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1. Abstract

Measurement of Inclination of a platform relative to ground level is important for sensing applications. Conversion of tilt angles to corresponding electrical signals is performed by inclinometers providing input to control circuits. Typical approach involves the usage of gyroscope module based integrated circuits like MPU6050. The major drawback of this approach is that a stable calibration is required for proper functioning of the sensor, which is time consuming. Besides, abrupt movement of the sensor can damage its calibration leading to false readings.

In this project, a different approach to measuring angle data and converting to electrical voltage level is studied. This method involves the measurement of water level in a spherical container which for the demonstration purposes, is kept limited within two directions.

2. Introduction

The conventional method of measuring inclination involves usage of a gyro-sensor, which contains an accelerometer and precisely detects smallest movement of the sensor. From that data complex algorithms generate tilt information. For this purpose, a precise calibration is required to softwire the initial stage of inclination depending on which, the sensor can output angular data in real time. This method is independent of gravitational field, therefore makes it universal.

In the presence of gravitational field, like on the surface of the earth, a different approach can be applied that employs the plastic quality of conductive fluid to detect inclination. Since the surface of the liquid is always at zero degrees (neglecting the contact angle with the container), it is a consistent property which is required in any measurement device.

The application of tilt sensor can be found in:

- Trench leveling machines, to monitor and control flatness.
- Vehicle photoelectric tracking device.
- Robotics and balance theory.
- Naval and avionics, like adjusting the hook of large ships.
- Civil Engineering applications.

3. Components

1.1 Arduino Uno

The Arduino Uno is one of the most popular microcontrollers used for small control applications. The Arduino Uno is a microcontroller board based on the ATmega328. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as programming (ICSP) header, and a reset button. It contains everything needed to support the microcontroller; simply connecting it to a computer with a USB cable or powering it with a AC-to-DC adapter or battery is enough to get started.[1]

