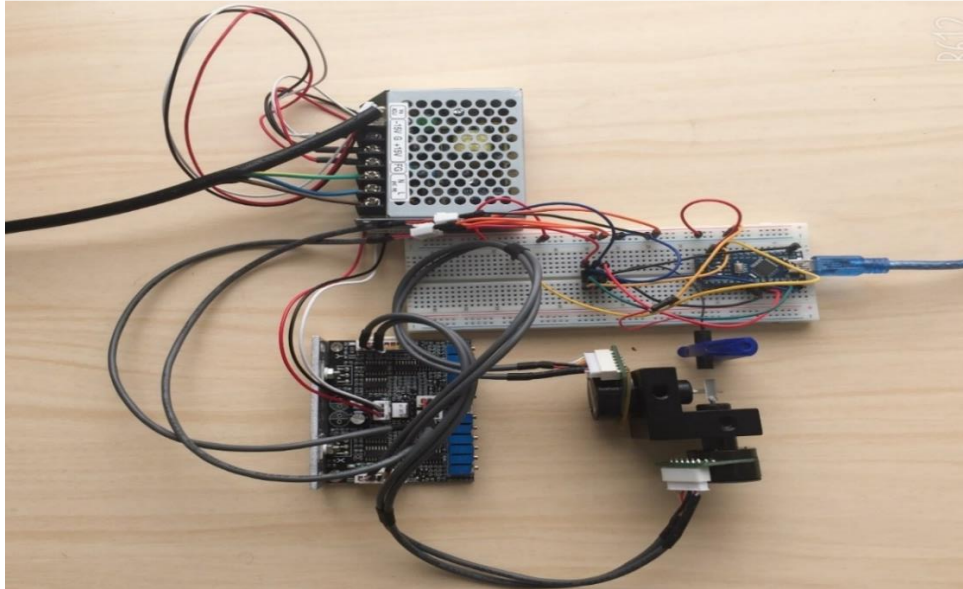


Figure 17. Experimental Setup

During the initial testing, a 5mWatt laser with a length of 515nm was used to ensure the stability of digital to analog converter for galvo function and graphical image generation technique without using with a powerful laser, at least for the first attempt. This laser pointer has a good brightness level. This is used for testing, and it is possible to update the project to a higher powerful laser diode, which would necessitate further safety precautions. This section contains important action for controls and related characteristics to device setup (laser, control board), connections to achieve transmission of data: Through laser communication with Arduino UNO and PC via USB data are transferred through windows.

Figure 18 presented MCP4822 device is a low power 2.7v-5.5v, a 12-bit internal voltage reference in a digital-to-analog converter (DAC) of the internal band, 2x-buffered output and serial interference peripheral (SPI).

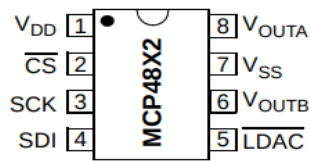


Figure 19. MCP4822 device (Microchip, 2011)

5.4 Experimental Results

The major goal of those experiments was to prove the laser projection idea used for utility during a construction project in order to assure the dependable operation of galvanometric scanning system hardware and control software. See following figures

