LASER DISPLACEMENT SCANNER FOR 3D RECONSTRUCTION

Project NO: 0001R001-2

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Contents

Introduction

The paper offers an overview of the 1st version of a precision 3D laser scanner that is being designed and built by Blue acre Technology. The precision 3d scanner is tailored towards device manufacturing industries. It could be used for various applications such as computer-aided design and post-inspection of small parts. Up to this designing phase, the scanner is capable of reconstructing the surface topography of a small object that has a maximum height of less than 30 mm. The 3D surface reconstruction is then treated using digital signal processing techniques to output a better representation of the actual object.

A laser displacement sensor is used to take a series of elevation data across an object. The data then used to reconstruct the 3d surface of an object. X-Y stage used to move the object so that the laser could take measurements at a different cross-section of the object. The data then possessed and analyzed using MATLAB.

Hardware

The hardware is consisting of 3 main components which are laser displacement sensor, compact DAQ board and X-Y stage as shown in Figure 1.

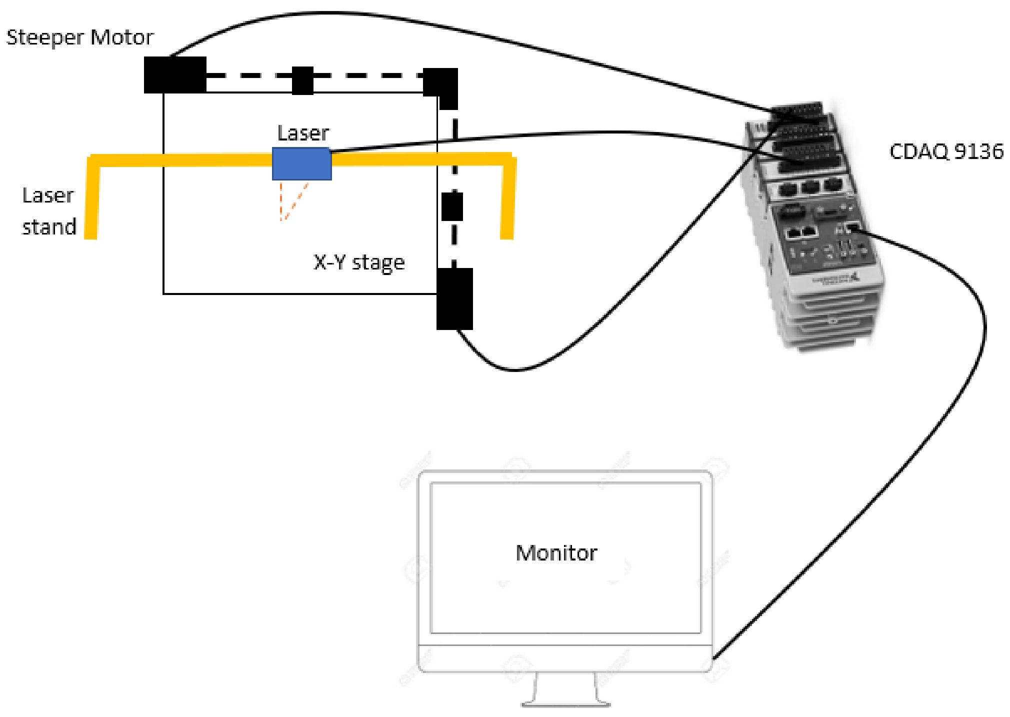


Figure 1 3d scanner schematic

Laser distance displacement

The theory of the laser displacement sensor is a method in which triangulation is applied by combining the emitting component with the position sensitive system to detect the displacement amount as illustrated in Figure 2 (panasonic, 2019).