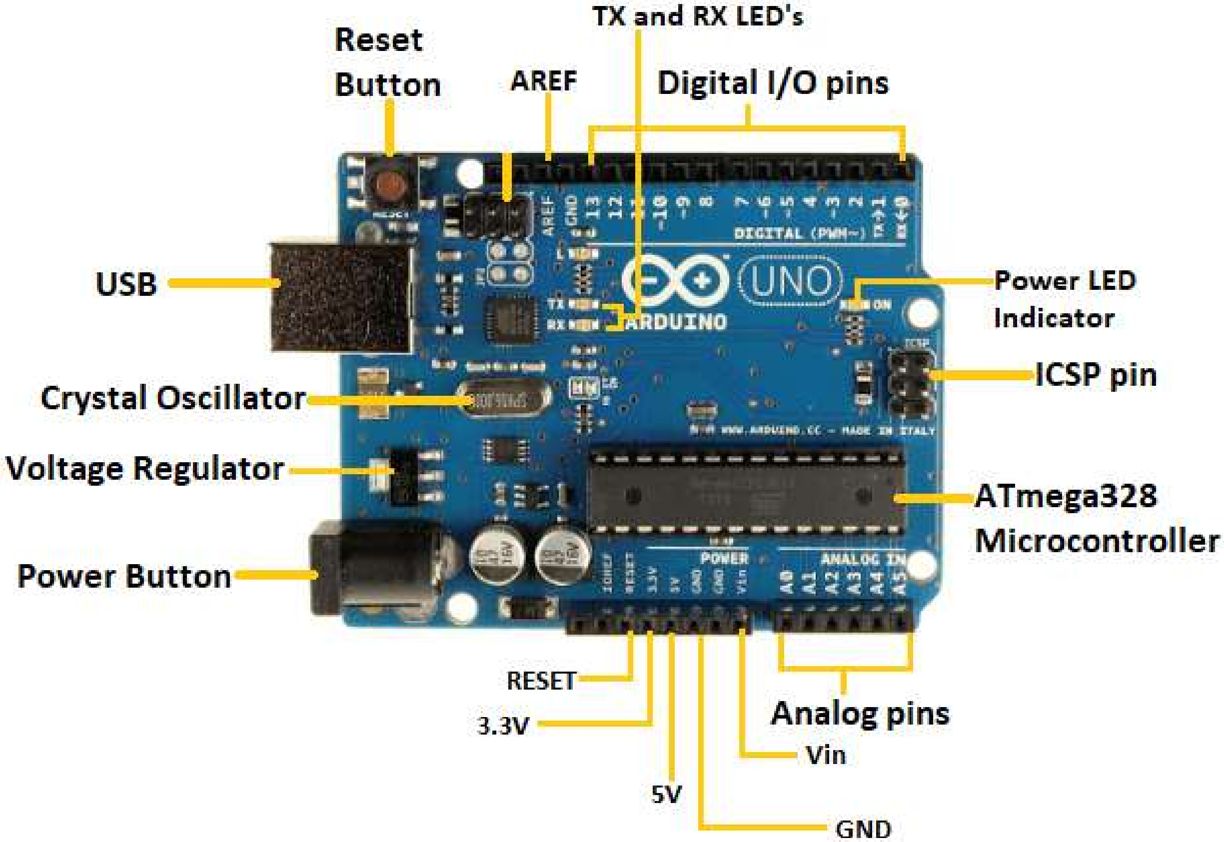


Figure 1: Arduino Uno

1.2 Seven Segment Display

A seven-segment display is a type of electronic display device for displaying decimal numerals that is an array of seven segments, which are usually LEDs (light-emitting diodes) or LCDs (liquid-crystal displays), where each segment has its own source of light. They are commonly used in digital clocks, electronic meters, and other electronic devices that display numerical information. The segments are arranged in a rectangular shape that can be used to display the digits 0-9 by illuminating the segments in different combinations.

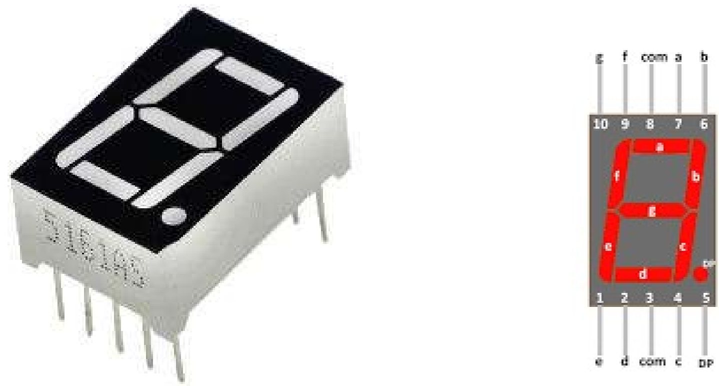


Figure 2: Seven-Segment Display

1.3 Micro Servo Motor (SG90)

The Servo Motor Micro SG90 work well for basic servo experimentation and can be used in applications where small size is a virtue and that don’t require a huge amount of torque, but they are still strong. Gears are nylon which is the case with most lower cost Servos. Servo motors can be commanded to go to a specific position and so are the usual go-to motor when accurate positioning is needed, such as for turning the front wheels on an RC model for steering or pivoting a sensor to look around on a robotic vehicle.[2]

Figure 3: Micro Servo Motor

1.4 Spherical Container (Table Tennis Ball)

A spherical container filled with salt water and probed periodically at a fixed space interval is required as the main sensing component. A standard table tennis ball has a diameter of 40 millimeters and thickness of 1 millimeter. Taking the number of probes to be around 10, the periodic interval is found to be 10 degrees which fits nicely within parameters. Therefore, a typical table tennis ball is mounted on the gimbal and pierced with jumper wires.

Figure 4: Table Tennis Balls

1.5 Bread Board

A modern solderless breadboard socket (invented by Ronald J Portugal for E&L Instruments, Derby CT) consists of a perforated block of plastic with numerous tin-plated phosphor bronze or nickel silver alloy spring clips under the perforations. The clips are often called tie points or contact points. The number of tie points is often given in the specification of the breadboard. The spacing between the clips (lead pitch) is typically 0.1 inches (2.54 mm). Integrated circuits (ICs) in dual in-line packages (DIPs) can be inserted to straddle the centerline of the block. Interconnecting wires and the leads of discrete components (such as capacitors, resistors, and inductors) can be inserted into the remaining free holes to complete the circuit. Where ICs are not used, discrete components and connecting wires may use any of the holes. Typically, the spring clips are rated for 1 ampere at 5 volts and 0.333 amperes at 15 volts (5 watts). The edge of the board has male and female dovetail notches so boards can be clipped together to form a large breadboard.[3]

