# DESIGN OF A TWO-AXIS LEVELLING DEVICE

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**ABSTRACT:** This levelling device can be used not only to achieve the parallelism between the surface on which it is fixed and the horizontal plane, but also to accomplish desired tilt angles around the two axis. The device consists of two main components: microcontroller development board and gyroscope sensor. The updating frequency of the displayed values is 10 Hz, these being displayed in the same time for both axes, presenting also the feature of holding the displayed values. At the same time, the device can perform the recalibration, which can also be used for the rescaling to a certain desired angle, thus simplifying the achievement of it. The measurement accuracy is two tenths of a degree, this being high considering the price and the characteristics of the components used. At the end, the designed device is appreciated as being useful, quite simple to implement and easy to operate.

**KEY WORDS**: output range expansion, gyroscope sensor, microcontroller based levelling, source code optimization, two-axis levelling device

## 1. INTRODUCTION

Gyroscope sensors are used in many applications that require the objects or persons tracking of movement. For instance, in the medical field, these sensors are used to track the motion of the patients and to reduce their walking dysfunctions. In order to realize this, a gyroscope-based sensor is embedded in a shoe. The embedded sensor sends signals to the microcontroller, and based on those signals, the microcontroller commands the electrical stimulator that is attached to the affected muscle. In this way, the system improves the affected leg's motion. The tests conducted with this system shown positive results [1]. This type of sensor is also used in the structure of smart phones. Android uses a standard 3-axis coordinate system for built-in sensor including the gyroscope sensor. Because of the high number of sensors in the smart phones, it has a big range of applications in various domains [2, 8].

Gyroscope sensor measures the device's rotation around each of the three physical axes. It is used to detect rotation around those axes. If the device is not rotating, the gyroscope sensor reading should be zero. Based on this sensor, location-based applications were developed. Accelerometer data can be used to determine different types of movement that are realized by the smartphone user. Using this data to generate distinct patterns, the smartphone can recognize certain types of activities (standing, walking, and running) [2, 7].

Precision-guided munition is a military domain where gyroscope sensor is used. Those devices are considered accurate and low cost to manufacture and are easy to implement. The main characteristic of the guided munition is to prevent countermeasure, signal jamming and not running off from its course. A gyroscope is implanted in the warhead to sense direction and the system is able to control its flight [3].

The swimming motions during the training can be measured also by a gyroscope based motion system. The system consists of a sensing unit attached to the swimmer's wrist that has a sensor to measure the swimming stroke and a receiver unit to collect the sensor data. In this way, the recording of the movements and the post measurement process are done much easier, comparing to the classic technique which implies video cameras. This system use a program to reconstructs the motions based on the sensor data [9].

In mechanical structure, to detect the damage in order to preserve its integrity and to extend the life span a Vibration Structural Health Monitoring Systems (VSHMS) can be used. The analyzed structure is excited and the response is acquired by the VSHMS using accelerometers or gyroscope sensors [10].

In this paper, the gyroscope sensor is used to develop an electronic device that measures the tilt angle around the two axes included into the horizontal plane.

## 2. DEVICE IMPLEMENTATION

In figure 1 is shown the functional block diagram of the levelling device. It displays the main components of the device and the links between them. Also it's established the informational flow that starts from the gyroscope sensor and ends at the LCD.

The gyroscope sensor measures the orientation and the angular acceleration. It sends the analogic signals (A1, A2) to the microcontroller (μC). The microcontroller receives them at the analogic inputs. The microcontroller calculates the values of the angles based on the implemented source code. The LCD can operate in two modes: 8-bit mode or 4-bit mode. In 8-bit mode, each character is sent in one stage. In 4-bit mode, each character is sent from the microcontroller to the LCD in two stages. In this implementation the values are sent by the microcontroller to the LCD in the parallel form of 8 bits ASCII coded digital signal. The LCD receives data at its 8 data pins (D0-D7). Enable (E) triggers the displaying of each character, and the reset (RS) resets the entire display. All blocks are supplied from 5V direct current.

