SELF LEVELLING TABLE USING GYROSCOPIC SENSOR AND LIDAR TECHNOLOGY

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Abstract: **In this research we are going to manufacture the table which is self-aligned with the help of the Gyroscopic Sensor and Lidar Sensor. The table Comprises of the Lead Screw, motor (as a actuator) and also this research consist of weight measurement which is an additional feature. The weight measurement is carried out with the help of the button type of load cell using the HX711 a load cell amplifier. The readings of the level are been displayed on the 16x2 LCD display, as well as the load on the table is also been displayed. This table is used in various industries where the alignment and the level is much more important. This table is also equipped with the Matrix Keypad to input the level value just in case of some unavoidable situation. All the things are controlled and the analytical calculations are done with the help of Arduino as a microcontroller unit.**

Index Terms**: LiDar Sensor, Gyroscopic Sensor, HX11, LCD, Matrix Keypad, Load Cell, Lead Screw, Stepper Motor, Motor Driver, coupling and table leveling.**

INTRODUCTION

We know that during the manufacturing process the alignment problem of the floor creates problem in the deformation, uneven machining, as well as the wrong readings in sensors. [2] Thus, in order to correct these errore some other methods are used. These methods increase the cost price of the parts to be manufactured.

On the other hand, during measuring, the sprit level gives wrong reading due to non-uniform floor area. This is where the proposed table is very useful. Most of the problems occurrs because of the misalignment. Another example in robotic manufacturing, all four wheels of the robot either autonomous or manual robot should touch the ground evenly. Thus, if it does not touch the ground evenly then the encoders fitted on the robot will give random values. Which ultimately results into error.

The proposed table can be used in the area of medical sciences, where a fractured patient can lift the legs on an elevated surface with relative ease. As a result of this, the table alignment plays a vital role at every stage. Moreover, at the construction sites, the mortar flow ability test can be been carried out with the help of proposed table. Further development in this invention may replace the dumpy level instrument and get automatically level difference of all the stages. So, in order to solve all these problems we are developing the self-aligning table which will be helpful to the industry. The main aim of this paper is to solve the alignment problem by self-leveling method off the table

BACKROUND

[2] There are some tables which are used on a ship, a gun platform, where it is required to level the table when the ship is in the ocean and the ship is continuously moving up and down. The invention consists in the construction, combination and arrangement of the devices. Thus, we derive that based on the self-alignment, various devices are manufactured on the basis of the optical principle and the sensors.

[4] Automatic table leveling system consists of linear accelerometer, a microcontroller, motor drivers, motors and lead screws. The microcontroller is used to read values from the linear accelerometer sensor which contains the table top attitude with respect to the gravity vector. Then the microcontroller passes the signal to the motor driver to drive the table legs up or down through a lead screw mechanism which aligns the table eventually.

LIST OF MATERIAL

1. Stepper Motor: It is used to move the table up and down by providing rotational motion.
2. Stepper Motor Driver: The motor runs at higher potential thus in order to compensate the voltage difference this motor driver provides the necessary potential and current to the motor so that the motor runs at that potential. But the controlling signals are sent by the microcontroller only in the form of PWM (write full form of PWM atleast once in the paper).

3. MPU 6050 Gyroscopic and accelerometer Sensor and LiDar Sensor: These sensors are used to check the level from the ground as well as from the gravity vector. The ground level is been measured from the LiDar sensor and the altitude is been measured from the gyroscopic sensor.
4. Button Type Load Cell (TAS 606): The applied load is measured from the load cell. Compactly designed and with variable load carrying capacity.
5. HX711 Load cell Amplifier: This is an amplifier used to amplify the signals from the load cell since the values from the load cell is very low thus microcontroller cannot read these signals.
6. Arduino Mega 2560: This is the microcontroller used to control the signals and performs the calculation.
7. Electro Mechanical Relays: These relays are used for the control of the power from the battery whenever it is required.
8. Display 16 X 2: Tt displays the altitude value and load applied on each leg.
9. Buck Converter Module: Tt is nothing but the voltage distributer used to distribute the required voltage to microcontroller, all sensors and the motor.
10. Power supply 24 V 10 Amp: The power supply is most basic this used to provide the power to all circuit.
11. Lead Screw: Tt is used to move the table up and down along with the help of the motor.
12. Bearings: Tt is used to reduce the friction during the up and down motion.
13. Motor Clamps: It is used to hold the motor at its original place without further movement.
14. NUT: When the lead screw is moving then this nut originally moves the table up and down.
15. Guide Rods : Supporting element during up and down motion.
16. Coupling: This is used to couple the lead screw with the motor shaft.