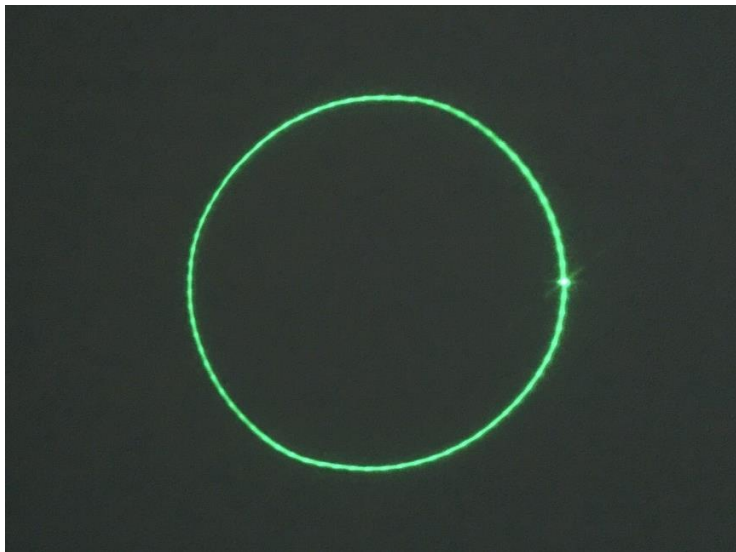


Figure 20. Circle laser projection on the wall

The 5mW laser diode utilized was sufficient to generate an image at a reasonable distance. However, one of this device's virtues is that the electro mechanics are distinct from the optics, allowing a stronger laser to be changed in with no effort. The resolution was great as expected. The greatest power consumption was 15V, however much of this dissipated through voltage regulators. The gadget may be made considerably more efficient if sufficient

attention was paid to power conservation. Rectangle laser projection are presented in figure20.

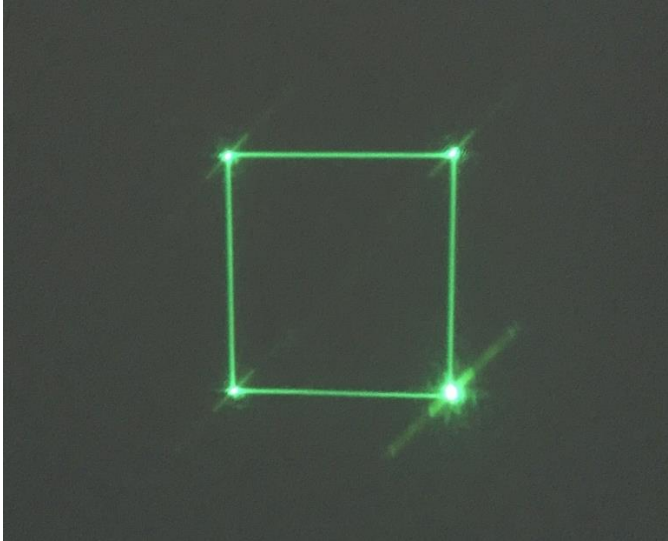


Figure 21. Rectangle laser projection on the wall

The result shown in Fig. 20 there is some distortion in the drawing at the corner and the brightness of the laser beam was good. From Fig. 20, when the scanning path goes into a corner, it is clear that the part has a major path error. When galvo mirrors move rapidly switch from one pose to the next, the inertia effect occurs due to the mirrors' inability to accurately follow the planned design route. Although this limitation does not apply to pen plotters or laser plotters, it is crucial to take to account when investigating laser projectors to ensure high- quality laser picture projection. Following figure 21 shows Triangle laser projection.