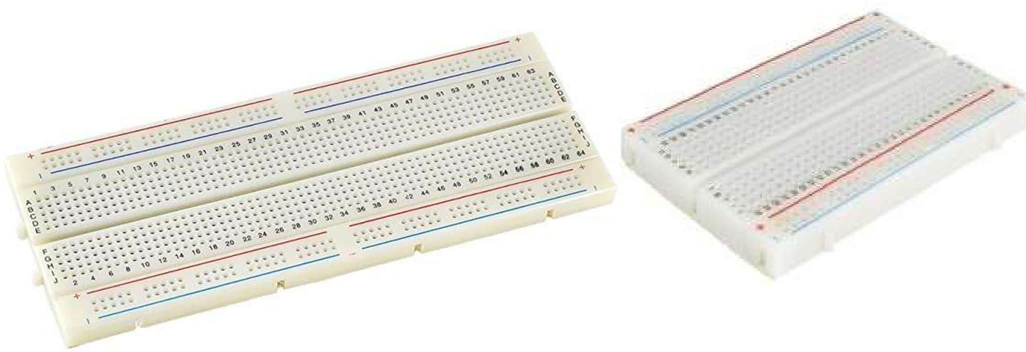


Figure 5: Bread Boards

1.6 Jumper Wires

A jumper wire is a conducting wire used to transfer electrical signals between two points in a circuit**.** The wires can either be used to modify circuits or to diagnose problems within a circuit. Jumper wires typically vary in color and size depending on what they are being used for. In breadboards, jump wires are used to establish connections between the central micro controller and other devices such as buttons and sensors. If possible, the jumper wire should always be placed on the component side of a circuit board during assembly. The wires should also be routed in an X-Y manner, avoiding any bends. Jump wires should never be raised more than 1/8 of an inch above the surface of the circuit board.

