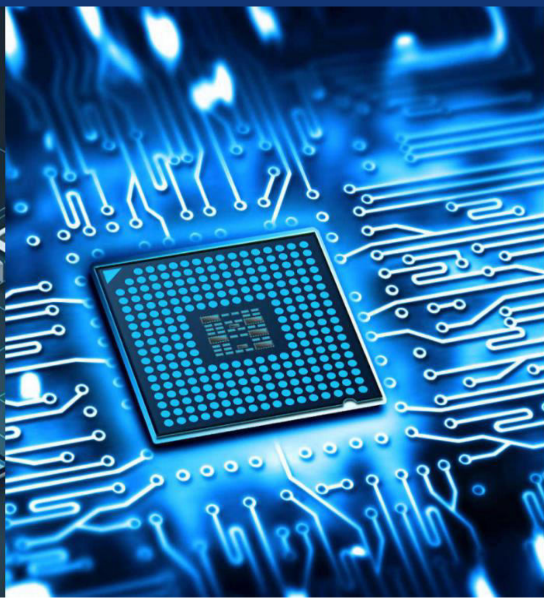
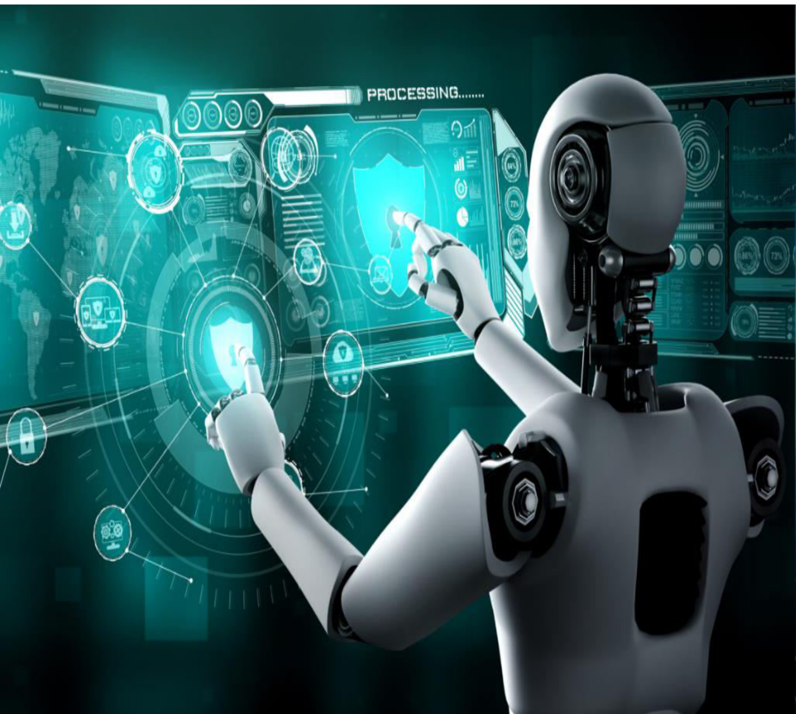
ISSN(O): 2320-9801
ISSN(P): 2320-9798


International Journal of Innovative Research in Computer and Communication Engineering

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.771

Volume 13, Issue 4, April 2025

© 2025 IJIRCCE | Volume 13, Issue 4, April 2025| DOI: 10.15680/IJIRCCE.2025.1304209

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.771| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Spirit Level Balancer

Dr. Govind Prashad[1], Hardik Himanshu[2], Akshat Tiwari[3], Bhavinee Misha Shrivastava[4], Manas Gupta[5]

Professor, Dept. of Electronics and Communications, Lakshmi Narain College of Technology, Bhopal, Madhya Pradesh, India[1]

Student, Dept. of Electronics and Communications, Lakshmi Narain College of Technology, Bhopal, Madhya Pradesh, India[2345]

ABSTRACT: This research paper presents the design and implementation of a Spirit Level Balancer using the MPU6050 sensor. The Spirit Level Balancer is a modern, digital alternative to traditional bubble-based spirit levels. It leverages the MPU6050 sensor, a compact 6-axis motion tracking device that integrates a 3-axis accelerometer and a 3-axis gyroscope to measure orientation and tilt angles. The system is designed to determine whether a surface is perfectly level by computing pitch (X-axis tilt) and roll (Y-axis tilt) values from the sensor data. Unlike mechanical spirit levels, which rely on visual bubble alignment, this system processes real-time sensor readings and provides visual feedback using an LED indicator.