CALCULATION

The system is used to lift the whole load with the help of the lead screw. The load carrying capacity of the threads and nuts are shown below by considering the factor of safety.

$$Mi = \frac{W\,d\,m}{2}\left(\frac{l + \pi\,\mu\,d\,m}{\pi\,d\,m - \mu\,l}\right)$$
$$= \frac{W\,d\,m}{2}\tan(\phi + \lambda)$$

$$Md = \frac{W\,d\,m}{2}\left(\frac{\pi\,\mu\,d\,m - l}{\pi\,d\,m + \mu\,l}\right)$$
$$= \frac{W\,d\,m}{2}\tan(\phi - \lambda)$$

$$\text{Efficiency} = \frac{\tan(\lambda)}{\tan(\varphi+\lambda)}$$

M = torque
w = load on the screw
dm = mean diameter
μ = coefficient of friction (common values are Found in the adjacent table)
l = lead
ϕ = angle of friction
λ = lead angle

Since the screw and nut is subjected to the torsional moment, compressive forces and bending moment. From strength consideration,
material required for the screw and nut is plain carbon steel having the following specification
Material Grade: 30C8
Yield Strength: 400 N/mm2
Elastic Modulus = 207000 N/mm2
Syt = 400 N/mm2
Assuming the FOS (factor of safety) = 5.
$\sigma c = \frac{\text{Syt}}{FOS} = \frac{400}{5} = 80$ N/mm2
$\sigma c = \frac{W}{AREA}$
W = weight on each legs
dc = Core diameter
d = Nominal diameter
dm = Mean diameter
Considering the uniformly distributed load of 2000 kg. Thus, by drawing the shear force diagram we get the reaction forces at each legs be $R = \frac{2000}{4} = 500$ Kg
Now the 500 kg= 500 X 9.81 = 4905 N
Notations:-

$$\sigma c = Compressive\ shere\ stress$$
$$\sigma b = Bending\ stress$$
$$\tau = torsional\ shere\ stress$$
$\tau\ max = Comb. torsional\ shear\ and\ bending$ F
$$Mb = bending\ moment\ due\ to\ motor$$
$$I = Inertia\ effect$$
$$A = Area$$
$$K = Slenderness\ ratio$$
L= length of the screw to be lifted
$$n = end\ flexibility\ coefficient$$
$$E = elastic\ modulus$$
$$Pcr = Critical\ buckling\ load$$
$$Z = No\ of\ thread\ req. to\ lift\ the\ load$$
$$Sb = Permissible\ bearing\ pressure$$
$$\mu = Coefficient\ of\ friction$$
$$Mi = Torque\ req. to\ raise\ the\ load$$
$$P = Pitch$$

For Calculation of SCREW [7]

$\sigma c = \frac{W}{AREA} = \frac{4905}{A} = 80$

$$A = 61.3125\ mm2$$
$$A = \frac{\pi}{4}\ X\ dc^2$$
$$dc = 8.8377\ mm$$
$$dc = 9\ mm$$

We know that the screw is subjected to additional external forces such as torque, bending, etc. So diameter of the screw must be increased to safe the design.

$$d = 16\ mm$$
$$considering\ the\ Pitch\ of\ the\ thread\ be$$
$$P = 3\ mm$$
$$Now,$$
$$dc = d - P$$
$$dc = 16 - 3 = 13\ mm$$
$$dm = 16 - 1.5 = 14.5\ mm$$

Assume the single started threads,
Lead = pitch = 3 mm

$$\tan(\alpha) = \tan\left(\frac{l}{\pi\ X\ dm}\right) = 0.06589$$
$$\alpha = \tan^{-1}(0.06589) = 3.76^0$$

