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Design of an electronic device for two-axis balance level measurement

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This 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.

Keywords*: gyroscope output range expansion, gyroscope sensor, microcontroller based device, source code optimization, two-axis balance level measurement*

1. Introduction

Gyroscope sensor is used in many fields, from those fields medical research holds an important place. Gyroscope sensor are used in applications where is necessary to track the movements made by the patients. For example, gyroscope-based sensor embedded in a shoe insole is used to help people with walking dysfunction. The device is embedded in the shoe and detects the movements that appear during the gait cycle. The sensor is connected to a microcontroller, and based on the signals that the microcontroller receives from the sensor it sends commands to the electrical stimulator that is attached to the affected muscles. In this way, the system improves the affected leg's motion. The tests with this system show 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 [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].

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. Hardware implementation

In figure 1 is shown the functional block diagram of the 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.

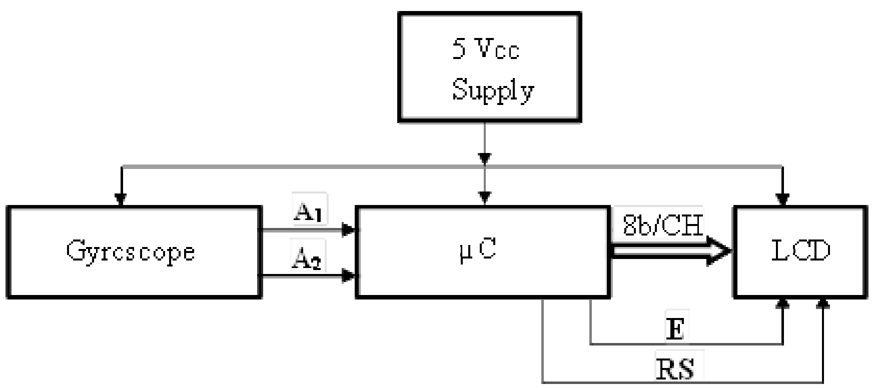

Figure 1. Functional Block Diagram of the device.

The gyroscope sensor measures the orientation and the angular acceleration. It sends the analogic signals (A_1, A_2) 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. Those 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.

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;
- SRAM: 2 kB (ATmega328P);
- EEPROM: 1 kB (ATmega328P);
- Clock speed: 16 MHz.

The liquid-crystal display (LCD) provides 16 rows and 2 columns and its main features are [6]:

- Display format: 16 characters and 2 lines;
- Input data: 4-bits or 8-bits interface available;
- Display font: 5 x 8 dots;
- Power supply: 5 V, ±10%;
- Backlight (SIDE): LED (white).

Figure 2 presents the first hardware implementation and also the initial tests. The connections between LCD and Arduino, and also between gyroscope and Arduino, were optimized in the electronic wiring meaning.

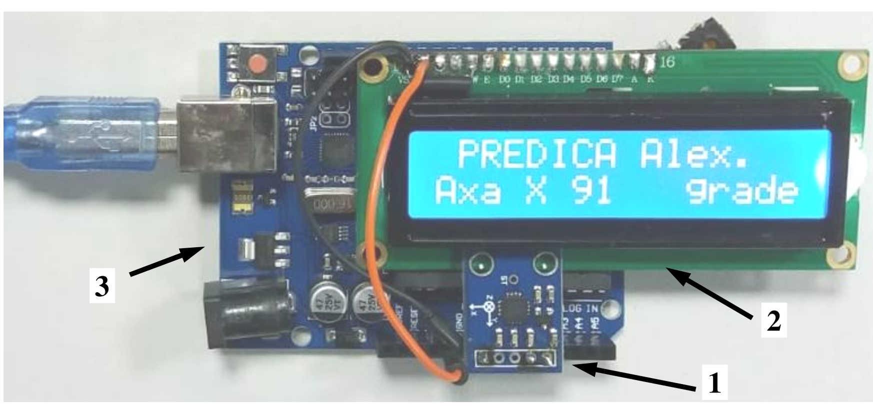

Figure 2. Assembled device and ready to use on X axis.

The main components of the first implementation of the assembled device are:
1. ADXL335 gyroscope sensor;
2. Arduino Uno R3 development board;
3. 16 x 2 LCD display.

3. Software implementation

The flowchart that implements the functional logic for the previewed device is provided in figure 3.