Figure 6: Jumper Wires

4. Circuit Diagram

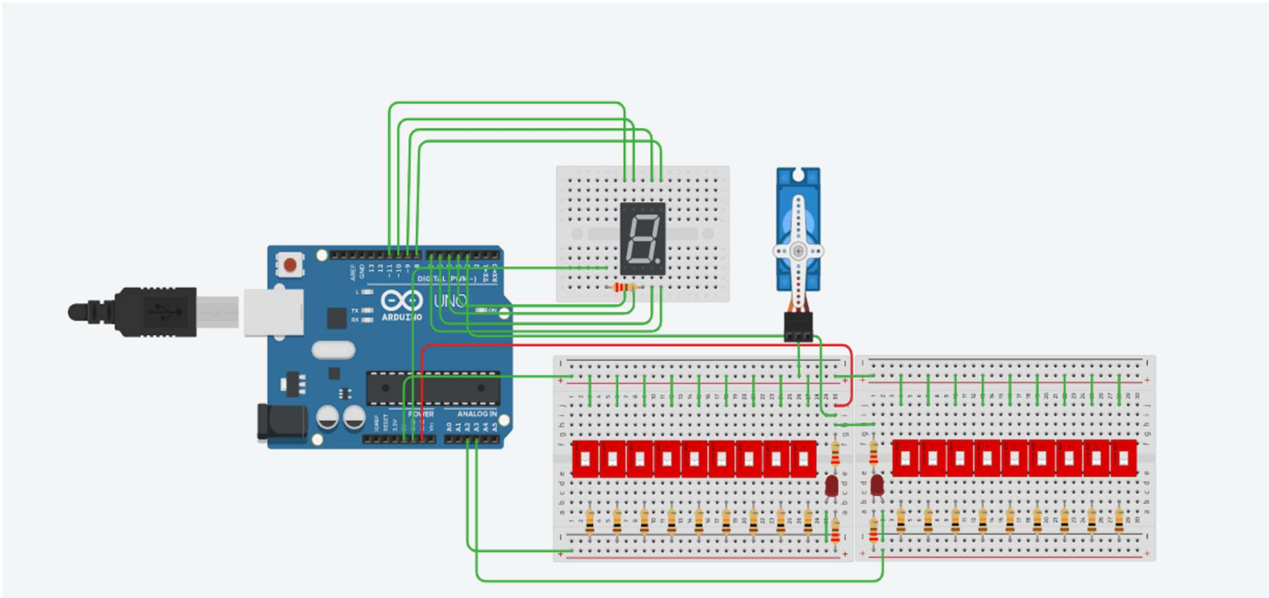


Figure 7: Circuit Diagram for Inclinometer

5. Methodology

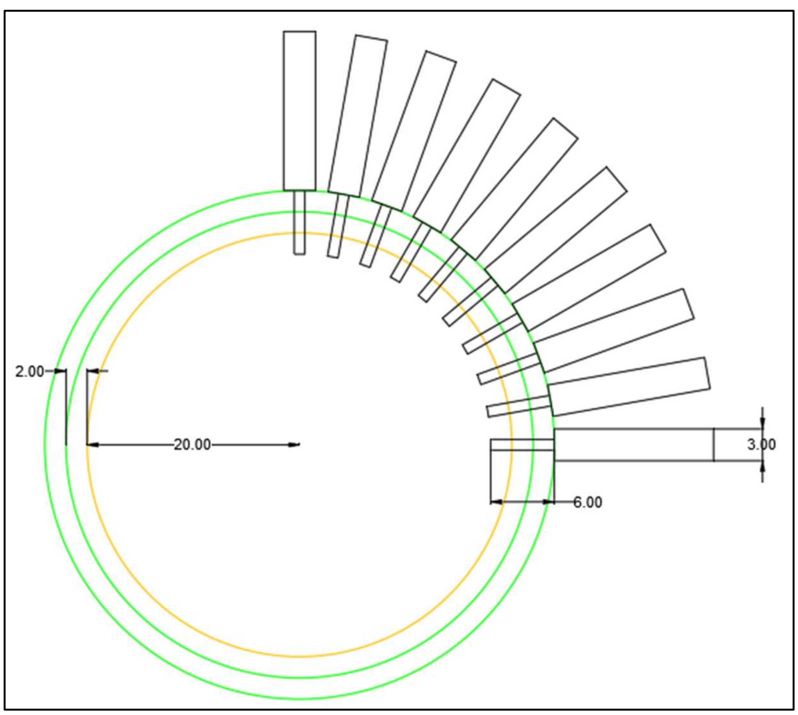


Figure 8: Cross-Section of Inclinometer

The Circuit Diagram given above is a simple ammeter implementation using Arduino. The switches shown in the circuit are replaced by electrodes of jumper wires. The basic principle on which the sensor works is that the surface of a Newtonian liquid always stays parallel to the ground, no matter at what angle it is tilted. Therefore, as the conductive liquid within the spherical container contacts the pins inserted within the container, current flows through the pins and the liquid. The more the setup is tilted, the more pins the liquid touches, and the more current flows through the circuit. The change in current is realized by parallelly connecting the pins along with a fixed 10k Ohm resistance in series each. An Atmel328 IC based control circuit detects the change in current level with the help of a sophisticated algorithm and suitable calibration. The entire setup is placed on a flat gimbal sustained on a servo motor shaft with a bearing mechanism to provide two degrees of freedom. The servo motor is used to make necessary corrections to the platform periodically. The angular value is also displayed in seven segment display.

Design Considerations

The Conductive liquid must have the following properties:

- Non-Corrosive
- Non-Electrolytic
- Good conductor of electricity
- Moderate viscosity
- Low degree of contact angle
- Consistent voltage level - surface tension characteristics

Highly viscous liquid will prevent abrupt vibration and improve stability but will have slower response time. For demonstration purposes, low concentration brine solution is used.

The containing system should have the following properties:

- The electrodes should be chemically inert and highly conductive. Their penetration depth should be proportionate to their distance from each other and the surface tension of the liquid.
- The container size should be proportional to the precision required and properties of construction components. It should be made of lightweight durable material with smooth hydrophobic surface inside. Wax coating can be applied to further increase repelling force on the liquid.
- The gimbal and the servo motors should be strong enough to hold the moving platform and show robustness towards disturbances.
- In bigger designs, the effect of localized ripples and waves must be considered as it may lead to false readings. As a preventive measure, a vibration resistant semi-submersible rig covering the entire surface area can be used.