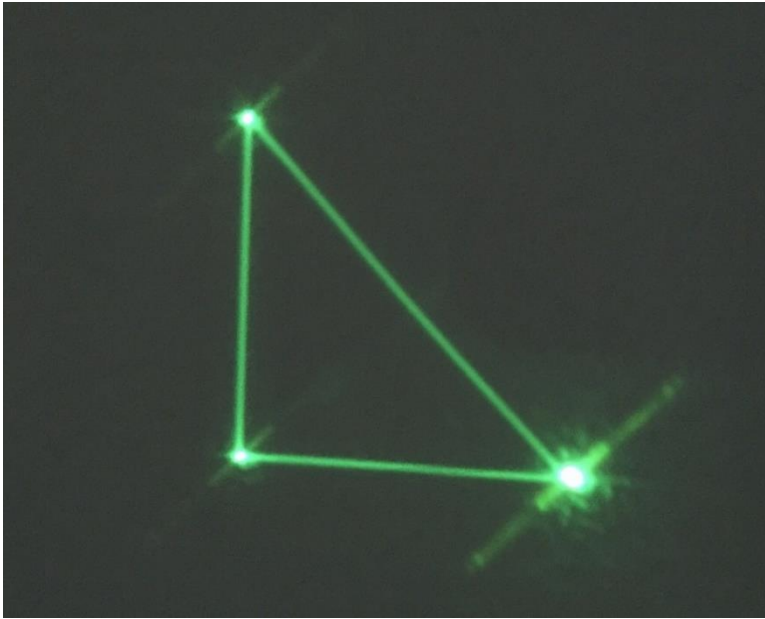


Figure 22. Triangle laser projection on the wall

Sharp corners of the photographs are impacted when the mirrors transfer from one position to the next because the X-Y mirrors are unable to follow the required route precisely. As a result, a laser projector produces high-quality pictures, particularly when the images have big angles, as seen in Figure 21. Because software tools now available do not account for the inertia effect, it is impossible to produce exact, sharp angles. To generate a high-quality laser image, one solution to this issue is to change the angle's time delay dependent on its degree value. Crossline laser projection shown in figure 22.

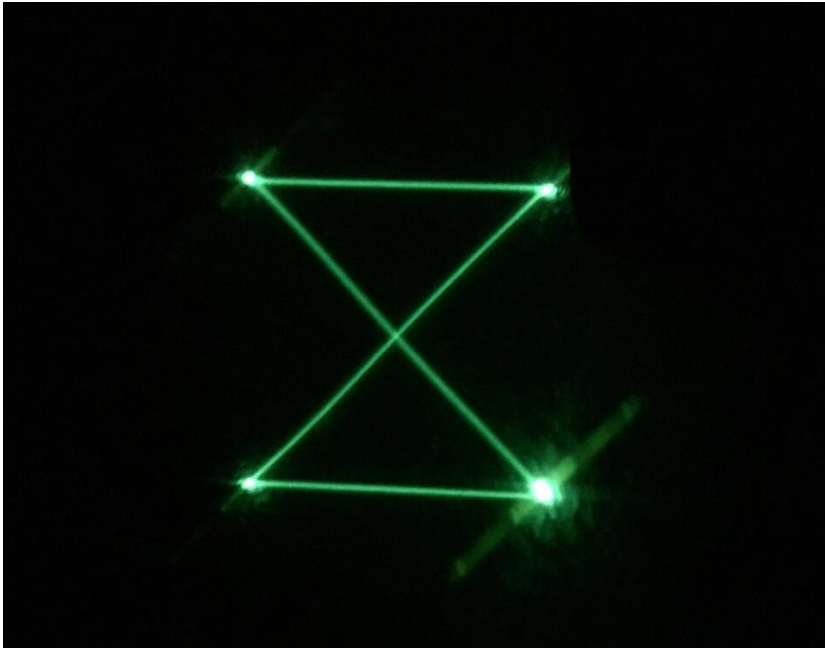


Figure 23. Crossline laser projection on the wall

The curving appearance and the separation of the angles are caused by the mirror changing its orientation too quickly at the corners. Reduce the scanning speed of the mirrors to solve this problem. Flickering happens when the scanning speed is too low. Adding some delay in the corners to assist the mirrors follow the target route more precise is effective technique to prevent the inertia effect.

6 Conclusion

The thesis presents a study on laser projection using the galvanometer scanning system. The design and implementation of laser projection primarily targeting galvanometer activities have been discussed in earlier chapters, as well as the theoretical foundation system function.

As the purpose of laser projection studied was to indicate the position of installation through the laser beam, analytical review of existing devices for laser projection processing, the operation of their key components was analysed and a reasonable choice was made for the design of the developed systems for focusing and deflecting the laser beam.

To improve the quality of the laser light focusing on the material being processed, an f-theta system was discussed. The concentrated possible spot size reached with rapid a pulse function in laser projection processes is less than that which can be produced with slow a continuous wave mode operation.

The hardware and advanced a software interface is used to control the system using an electronic design controller were discussed. A description of the galvanometer scanning system and its related parts, such as (mechanical, electrical, and optical), an understanding of operating principles related experimental work, evaluation of laser projecting techniques, and issues related with the target laser projection applications.

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