Coefficient of friction between nut and screw is in between 0.15 to 0.25
Considering the friction be to a critical limit that the user provides poor lubrication as μ = 0.2
$\tan(\varphi) = \mu = 0.2$

$$\varphi = \tan^{-1}(0.2) = 11.309^0$$
$$Mi = \frac{W\ dm}{2}\tan(\varphi + \alpha) = 9575.144\ Nmm$$

At the contact between the nut and screw there the shear force and bending force be,

$$\tau = \frac{16\ Mi}{\pi\ X\ dc^3} = 22.2078\frac{N}{mm^2}$$
$$\sigma c = \frac{W}{A} = 36.97\frac{N}{mm^2}$$

As the P is the force given by the motor and thus we assume that according to the motor available in stock the of torque 97 kg-cm which is Mb = 97 X 9.81 X 10 = 9515.7 N mm.
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$$\sigma b = \frac{32\ Mb}{\pi\ X\ dc^3} = 44.139866\frac{N}{mm^2}$$
$$Now\ finding\ out\ the\ combine\ effect\ of\ the$$

Torsional shear and the bending stress we get the equation as,

4. τ max = $\sqrt{\left(\frac{\sigma b}{2}\right)^2 + \tau^2}$ = 31.309237 N/mm2

$$Fos = \frac{Ssy}{\tau\ max} = \frac{0.5\ X\ 400}{31.309237} = 6.38789$$

Thus, $fos\ assume < fos\ obtain$
Thus, design is safe from bending load
Now as the load is been lifted to a certain limit the phenomenon is resulted into buckling of the beam
Thus, we need to find out that weather the screw is safe in buckling or not by Euler's formula and by Johnson's equation as follows:

$$l = 350\ mm$$

$$I = \frac{\pi\ dc^4}{64} = \frac{89681.54}{64} = 1401.274\ mm^4$$

$$A = \frac{\pi\ dc^2}{4} = 132.665\ mm^2$$

$$K = \sqrt{\left(\frac{I}{A}\right)} = 3.25$$

$$Slenderness\ ratio = \frac{l}{A} = \frac{350}{3.25} = 107.6923$$

End flexibility coefficient = 0.25

$$\frac{Syt}{2} = \frac{n\,\pi^2 E}{\left(\frac{l}{k}\right)^2}$$

$$\frac{200}{2} = \frac{0.25\ X\ 3.14^2\ X\ 207000}{\left(\frac{l}{k}\right)^2}$$

$$\left(\frac{l}{k}\right) = 50.509$$

$$Syt\ X\ A\left[1 - \frac{Syt}{4\pi^2 X\ 0.25X207000} X50.509^2\right] = 26533.12916\ N$$

$$Fos = \frac{Pcr}{W} = \frac{26533.129}{4905} = 5.40904$$

Thus, $fos\ assume < fos\ obtain$
Screw is safe in buckling load
For Calculation of NUT [7]
Permissible bearing pressure between the steel screw and steel nut is 10 N/mm2
Thus Total No. of threads required to hold the load is,

$$Z = \frac{4\ W}{\pi\ Sb\ (d^2 - dc^2)} = 7.1820$$

Z = 8 No of threads
Axil Length of the Nut = Z X P =8 X 3 = 24 mm
So transvers shear stress is given by,

$$\tau = \frac{W}{\pi d \frac{p}{2} Z}\ 8.135 \frac{N}{mm^2}$$

$$Fos = \frac{Syt}{\tau} = \frac{400\ X\ 0.5}{8.135} = 24.58$$

Thus From This We Get the Dimension of the Nut and Screw As,
dc = 13
d= 16 mm
dm = 14.5 mm
l = 350mm
H = 24 mm
Z= 24
Thus from This the Torque Of The motor should Be, 97 kg-cm.

