ARDUINO - BASED SYSTEM FOR MEASURING WEIGHT AND QUANTITY OF ITEMS (DIGITAL SCALE)

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Abstract: In this project a system for measuring weight, as well as for measuring quantity of elements of the same type is presented. It has been developed on the principle of working of a digital scale, but is built using the Arduino microcontroller development board. The application of the system is oriented to the environment of production processes. Also, experimental studies have been presented concerning a number of factors that are relevant to the accuracy of the system, as well as an analysis of the results obtained.

Key words: Arduino, Elements, Scale

1. Introduction

Nowadays, weight measurement systems are widely used in different areas of work. The system being developed is oriented towards the sphere of production processes. The application is directed in this direction because there are mostly elements identical in type and weight in large quantities. Daily they must be weighed to determine their number for different purposes in the manufacturing process.

The system uses a sensor - load cell. It is the most commonly used for such systems. Based on this sensor and its combination with the Arduino UNO R3 microcontroller development board was developed a way that determines the quantity of elements as well as their weight.

In this project a developed system for weight and quantity measurement (digital scale) is presented, the hardware being a combination of load cell, delta sigma analog digital converter, Arduino development board, LCD display and contactless circuit board.

2. Model and way of operation of the system.

The model is a 2D visualization of the hardware part of the system. It is developed using the special software "Fritzing". The model can be seen in the following figure:

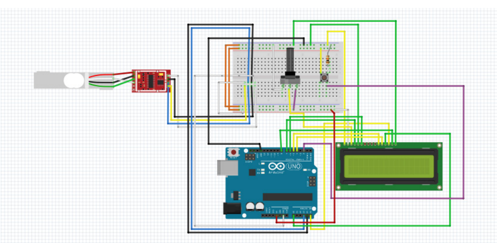

Figure 1 - System model.

The load cell is a transducer that is used to convert a mechanical force into an electrical output signal. This sensor has four strain gauges in a Wheatstone bridge circuit.

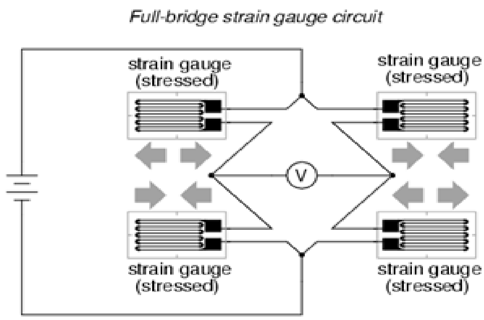

Fig. 2 – Four strain gauges in a Wheatstone bridge configuration [1].

When force or load is applied to the load cell, the strain gauge deforms causing a change in its electrical resistance with a voltage proportional amount. The change in resistance of the strain gauges gives an electrical signal. The output signal is of the order of several millivolts. An amplifier is needed to use this signal.

The HX711 amplifier is a precision 24 - bit analogue digital converter (ADC) specifically designed for load cells and applications in industrial control with the ability to connect directly to the sensor [2]. The information processed by it is submitted to the Arduino processing board.

The Arduino UNO R3 board is a physically programmable board (microcontroller) and part of the Integrated Development Enviroment (IDE) software that can be used by a computer and also can be used to upload the computer code to the board. Unlike the other programmable arduino boards, there is no need for separate hardware to upload a new PCB code, the only thing you need here is a USB cable. Also, IDE software is a simplified version of a C ++ compiler. The Arduino board has 14 digital input and output pins, 6 of which can be used as outputs for wide pulse modulation, USB connection, power jack, reset button [3].

Once the Arduino PCB processes the information, it is sent to a computer system via the serial USB connection and timely to the LCD display.

3. Arduino IDE software

Arduino IDE is an integrated development environment that contains a text editor, a message zone, a text console, and a toolbar for menu functions and a series of menus. The environment is directly connected to the board hardware to communicate with it as well as to upload programs [4].

Two programs with different functions have been developed for the system. One of the program is used when the device has to be calibrated. The second program is the main one which is used after the calibration is done. The program contains all the necessary instructions for carrying out the weight measurement as well as the calculation of the quantity of items.

Calibration

After the calibration operation is performed, the main program has to be loaded to the Arduino board. The purpose of the program is to find the load cell calibration factor, which is unique to any sensor of this type. Based on this factor, data are given in the respective unit of weight, in this case in grams, according to the following formula, which is set out in the program code:

$$y = mx + b \quad (1)$$

• *y* – Represents the actual weight in grams.

• *x* – It is a rough value obtained from the HX711 amplifier.

• *m* – It is the calibration factor.

• *b* – Represents the point of displacement.

To find the factor we place a load with a weight that is known. A reference weight of 500 grams is used in this project. The value of the factor is then increased or decreased until the weight is reached. When that is accomplished the system is calibrated.

Weight

To obtain the weight, a specific amplifier library is used, which contains a set of instructions. The instruction scale.read_average (10); takes ten rough values obtained from the ADC, which are averaged. The averaging is done in order to obtain a more accurate result.

Quantity of items

The main program is used to measure the quantity of items. It has a formula that implements this function. The formula is as follows:

$$a = y/z \quad (2)$$

• *a* – Represents the reported quantity of items;

• *y* - Represents the reported weight in grams

• *z* – Represents the value of the variable that is equal to the weight of one item count.

4. Simulation and experimental results

Once the correct calibration factor is detected, it is replaced in the master program and loaded onto the Arduino board.

• Calibration Factor - 1900.