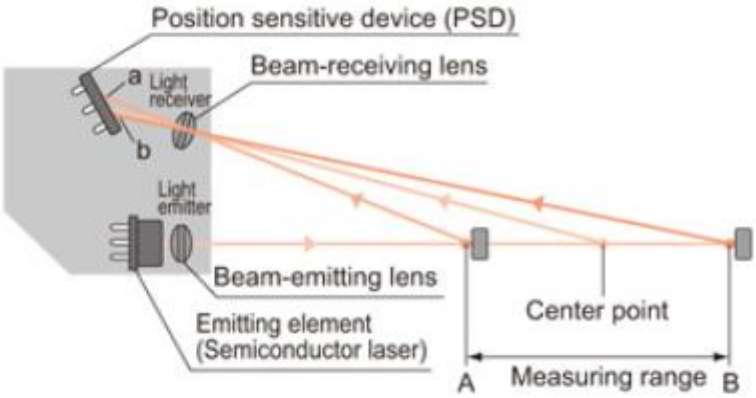


Figure 2 Laser displacement sensor principle

The user used in this project is Z4M-N30V Regular reflective displacement sensor developed by Omron. The specification of the product indicates that the laser should be mounted 30 mm above the measured surface. Variation in height results in variation in current from 4 to 20 mm. the spot size of the laser is 100um diameter at maximum. Note that the diameter varies depending on how reflective the material is being scanned.

Item		Z4M-N30V
Measurement range		±2 mm
Measurement point		30 mm
Light source		Visible-light semiconductor lasers with a wavelength of 670 nm and an output of 1 mW max.; class 2 (EN/IEC), class II (FDA))
Spot diameter (see note 1)		100 µm dia. max. (at measurement point)
Linearity (see note 2)		±0.5% FS (The full-scale value is 4 mm.)
Temperature drift (see note 3)		Sensor: 0.03% FS/°C Amplifier: 0.02% FS/°C
Analog output	**Current output**	4 to 20 mA/28 to 32 mm Output impedance: 300 Ω max.
	Resolution (see note 4)	4 µm (1 ms) or 0.4 µm (100 ms)
	Response time (see note 5)	1/100 ms switch-selectable
Digital output	**Output**	12-bit binary output at a transmission cycle of 0.1 ms
	Repeat accuracy (see note 6)	10 µm
	Response time	0.4 ms
Control outputs	**Output**	NPN open collector, 100 mA max. at 30 VDC, residual voltage: 1 V max.
	Hysteresis	±1% FS
	Response time	0.4 ms
Enable output		NPN open collector, 100 mA max. at 30 VDC
Laser emission OFF input		ON with a max. current of 15 mA at a min. ON voltage of 10.2 V: Laser emission will be turned off. Open at a max. OFF voltage of 3 V: Laser emission will be turned on. A function holding all output and indicator statuses incorporated.

Figure 3 Z4M-N30V obtained from (Omron)

The configurations manual and layout of the laser are attached in the appendix.

The laser is connected to the NI-DAQ controller in the following circuit Figure 4:

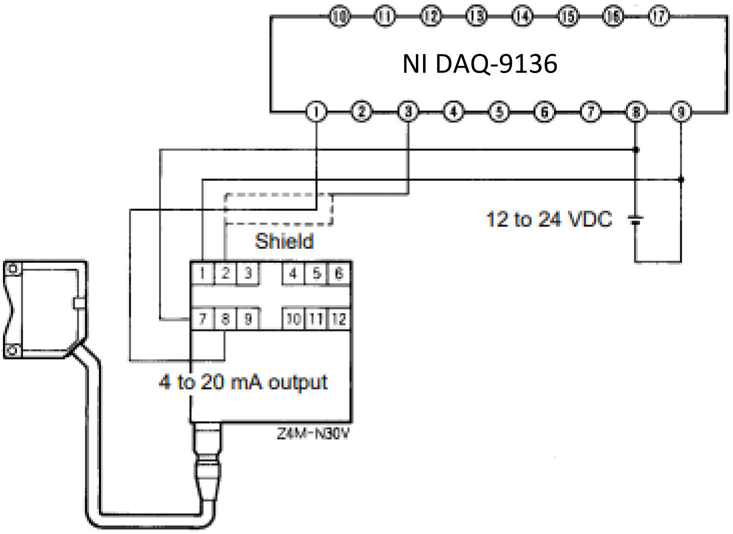


Figure 4 laser circuitry

The laser displacement sensor outputs 4 to 20 mA. However, the DAQ controller can take up to 10 mA. In order to achieve that, both current and voltage dividers used to divide the current to half.