ASSEMBLY OF THE PRODUCT WITH ALL THE PART DRAWING

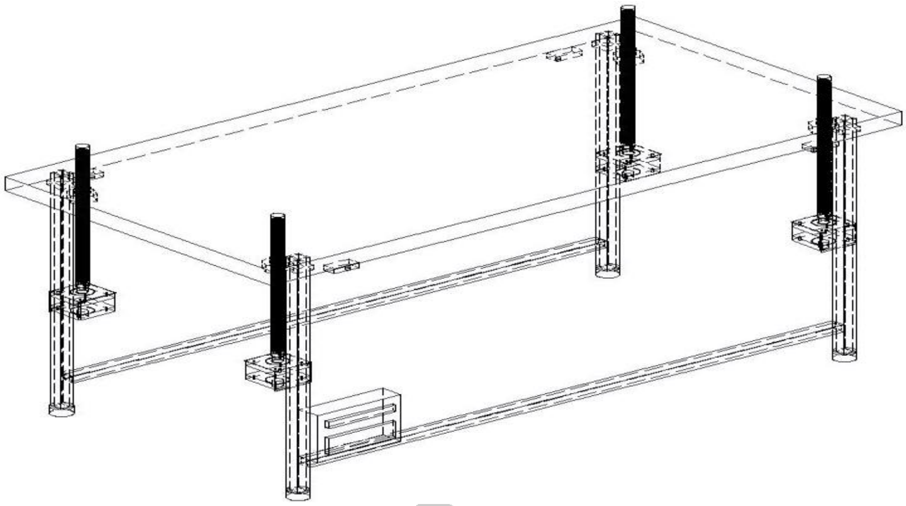

Figure 1: Isometric View Of Product

Figure 1 shows the isometric view of the whole system. All the component shown in the figure are fixed at the exact places as in the figure. Figure is scaled version of the actual model. Figure 1 consist of the all hidden component from the figure 2 and 3.

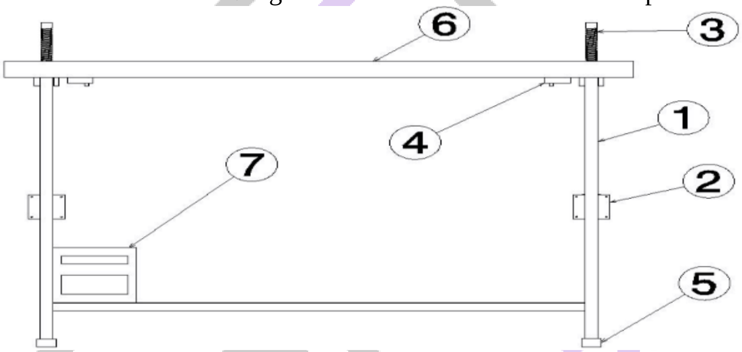

Figure 2: Front View of Product

Figure 2 consist of the part 1 chassis which supports the whole system. Part 2 stepper motor used to rotate the lead screw part 3. The lead screw part 3 is then connected to the part 8 Nut which allows the table top portion part 6 to move up and down without allowing the up and down motion of the motor and lead screw part 2 and 3 respectively. Part 4 is the gyroscopic sensor along with the Lidar sensor used for the sensing the distance from the ground level. Part 7 is the control panel used to control the movement of the motor and the perform the analytical calculation for the data received from the part 4. Part 6 is the upper portion of the table used to perform the various types of application. Part 5 is the load cell used to measure the reaction forces on each legs.

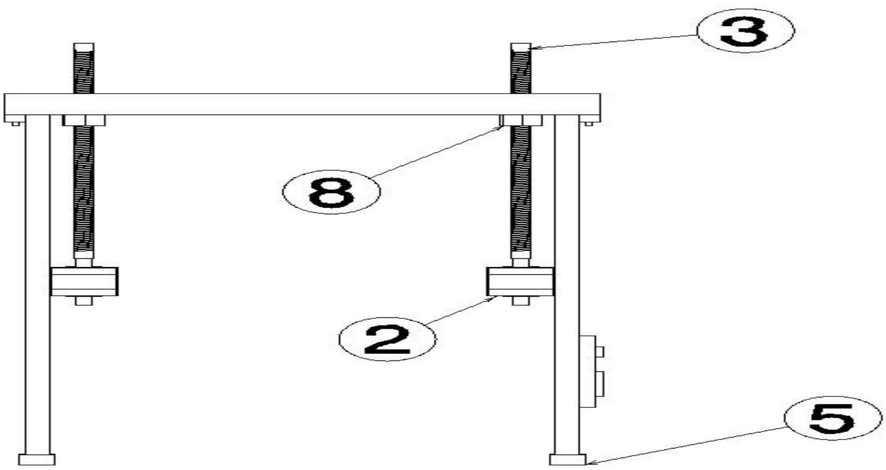

Figure 3: Side View of Product

Figure 3 shows the side view of the System which consist of part 8 which is nut whose application is mention above.