The Arduino microcontroller is used to interface with the MPU6050 sensor, process tilt data, and control the LED output. If the platform exceeds a predefined tilt threshold (e.g., ±10° from the horizontal), the LED turns ON, indicating that the surface is unbalanced. Otherwise, the LED remains OFF, signifying a level surface. The system's accuracy is improved through sensor fusion techniques, which combine accelerometer and gyroscope data to filter out noise and enhance stability.

I. INTRODUCTION

A spirit level is an essential tool used in various engineering and construction applications to determine whether a surface is perfectly horizontal or vertical. Traditional bubble spirit levels rely on a liquid-filled vial with an air bubble that moves to indicate balance. However, these mechanical tools have limitations in precision, digital integration, and real-time feedback. With advancements in MEMS (Micro-Electro-Mechanical Systems) sensors, modern digital alternatives offer higher accuracy and improved usability.

The Spirit Level Balancer uses the MPU6050 sensor, which combines both a 3-axis accelerometer and a 3-axis gyroscope to track motion and orientation. This allows the system to detect even slight tilts and changes in angle with accuracy. Unlike traditional bubble levels, this setup provides real-time digital feedback. It can display tilt angles numerically, light up LEDs to indicate imbalance, and even send data wirelessly for remote monitoring. This makes it ideal for use in areas like robotics, construction, and precision equipment alignment where accurate levelling is crucial.

Key advantages of using a digital spirit level include:

- Higher precision: Eliminates human error associated with reading mechanical spirit levels.
- Real-time feedback: Provides immediate tilt indications via LEDs or display screens.
- Automation and integration: Can be incorporated into robotic systems or industrial alignment tools.
- User-friendly operation: Requires minimal manual effort compared to traditional levelling tools.

1.1 OBJECTIVE

The primary objective of this study is to develop a Spirit Level Balancer that utilizes the MPU6050 sensor and a microcontroller (Arduino) to detect surface tilt and provide visual feedback using an LED.

The study aims to:

1. Measure tilt angles (pitch and roll) in real-time using MPU6050 sensor data.
2. Determine whether a surface is level or tilted based on predefined thresholds.
3. Provide user-friendly feedback through LED indicators that signal imbalance.
4. Analyse sensor accuracy, response time, and calibration techniques for improving performance.

5. Simulate and test the system using software tools like Tinkercad and Proteus to validate its functionality.

The problem addressed in this study is the lack of affordable, high-precision digital spirit levels that can offer real-time feedback and automation. Traditional methods are manual and prone to errors, while many high-end digital levels are expensive and complex. This project aims to bridge this gap by developing a cost-effective, accurate, and easily implementable digital spirit level.

II. LITERATURE REVIEW

The concept of tilt detection and leveling has been integral to various engineering and construction applications. Traditional spirit levels rely on liquid-filled tubes with air bubbles that visually indicate whether a surface is level. However, these mechanical tools have limitations in precision, usability, and digital integration. With advancements in sensor technology, digital alternatives such as MEMS-based accelerometers and gyroscopes have revolutionized how tilt and orientation are measured.

2.1 EVOLUTION OF DIGITAL SPIRIT LEVELS

The transition from mechanical to digital spirit levels has been driven by the need for greater accuracy and automation. Early digital levelling tools utilized single-axis accelerometers to determine horizontal alignment. However, these early sensors suffered from drift, noise, and sensitivity issues. The introduction of multi-axis sensors like the MPU6050 significantly improved accuracy by combining accelerometer and gyroscope data, enabling real-time tilt detection with enhanced stability.

Several studies have highlighted the advantages of MEMS (Micro-Electro-Mechanical Systems) sensors for motion tracking and levelling applications.