The current stepped down by adding a resistor in parallel, and voltage stepped down by using voltage divider as shown in Figure 5.

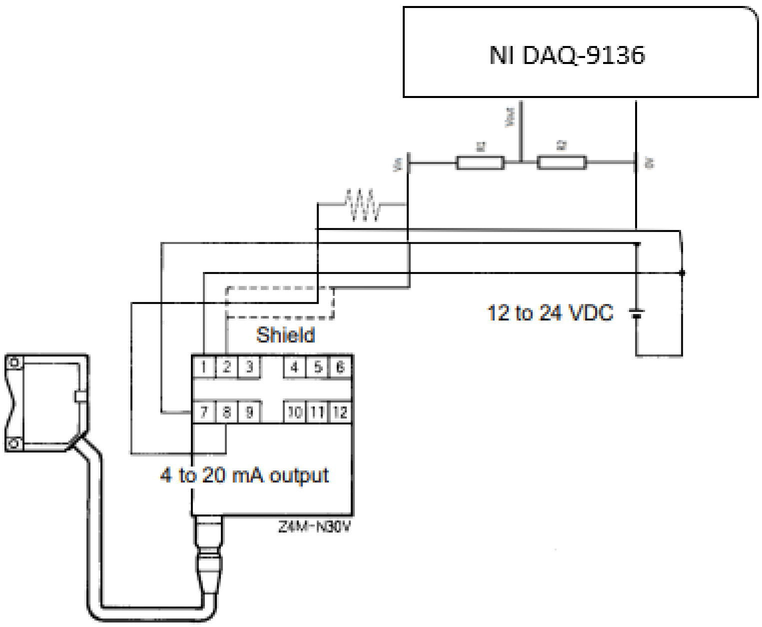


Figure 5 laser circuitry to stepdown the current

X-Y stage

Figure 6 shows x-y stage used, it moves in x and y directions and controlled using stepper motor drivers. The stage is relatively big compared to the actual area that would be scanned.

Figure 6 x-y stage

NI DAQ-9136 controller

CDAQ-9136 controller manages the transfer of data between the I/O modules of the C Series and the integrated processor. This involves Intel Atom, 32 GB data logging and embedded monitoring memory. It allows up to four C Series I/O modules. It is a standalone computer that comes with preinstalled windows.

For this initial version of the project. It requires the presence of two I/O modules installed into DAQ-9136 which are NI 9401 Digital I/O used to drive XY stage and NI 9215 analog I/O to acquire the laser signal.

Software

The program is written in LabVIEW, it could be divided into three main sections:

1. Drive the XY stage

In this section of the program, the stepper motors are being controlled by outputting three signals, the first is to control the motor speed by varying the frequency pulses. The second is controlling on/off enable line. The third signal is to control the direction of each motor. The VI shown in Figure 7 illustrates how it was done.