METHODOLOGY

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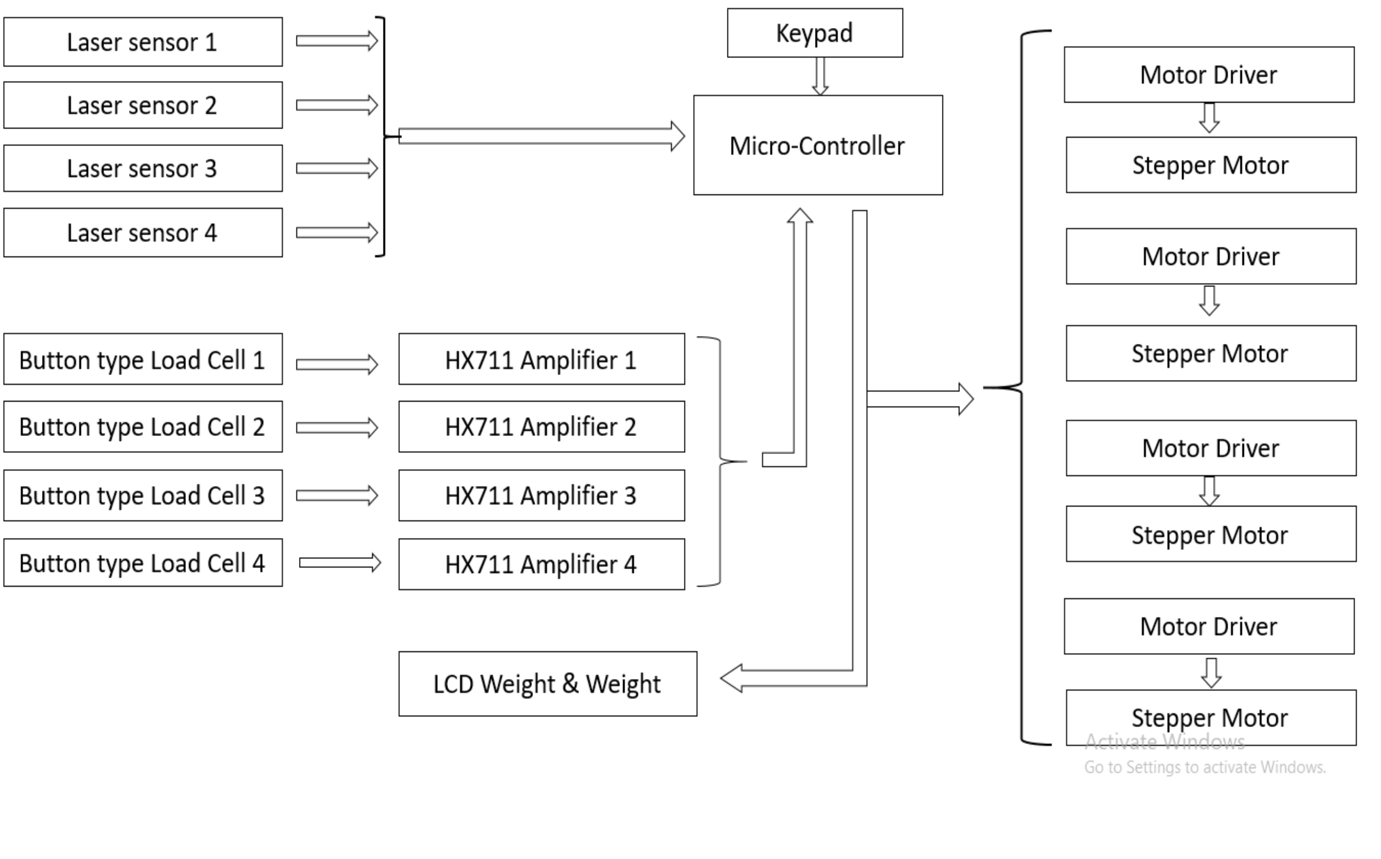