Advantages over Gyro-sensors

1. No start-up calibration is required, once constructed.
2. Can start measurement from any arbitrary angle and display with minimal error.
3. The precision can be increased arbitrarily with a tradeoff of size.
4. Robust against abrupt disturbances which can damage the calibration of gyro-sensors.
5. Simple construction, easier to build.

Disadvantages

1. High size to accuracy ratio.
2. Does not work in microgravity.
3. Increased error margin in bigger designs.

6. Practical Implementation

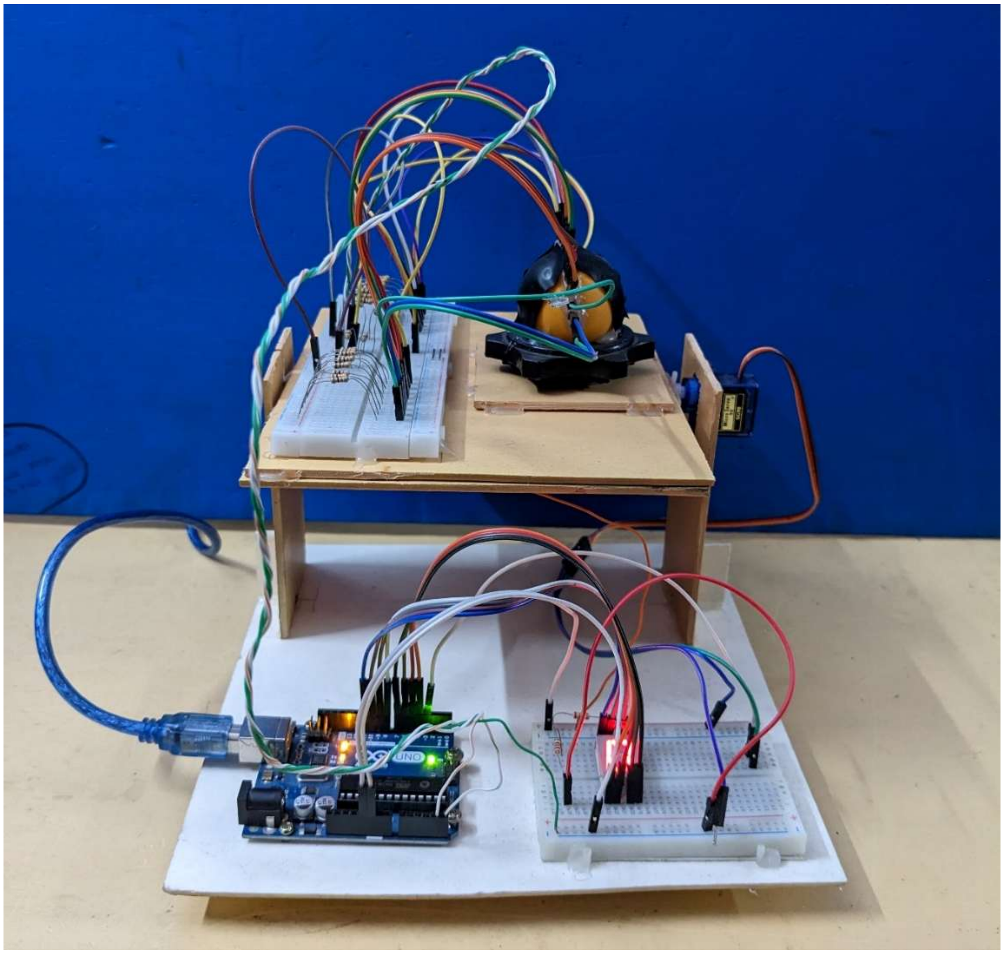
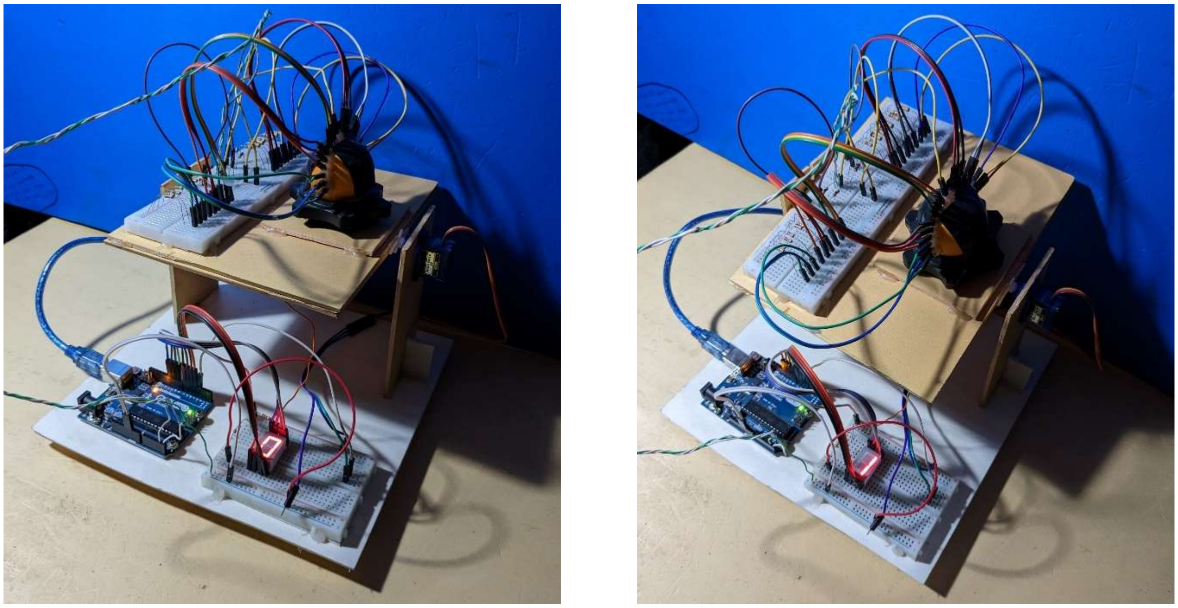