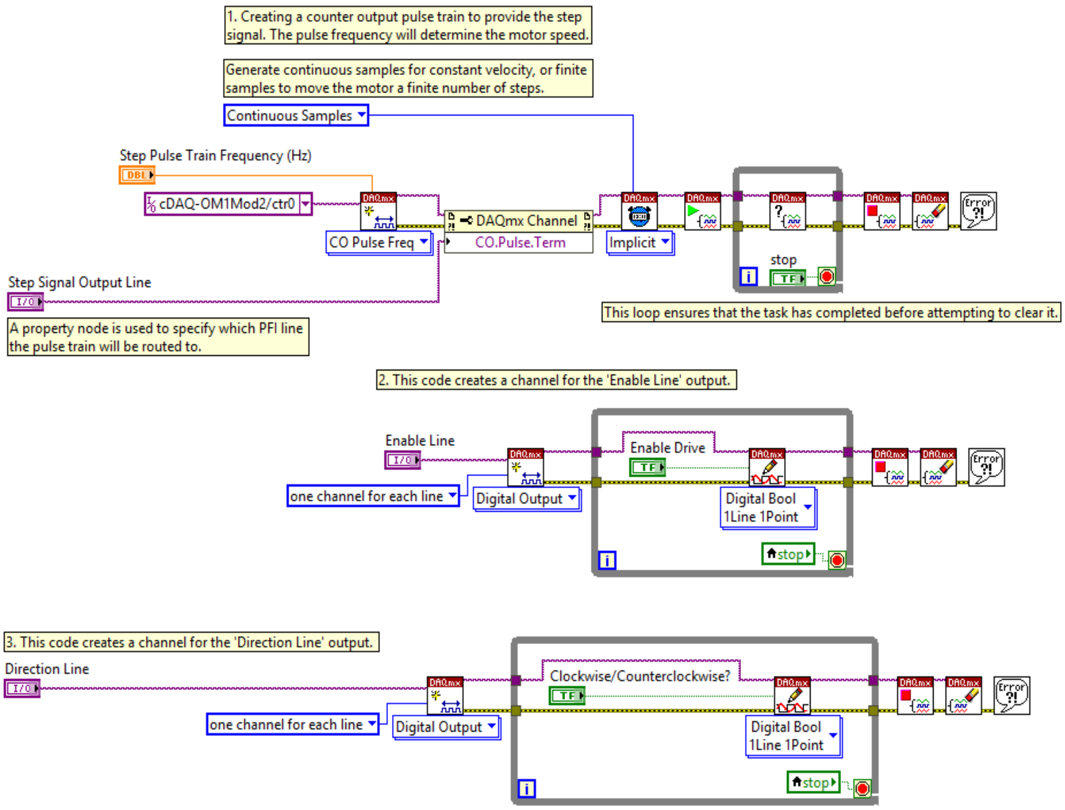


Figure 7 VI to control stepper motor

In the user interface, the step single output line, enable line and direction line has to be linked by listing the I/O channel on I/O digital slot. The speed could be varied by varying the step Pulse as shown in Figure 8.

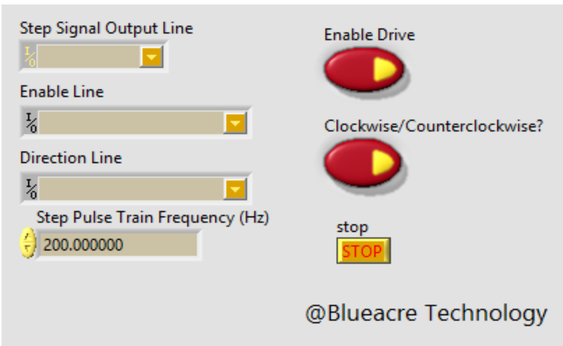


Figure 8 User interface

2. Obtain signal from the laser
   The analog I/O is used to obtain the laser signal the VI is shown in Figure 10.

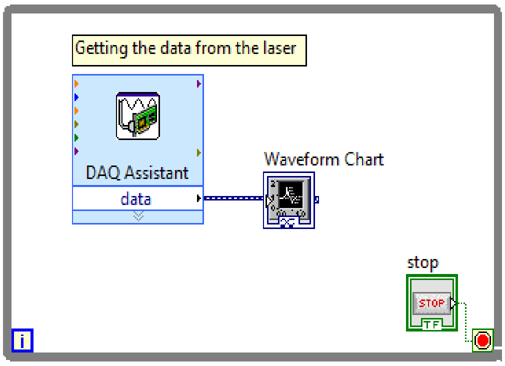


Figure 10 VI block diagram

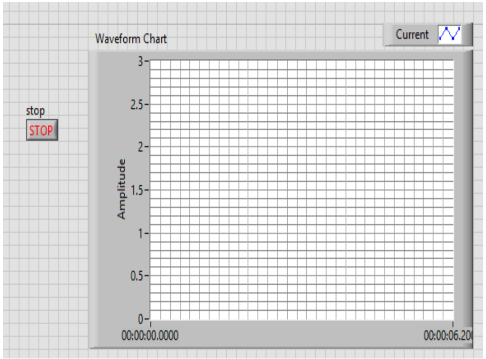


Figure 9 Front panel

The laser must be calibrated on X-Y stage. Besides, an adequate sampling rate should be selected.