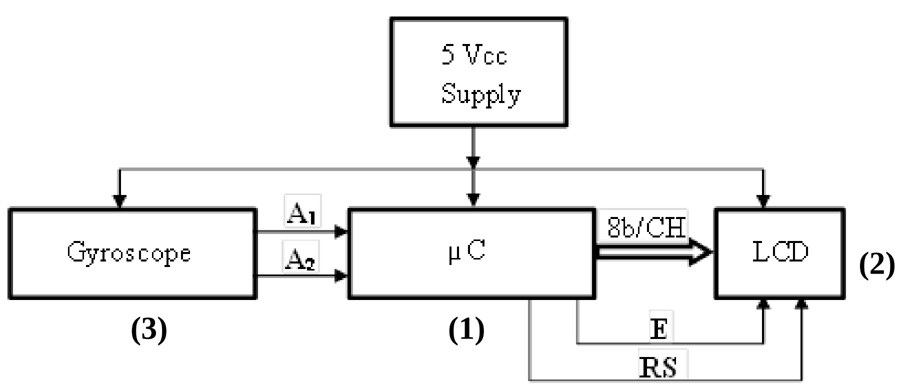

Figure 1. Functional block diagram of the levelling device.

The main features and specifications of the components used are given below, starting with the gyroscope sensor [4]:

- Three-axis magnetic field accelerometer module;
- Sensor chip ADXL335;
- Operating Voltage Range: 3 ~ 5 V;
- Supply Current: 350 µA;
- Interface: Analog output.

Arduino Uno R3 development board has the following features [5]:

- Microcontroller: ATmega328P;
- Digital I/O pins: 14 (of which 6 provide PWM output);
- Analog input pins: 6;
- Flash memory: 32 kB;
- EEPROM: 1 kB (ATmega328P);
- Clock speed: 16 MHz.

The liquid-crystal display is recommended for industrial application and it is type LCD 1602 provides 2 rows and 16 columns and its main features are [6]:

- Display format: 16 characters and 2 lines;
- Power supply: 5 V, ±10%;
- Backlight (SIDE): LED (white).

Figure 2 presents the wiring connections diagram of the two-axis leveling devices.

This diagram has the role to illustrate the connections that are made between the system's components. Depending of the role, the conductors were represented in different colors, as follows:

- Red (+) and black (-) supply of the system's components;
- Yellow sends the binary code for each character that is displayed on LCD;
- Violet to send commands from the microcontroller to the LCD;
- Blue represents the two gyroscope's analog outputs;
- Green represents the conductors that are connecting to the Menu and Hold buttons and the Arduino Uno R3 development board.

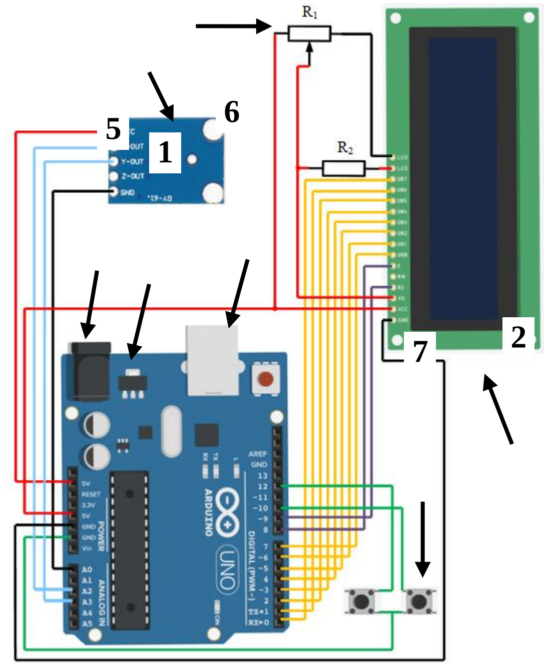


Figure 2. Wiring connection diagram of the levelling device.

By the R1 potentiometer the adjustment of the backlight intensity is accomplished, and through the R2 resistor the limitation of the current supply of the LCD display is achieved.

The figure 3 presents the hardware implementation of the levelling device, there the main components of the assembled device are highlighted and they are the folowing:

1. Arduino Uno R3 development board;
2. LCD;
3. ADXL335 gyroscope sensor;

4. R1 potentiometer;
5. Supply connector;
6. USB connector for data transfer;
7. ***Menu*** and ***Hold*** buttons.

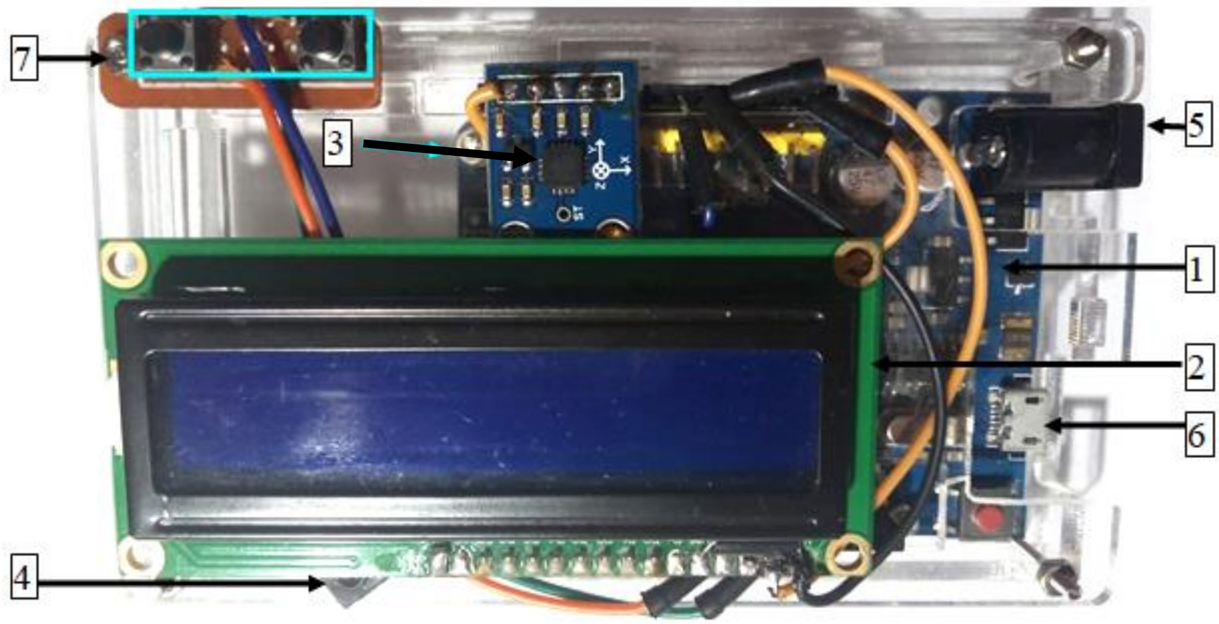


Figure 3. Hardware implementation of the levelling device.

## 3. SOFTWARE DETAILS

The functional logic is as following, when the device starts to operate, firstly the microcontroller acquires the values of X and Y axes. If the value of the next iteration is not equal to the previous one, then the μC calculates the new value of the X axis and this value will be displayed on the LCD. The same thing is valid also for the ***Y*** axis. If ***Menu*** button is triggered, the microcontroller runs on demand the calibration of the desired axis. If ***Hold*** button is shortly pressed, on the LCD display continuously will be shown the same values for the axes, as an average of ten values acquired during the last second, this happens while ***Hold*** is in the high state logic. If ***Hold*** is again triggered the device is switched in the base mode.

The source code that is implemented in the microcontroller was designed to be as simple as possible. The purpose of the software optimization was to eliminate the unnecessary code lines. Also, in order to increase the efficiency, the LCD is working in 8-bit mode. In this way is shortened the necessary time of the LCD for data receiving. LCD is initialized as following:

```
#include <LiquidCrystal.h>
const int rs = 8, en = 9, d0 = 7 to d7 = 0;
LiquidCrystal lcd(rs, en, d0, d1, d2, d3, d4, d5, d6, d7).
```

***Menu*** and ***Hold*** are define to Arduino d10 and d11 digital pins as input pull-up, in this way buttons just link the inputs to the ground potential.

In order to reach the right position for the ADXL335 gyroscope sensor, its ground connection is established by a trick, the Arduino's analog input A2 is changed to a pull-down input, so that a supply ground is created.

The flowchart that implements the functional logic for the previewed levelling device is provided in figure 4.