Figure 4: General Block diagram of the electronics circuit

Above figure is the flow diagram of the complete circuit used to carry out the task. The block diagram figure 4 shows that the microcontroller takes input from the Laser sensors thus when the readings from the ground is been measured we get the distance from the ground of each leg. In advance this distance is displayed on to the display for the user purpose, thus the value is taken and then the motor is adjusted till the all the legs are in one plain and thus we get the level of the upper surface from the ground level. In this the value obtained by the Laser sensors are in the binary format. In general language we called it as U art communication therefore this data is converted into the user friendly language and then the calculation is carried out. This mode of leveling is called as the autonomous leveling while there is another mode which is called as the manual mode where the user is provided with the keypad.

In the keypad mode the value is defined by the user through the keys provided on it from 0 to 9 and also there are mode button to switch the mode from autonomous to manual. There are some extra button to switch from each legs to whom we need to change the values thus in these way the function of the keypad is carried out. Not only the distance from the ground is displayed but also the value we need to enter to get the required value is also displayed. So, we do not need to calculate the value always to level them up. In order to rotate the motor, there is another device fitted in between the microcontroller and the motor to drive the motor. Since we know that the motor works on the 9 Volts or 12 Volts with the 4 ampere per phase i.e. to each coil we need to supply 4 amperes but our microcontroller works on the 5 V and half ampere supply. Thus, we need to provide the supply required to operate the motor. Also, in order to operate the motor, we need to switch the supply form one coil to another to continuous rotation. As the stepper works in number of steps, we donot need the encoder to measure the number of rotations to get the desired position. There are 4 terminals for motor, two for each coil. Thus, the motor is a bipolar 2 coil stepper motor.

The table is provided with load cell which is compact type (button type load cell) to measure the load put onto it. This load cell is mounted at the end of the table. When the load is measured, the value is displayed on the display of each leg and the resultant value. The load cell value is changed in milli-volts,thus this value is not readable by the Arduino since the Arduino can only read the value between the ranges of 0.3 V to 5 V with the minimum current of 0.3 ampere. The value obtain from the load cell is below 0.3 V so we need to amplify the value thus we used the load cell amplifier known as the HX711. This load cell amplifier converts the negligible value by adding the gain into the previous value. This Amplifier is specially designed for the load cell. Moreover, this load cell is having the accuracy up to 2%. Thus, we are using the load cell of range up to 1000 kg, with an error of 2% that is 20 kg. We can read the value in between 20 kgs to 1000 kgs. As the self-weight of the table is approximately 100 kg, the 2% error is neglected and don't need to add that the value again. Most important characteristic of this type of load cell is its compact size and easy to use and also easy to mount.