3. Compute the data and outputs a 3d surface of the scanned object

The induvial 2D sectional scans plotted in terms of X, Y and Z planes that yields the 3d surface reconstruction of the object the VI used is in Figure 11.

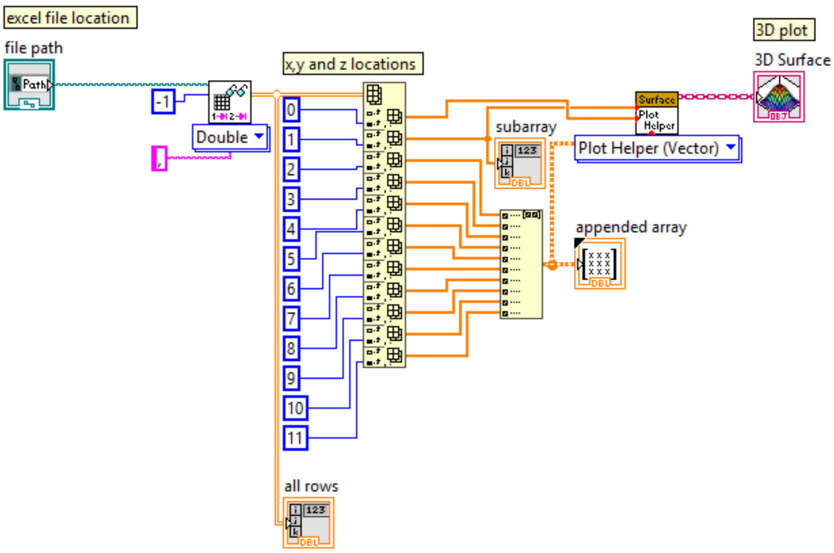


Figure 11 3D reconstruction of the object

The front panel of the program displays the data in X, Y and Z coordinates. The 3D surface reconstruction Figure 12 could be enhanced by adjusting certain settings in the properties of 3D.

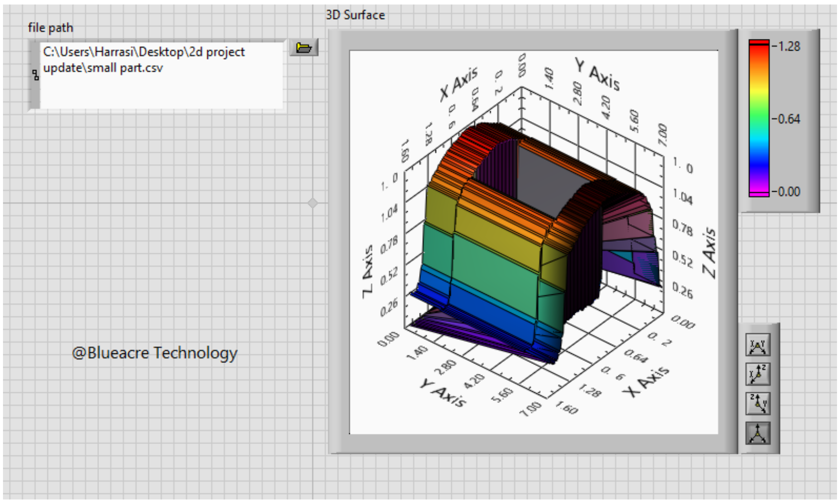


Figure 12 front panel of 3D surface

Alternatively, the data could be analyzed using MATLAB as it has better 3D analysis capabilities.

Results

Figure 13 shows number 5 being scanned from the coin.

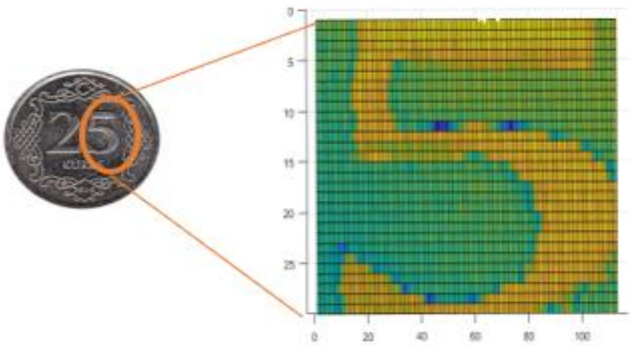


Figure 13 number 5 scanned

The surface of the scan is noisy as illustrated in Figure 14. to improve the surface some filtering is used in MATLAB (MATLAB code attached in the appendix).