Figure 9: Practical Implementation



(a) Output at surface level (0 degrees) (b) Output at 10-degrees inclination

Figure 10: Output at 10-degrees inclination

7. Results and Discussion

For practical implementation of the concept, a simple structure was constructed with cardboards and plastics. The table tennis ball and sensory breadboard was put atop a platform that was held by the servo motor above a foothold; all made with cardboard. The sensor was built with drilling the table tennis ball and inserting the jumper wires. Hot glue was used in the junctions as insulation, waterproof seal, and to reduce the insertion depth. The Arduino Board was attached using screws whereas the breadboards were with hot glue. The program above was compiled and uploaded to the Arduino Uno U16 attached to the setup. In the beginning, when the platform held by the servo motor is at plane level, the seven-segment display showed 0. The setup has a precision of 10 degrees, which means, with every 10 degrees of inclination, the output of the seven-segment display will increase by 1, the maximum limit of inclination being 90 degrees each side to prevent tangling of the wires. The setup does not provide information on direction but can be understood intuitively. A more elaborate implementation can include much wider-angle measurement, dual axis inclination information, and direction by involving more electrodes, seven-segment displays, and code extensions.

8. Conclusion

This project was a part of the course EE3200 titled Electrical and Electronic Project Design, performed by Saikat Chakraborty, and arranged by The Department of Electrical and Electronic Engineering, Khulna University of Engineering and Technology, Khulna. It was about designing and developing a project that encompasses the knowledge attained from the journey through the previous courses of Electrical and Electronic Engineering discipline. Following the criterion of novelty, a two directional inclinometer was selected for this project.

The initial idea was to make a movable platform with an entangled plane within a computer simulation. But to keep the project more focused on Electrical Engineering, it was shifted towards a self-correcting platform.

A prototype was built as proof of concept where vertically inserted pins in a water bottle indicated water level using LED array. The design was later modified into a spherical shape with more pins and changed value of series resistors.

The project employed some physical concept to demonstrate a different approach towards achievement of solution to an existing problem. Although in some cases it may outperform the typical sensors used, the biggest achievement was application of theoretical knowledge learned from the curriculum of Electrical Engineering.

9. Reference

[1] http://www.pololu.com/product/2191

[2] https://protosupplies.com/product/servomotor-micro-sg90

[3] https://en.wikipedia.org

[*] https://www.tinkercad.com

[*] https://www.create.arduino.cc/projecthub