METHODOLOGY 2

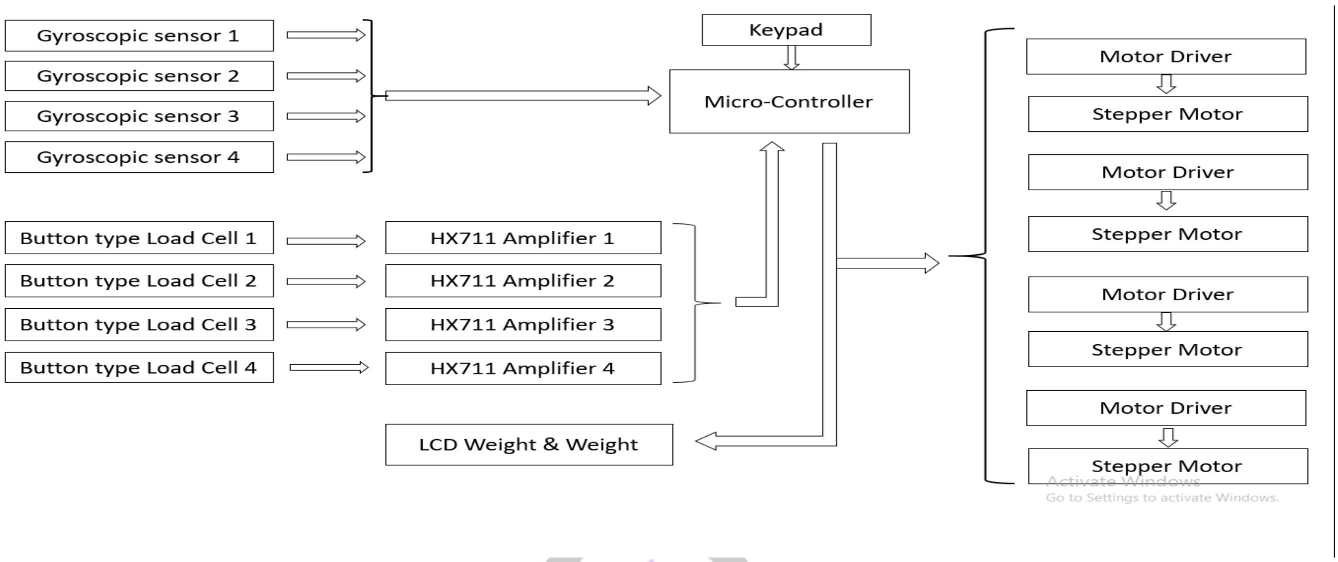

Figure 5: General Block diagram of the electronics circuit

In second methodology, rest all the circuit remains the same but the only change is the sensor, here we use the gyroscopic sensor. Above Figure 5 is the flow diagram of the complete circuit used to carry out the task. The block diagram explains that the microcontroller takes input from the gyroscopic sensor when the readings of each level of the sensor from the ground of each leg. In advance, this altitude is displayed on to the display for the user purpose, thus the value is taken and then the motor is adjusted till all the legs are in one plane and thus we get the level of the upper surface from the ground level. In this, the value obtained by the sensors are in X, Y, Z coordinate format where X determines the value in X direction, same as Y denotes the value in Y direction and the Z value denotes the Z direction i.e. vertical distance. In this data, we only use the z value of the sensors then the calculation is been carried out. We first convert the coordinate value to the distance value by mapping the value. This mode of leveling is called as the autonomous leveling while there is another mode which is called as the manual mode where the user is provided with the keypad. Rest all the function remains the same and we get the value from the gyro sensor.

CONCLUSION

The table successfully carried the load of 2000 kgs Thus, performing these experiments, we were able to self-align the table. These table is used in the ships and also in the robotics laboratory for checking the alignment. By designing the lead screw and nut with the factor of safety obtained was 6. Thus, our design is safe in buckling and lifting the load. The selection of motor wassafe in carrying the load.

In future we are creating the table to displace from one place to another. And also, to lift more load at a time. The combination of the LiDar sensor and the accelerometer sensor to bring the alignment of the table will be the first attempt to combine both the sensors to bring the table alignment in accuracy and with acceptable resolution.

REFRENCES

[1] Billiard Table Leveling And Holding Device, Us Patent No. Us821, 225,
[2] Sele-Leveling Table. Us Patent No Us1260181
[3] Optical Table Active Leveling And Vibration Cancellation System Us Patent Number: 5,285,995
[4] Portable Leveling Table Us Pub. No.: Us 2009/0299689 A1
[5] Bholanath Stepper Motor Datasheet Bh86sh156-6004aks-Ip68 (133kgcm)
[6] Benewake (Beijing) Co. Ltd. Datasheet Of Lidar Sensor. Benewake-Tfmini-Micro-Lidar-Module-Ip65-12-M-Datasheet
[7] Design Of Machine Element By V.B.Bhandari
[8] Invensense Inc. Mpu-6000 And Mpu-6050 Register Map And Descriptions Revision 4.0 Document Number: Rm-Mpu-6000a-00
[9] www.Robu.In (replace with a web address citing to an exact information on your research)