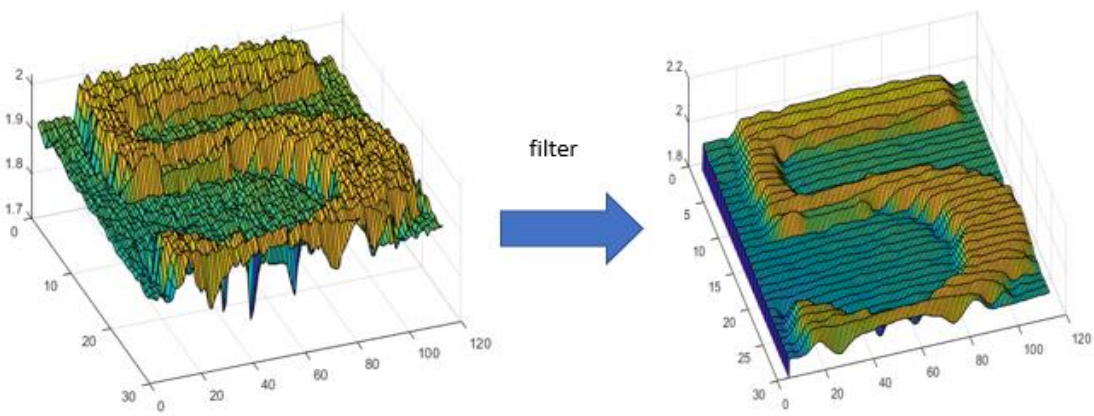


Figure 14 smoothing the 3D surface

The 3d precision scanner is capable to give a good representation of tiny details as shown in Figure 15.

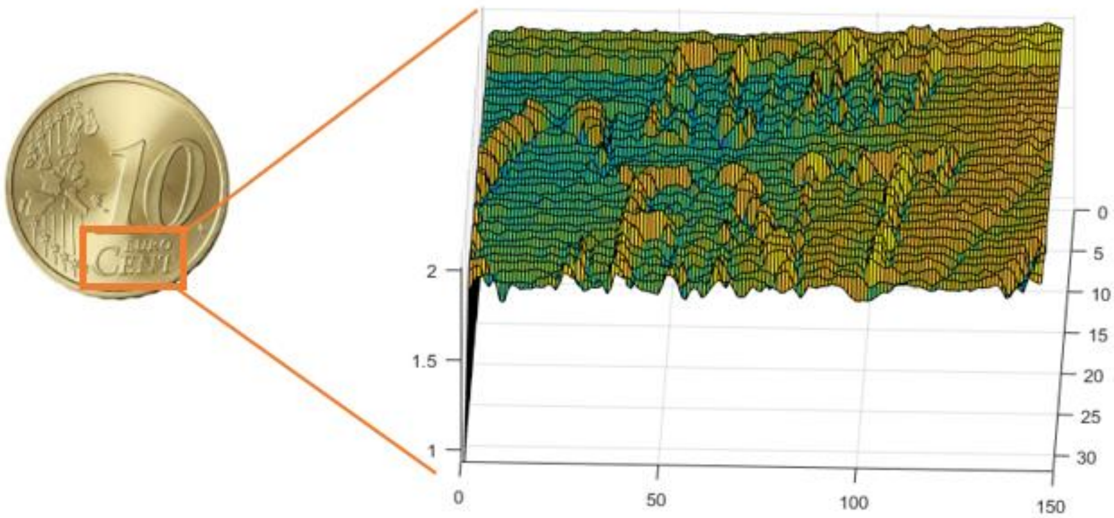


Figure 15 EURO CENT scanned from 10 cent

Conclusion

The spatial resolution of the y-axis of the x-y stage is restricted by the diameter of the laser beam, which is 100 µm max, it varies depending on the reflection coefficient of the material. This could be enhanced by replacing the leaser with a laser that has a beam of smaller diameter. However, with the current resolution, the scanner outputs a good reconstruction representation.