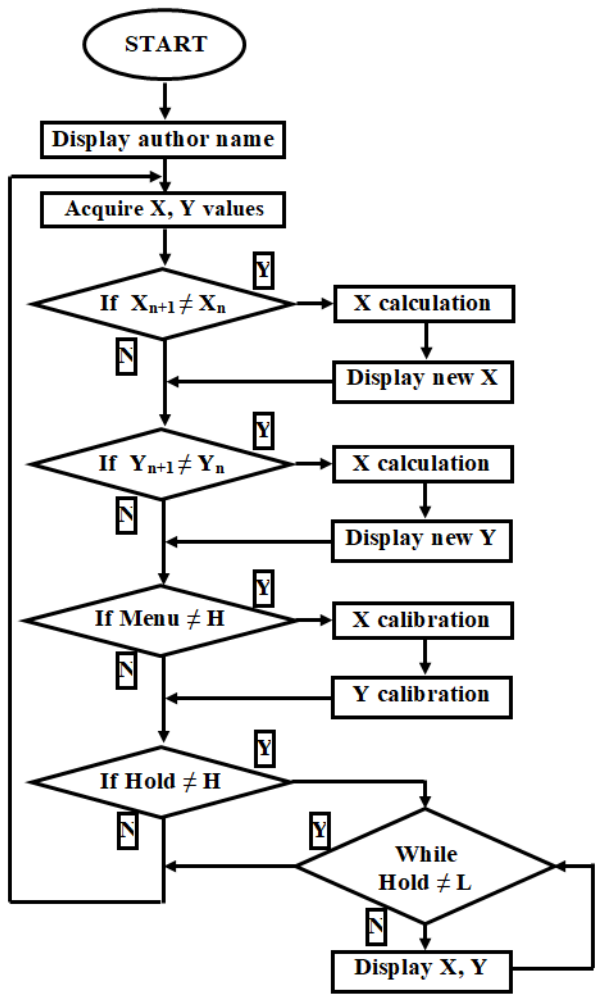

Figure 3. The flowchart of the implemented functional logic.

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.

4. Testing and optimization

Test were accomplished to optimize the source code, respectively the functional logic, and to check the precision of the electronic balance level device.

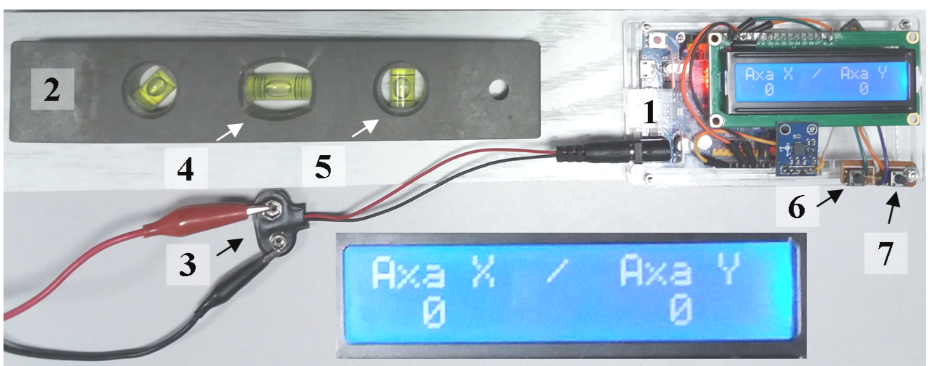

Figure 4. Functional Block Diagram of the device.

In figure 4 the device calibration result is presented. Calibration was performed in parallel with a classic 3 bubble spirit level (**2**). Test setup consists of mechanical balancing on ***X*** axis (**4**) and ***Y*** axis (**5**) of the spirit level, and the calibration of the electronic balance level device (**1**) , which is supplied by plug **3**, having that reference. Pushing the ***Menu*** button (**6**) the device rearranges the entire scale of grades, -90 to 90, so that the zero point is reached, firstly for ***X*** and for ***Y*** axis afterwards. ***Hold*** button (**7**) is not used in this scenario. A magnified screenshot of the LCD display is given in the bottom side of the image.

5. Conclusion

The electronic balance level device was designed and tested in order to achieve the maximum performance form usual components assembled in a simple schematic. This device can be useful in mechanical balancing level and also to achieve some angular desired tilt.

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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