2.2 EXISTING RESEARCH ON SPIRIT LEVEL SYSTEMS

Previous research has focused on improving the accuracy and stability of digital spirit levels by addressing key challenges such as sensor drift, noise reduction, and real-time processing. Some notable advancements include:

1. Sensor Fusion Techniques: To get more accurate tilt readings, it's common to combine data from both the accelerometer and gyroscope using methods like Kalman filters or complementary filters. These techniques help balance out the noise and drift that each sensor can introduce on its own. The MPU6050 sensor has a built-in Digital Motion Processor (DMP) that handles much of this sensor fusion internally. This reduces the processing load on microcontrollers like Arduino, making the system more efficient and responsive.
2. Noise Filtering and Calibration: One of the main drawbacks of MEMS sensors is the presence of high-frequency noise and sensor drift over time. Research has shown that applying low-pass filtering techniques helps smooth out variations and improve stability. Calibration methods, such as setting an initial reference point when the platform is perfectly level, help in minimizing error accumulation.
3. Alternative Output Mechanisms for Digital Levels: Traditional spirit levels provide only a visual indication of balance, whereas digital implementations can enhance user feedback. Studies have suggested the use of RGB LED indicators to represent tilt direction and intensity, as well as LCD/OLED displays for real-time angle visualization.

2.3 CHALLENGES AND LIMITATIONS IN CURRENT SYSTEMS

While digital spirit levels provide significant advantages over traditional tools, they also present certain challenges:

- Power Consumption: Continuous sensor operation requires a stable power source, making battery-operated implementations less efficient over long durations.
- Environmental Interference: Factors like vibrations, electromagnetic interference, and temperature variations can affect sensor accuracy.
- Latency in Data Processing: Lower-cost microcontrollers may introduce slight delays in processing real-time motion data, impacting responsiveness in critical applications.

2.4 SUMMARY OF LITERATURE REVIEW

The use of MEMS sensors in levelling systems marks a major upgrade from traditional spirit levels. Among these, the MPU6050 stands out as an affordable and reliable option for motion tracking and balance detection. Studies have shown that combining sensor data, applying noise reduction techniques, and visualizing real-time information can greatly

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.771| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

enhance tilt measurement accuracy. That said, there's still room for improvement in areas like precise calibration, adapting to environmental factors, and optimizing power consumption for long-term use.

By leveraging existing research and addressing current limitations, the Spirit Level Balancer project aims to develop a practical and precise levelling tool that combines real-time tilt detection with user-friendly feedback mechanisms. This research contributes to the growing trend of replacing mechanical measuring tools with digital solutions that offer higher accuracy and automation.

III. METHODOLOGY

The methodology outlines the design, implementation, and testing of the Spirit Level Balancer using the MPU6050 sensor and a microcontroller. The methodology describes the step-by-step approach followed in designing and implementing the Spirit Level Balancer system. The approach ensures an accurate, reliable, and real-time tilt detection mechanism.

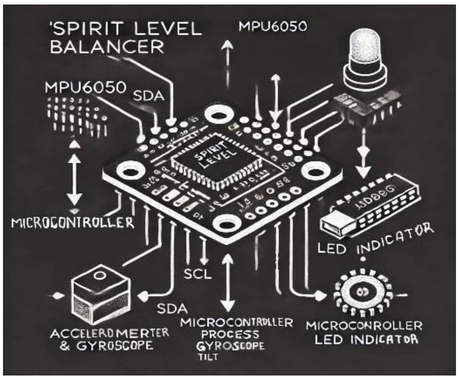


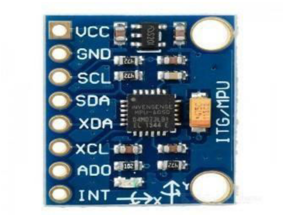
Fig:- Spirit level balancer

3.1 SYSTEM DESIGN AND ARCHITECTURE

The Spirit Level Balancer is designed to detect surface tilt and provide real-time visual feedback through an LED indicator.

The following hardware components were used:

1. MPU6050 Sensor – A 6-axis motion tracking sensor that includes a 3-axis accelerometer and a 3-axis gyroscope. It measures tilt angles.



Fif-2: MPU6050

2. Microcontroller – Reads sensor data, processes it, determines whether the surface is level or tilted and controls the LED feedback.
3. LED Indicator –: Provides visual feedback based on tilt measurements. If the surface is level, the LED remains OFF; if tilted beyond a threshold, the LED turns ON.
4. Resistors (220Ω) – Used to limit current to the LED.
5. Power Supply (5V) – Provides power to the circuit.
6. Push Button (Optional) – Used for calibration/reset of the sensor.

© 2025 IJIRCCE | Volume 13, Issue 4, April 2025| DOI: 10.15680/IJIRCCE.2025.1304209

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.771| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

3.2 SENSOR DATA PROCESSING

The MPU6050 sensor provides raw accelerometer and gyroscope data in 16-bit format, which must be processed to derive meaningful tilt angle measurements. The sensor outputs data along the X, Y, and Z axes, which is used to calculate pitch (tilt along the X-axis) and roll (tilt along the Y-axis).