In terms of data processing, the data should be processed more efficiently by packing the code into one excitable application.

The physical design could be improved to be more aesthetically pleasing for example by adding an interactive LCD screen and design a more compact x-y stage.

Bibliography

Omron. (n.d.). Z4M-N30V. Retrieved from Regular Reflective Displacement Sensor INSTRUCTION MANUAL: http://faomron.co.kr/fs/SCEL-003.pdf

panasonic. (2019). Laser Displacement Sensor - Displacement Sensors. Retrieved from AUTOMATION: https://www3.panasonic.biz/ac/ae/service/tech_support/fasys/tech_guide/measurement/laser/index.jsp

Appendix

configurations and layout of the laser

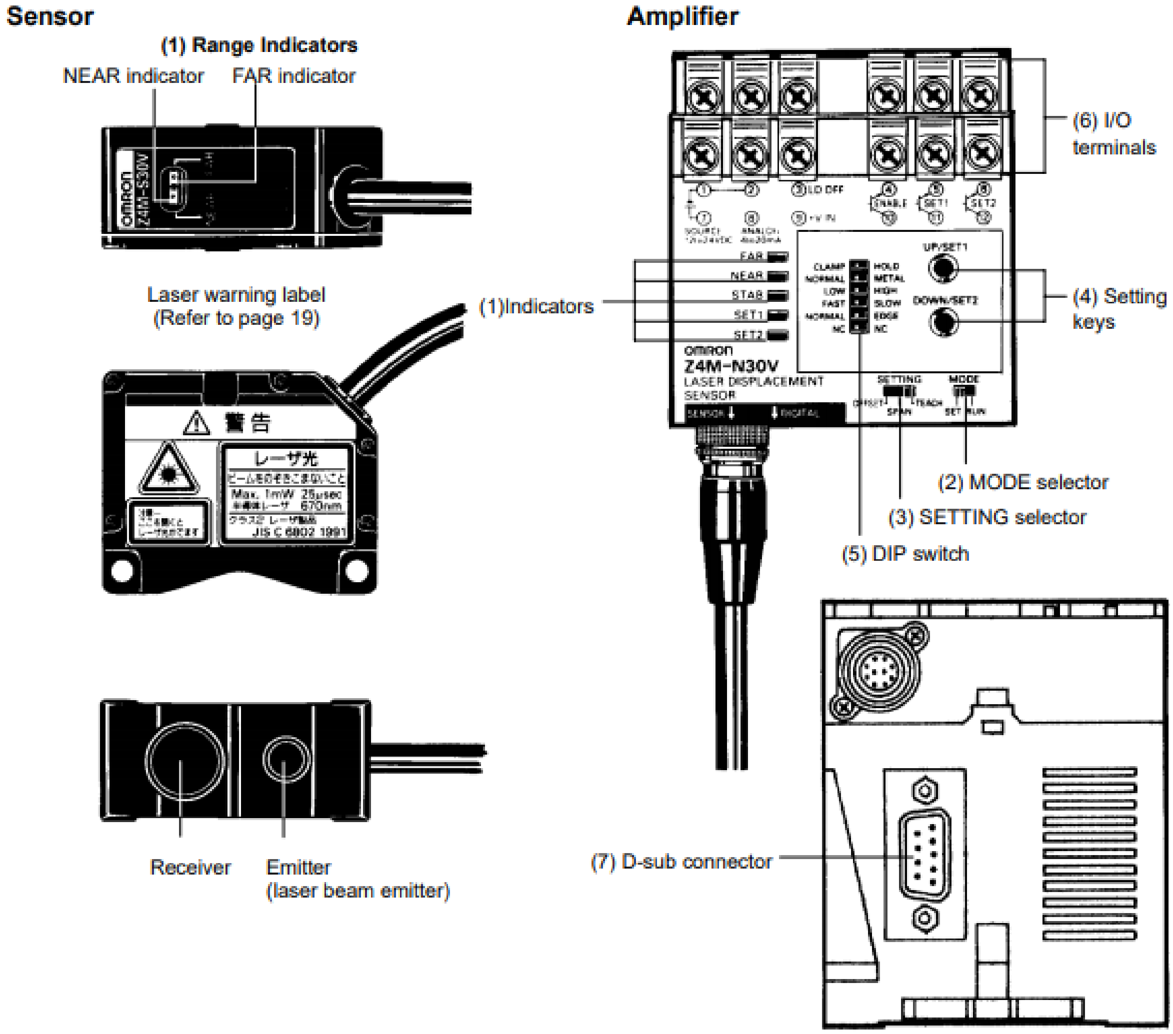


Figure 16Z4M-N30V laser displacement sensor

MATLAB filtering code:

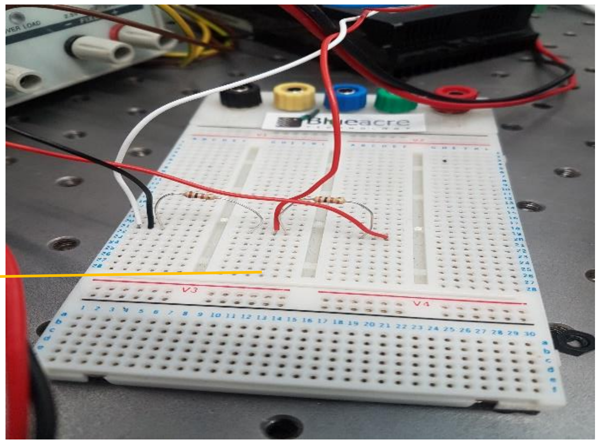
```matlab
%Mohamed Harrasi
%Blueacre Technology
%filtering of 3d surface

windowSize = 2; % window size could be varied, would be big for big
                %surfaces and small for smaller details
b = (1/windowSize)*ones(1,windowSize);
a = 1;
y = filter(b,a,z);
figure(1)
surf(y)
figure(2)
surf(z)
```

Project setup

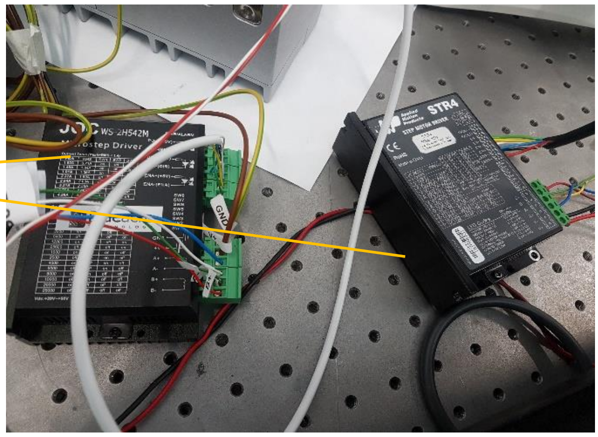
Laser displacement sensor

X-Y stage

Voltage divider



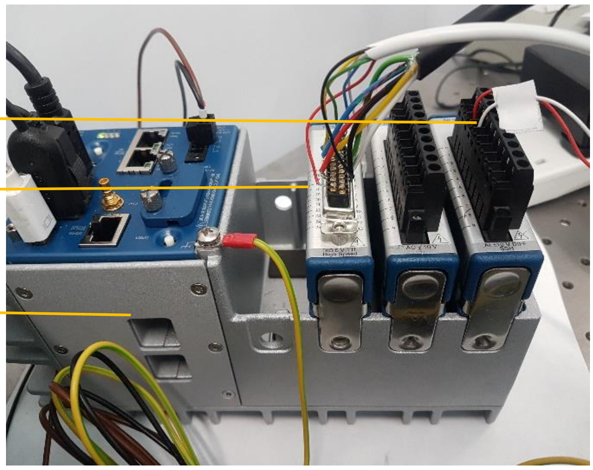
Stepper motor drivers



Analog I/O module

Digital I/O module

CDAQ-9136 controller



Power supply