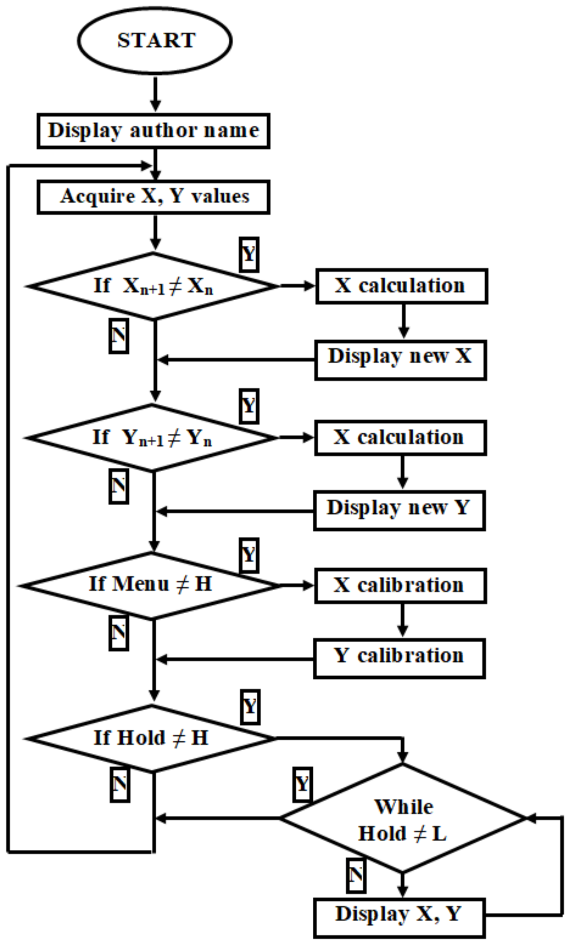


Figure 4. Flowchart of the functional logic.

## 4. TESTING THE DEVICE

Tests were accomplished to adequately optimize the source code, respectively the functional logic, and to check the precision of the electronic balance level device in few work scenarios.

The most important test's step is given in figure 5, and it is the device's calibration result. Calibration was performed in parallel with a classic bubble spirit level (8). Test setup consists of mechanical balancing on X axis (9) and Y axis (10) of the spirit level and also of the levelling device. By pushing the ***Menu*** button, the device rearranges the entire scale of grades between -90° and 90°, so that the zero point is reached, firstly for X and for Y axis afterwards. Hold button is not used in this scenario. A magnified screenshot of the LCD display is given in the bottom side of the image.

During tests the device shows stability and accurate values for angles have been accomplished.

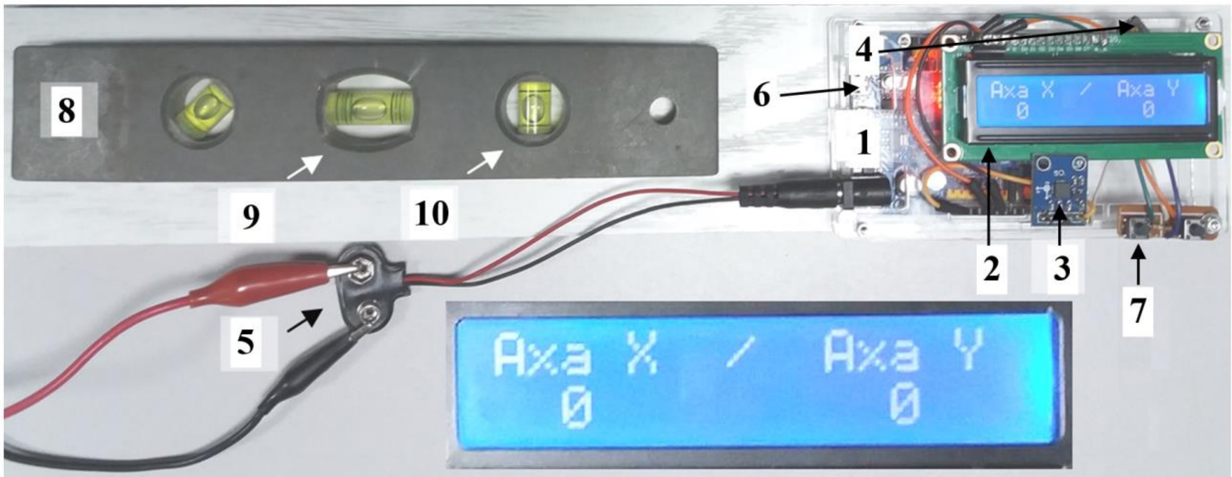

Figure 5. Testing of the levelling device.

## 5. CONCLUSION

The electronic levelling device was designed and tested in order to achieve the maximum performance by using low-cost components, which were assembled in a simple schematic. This device can be useful in mechanical balancing level and also to achieve some angular desired tilt.

The levelling device also has the important advantage of values visibility, and in this way it not stress the visual acuity of the operator, being faster and easier readable due to the clear values displayed and adjustable backlight.

From tests is resulted a precision of 1.3 degree and a need of low movement, under 0.5 Hz, for maximum measuring accuracy. The measuring range is from -90$^{o}$ to 90$^{o}$ around 0, which is along gravitational direction.

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