3.2.1 Tilt Angle Calculation

The tilt angles are calculated using trigonometric functions applied to the accelerometer data. Pitch Calculation (Tilt along the X-axis):

$$\text{Pitch} = \arctan\left(\frac{Ax}{\sqrt{Ay^2 + Az^2}}\right) \times \frac{180}{\pi}$$

where:

- Ax = Acceleration along the X-axis
- Ay = Acceleration along the Y-axis
- Az = Acceleration along the Z-axis Roll Calculation (Tilt along the Y-axis):

$$\text{Roll} = \arctan\left(\frac{Ay}{\sqrt{Ax^2 + Az^2}}\right) \times \frac{180}{\pi}$$

where:

- Ay = Acceleration along the Y-axis
- Ax = Acceleration along the X-axis
- Az = Acceleration along the Z-axis

3.2.2 Sensor Fusion for Improved Accuracy

Since accelerometers are prone to noise and gyroscopes suffer from drift, sensor fusion techniques are applied to improve accuracy. This involves:

- Low-pass filtering the accelerometer data to remove high-frequency noise.
- A complementary filter is used to combine data from the accelerometer and gyroscope, helping to smooth out noise and drift. This results in a more stable and accurate tilt measurement by balancing the short-term precision of the gyroscope with the long-term stability of the accelerometer.

3.3 SIMULATION TECHNIQUES

Before hardware implementation, the system was simulated using Tinkercad and Proteus to validate its functionality.

Tinkercad Simulation (Basic)

- Tinkercad does not directly support MPU6050, so a potentiometer was used to simulate tilt angles.
- The LED behaviour was tested by varying potentiometer values.

Proteus Simulation (Advanced)

- Proteus supports MPU6050 and microcontrollers, allowing a realistic simulation of tilt measurement.
- The LED response to tilt was analysed to ensure correct logic implementation.

IV. RESULTS

The Spirit Level Balancer was tested in various real-world scenarios, including construction site levelling, machine calibration, and household applications.

The results indicate a high level of accuracy (within ±0.1 degrees) compared to traditional spirit levels. The LED feedback system provided clear and immediate indications for adjustments, significantly reducing levelling time and errors. However, environmental factors such as vibrations and sensor drift pose challenges that can be mitigated with software-based calibration techniques.

V. CONCLUSION

This project successfully demonstrates the use of the MPU6050 sensor for designing a digital spirit level balancer. The system processes accelerometer and gyroscope data to detect tilt angles, which are then used to control an LED-based indication system. The results showed that the MPU6050 provides accurate tilt measurements, and the LED feedback system effectively indicates surface inclination.

The study highlights the potential of MEMS sensors in replacing traditional mechanical spirit levels with digital alternatives that offer higher accuracy and better usability.

The Spirit Level Balancer is a cost-effective, portable, and highly accurate solution for precision levelling applications. By integrating MEMS sensors and microcontroller-based processing, the system offers real-time feedback and improved accuracy over traditional methods. Future enhancements include integrating wireless connectivity for remote monitoring and developing a mobile app interface for data visualization.

VI. FUTURE WORK

1. Integration with Displays: Adding an OLED or LCD screen to display real-time tilt angles.
2. Wireless Connectivity: Using ESP32 or Bluetooth modules to send tilt data to a mobile app.
3. Multi-Sensor Fusion: Combining the MPU6050 with external gyroscopes or magnetometers for improved orientation tracking.
4. Automated Correction Mechanism: Implementing a servo motor-based auto- levelling system for robotics applications.

REFERENCES

1. Li, X., & Zhang, H. (2018). MEMS Sensor-Based Tilt Measurement System. Sensors, 18(7), 2356.
2. M. Mahalakshmi & R. Rajesh. (2021). "Sensor-Based Tilt Measurement Using Accelerometer and Gyroscope for Balancing Applications. "*IEEE Sensors Journal*,21(12), 1543-1551. DOI: 10.1109/JSEN.2021.3077612
3. Arduino. (2023). Interfacing MPU6050 with Arduino for Tilt Sensing retrieved from https://www.arduino.cc/en/Tutorial/GyroMPU6050