The next step that is performed consists of several tests:

Test the sensor at different points

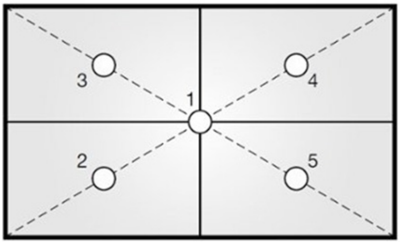

Figure 3 - Five measurement test points [4].

In Fig. 3, you can see the order and position of the weighing point for the test. The weighing scale we have selected has a weight of 500 grams.

Table 1 - Test results of sensor at different points

	Point № 1	Point № 2	Point № 3	Point № 4	Point № 5
Result	500,5 g	500,6 g	500,6 g	500,7 g	500,7 g
	500,4 g	500,9 g	500,5 g	500,6 g	500,8 g
	500,6 g	500,8 g	501 g	500,8 g	500,5 g
	500,4 g	501 g	500,7 g	500,5 g	500,6 g
Average value	500,4 g	500,8 g	500,7 g	500,6 g	500,6 g

This test demonstrates the effect of placing the load at a different location on the load cell. After averaging the results, it is determined that the impact is in the range of 0.4 years.

Table 3 - Results from weighing test.

Load	10 g	20 g	50 g	200 g	500 g
Result	9,7 g	19,9 g	50,8 g	199 g	500,2 g
	9,6 g	19,7 g	50,6 g	198,8 g	500,1 g
	9,8 g	20 g	50,5 g	199 g	500 g
	9,5 g	19,9 g	50,1 g	199,2 g	500,1 g
Average value	9,6 g	19,8 g	50,5 g	199 g	500,1 g
RMS	±0,129099	±0,125831	±0,294392	±0,163299	±0,08165
Load	500 g	200 g	50 g	20 g	10 g
Result	500 g	199 g	50,3 g	19,8 g	9,9 g
	500,1 g	198,8 g	50,2 g	19,7 g	10 g
	500,3 g	199,5 g	50,7 g	20 g	9,6 g
	500 g	199,3 g	50,6 g	19,9 g	9,7 g
Average value	500,1 g	199,1 g	50,4 g	19,8 g	9,8 g
RMS	±0,141421356	±0,537742193	±0,294392029	±0,15	±0,189296945

Repeatability test

The measuring instrument is susceptible to problems with the repeatability of the measurements. This means that when the same load is measured several times, the result will not be exactly the same. To find out what the repeatability is, do this test.

Table 2 - Repeatability test results

Load	Test № 1	Test № 2	Test № 3	Test № 4	Test № 5	Average value
200 g	199,1	198,9	199	199	198,9	198,9
500 g	500,3	500,6	500,5	500,3	500,4	500,4

The test was carried out with standard weights of 200 grams and 500 grams. There is slight fluctuation in the results. However, they will not lead to any significant change in the measurements made with the system.

Weighing test

The aim of the weigh test is to test the accuracy of the measuring instrument in its entire range, in several steps, increasing and decreasing the load sequentially.

The standard deviation is determined by the following formula:

$$S(\Delta y) = \sqrt{\frac{\sum_{i=1}^{n}(\Delta y_i - \overline{\Delta y})^2}{n-1}} \qquad (3)\ [5].$$

From the results obtained in the table with a confidence interval of 95%, it shows that the results are close and grouped around the average. There are slight differences in deviations depending on the direction of the loading the device. They will not affect the measurements for which the device is fitted.

After these three tests are performed, the tests with the elements are carried out. To do this, you first have to measure the weight of one item count. The items examined in this project are two Bulgarian cents.

Table 4 - Weight per item count.

Object	Weight
Coin of two Bulgarian cents	2.5 grams

Weighing test of a quantity of items

Table 5 and Table 6 again revealed a mean square error at a confidence interval of 95%. The values are grouped around the average. There is also a difference in the results of the ascending and descending direction tables, but it is insignificant. Therefore, the effect on the measurements is minimal.

5. Conclusion

From the tests carried out and the results obtained, it was established that the Arduino - based system for measuring the weight and quantity of elements was realized. There are system deviations which are insignificant in the application of the system. The deviations are mainly due to the lack

Table - 5 Test results for the weighing of a quantity of elements in an upward direction of loading

Coin of two Bulgarian cents	10	20	30	40	50	60	70	80
Result - quantity	10	20	30	41	51	60	69	80
Result - weight	25,2 g	50 g	75,5 g	102,6 g	127 g	150 g	173,8 g	199,8 g
	25 g	50,3 g	75,6 g	102,7 g	126,8 g	150,5 g	173,5 g	199,6 g
	24,9 g	50,2 g	75,4 g	103 g	127,5 g	150,3 g	173,6 g	199,4 g
	25 g	50 g	75,5 g	102,5 g	127,6 g	150,1 g	173,9 g	199,7 g
Average value - weight	25 g	50,1 g	75,5 g	102,7 g	127,2 g	150,2 g	173,7 g	199,6 g
RMS	±0,125831	±0,15	±0,08165	±0,216025	±0,386221	±0,221736	±0,182574	±0,170783

Table - 6 Test results for weighing a quantity of elements in a downward direction of loading

Coin of two Bulgarian cents	80	70	60	50	40	30	20	10
Result - quantity	80	69	60	51	41	30	20	10
Result - weight	199,5 g	173,9 g	150 g	127 g	102,6 g	75,2 g	50 g	25,1 g
	199,7 g	174 g	150,1 g	127,5 g	103 g	75,4 g	50,2 g	25 g
	199,6 g	173,8 g	150,2 g	127,8 g	102,5 g	75,6 g	50 g	24,9 g
	199,8 g	173,7 g	150,2 g	126,8 g	102,7 g	75,3 g	50,1 g	25,2 g
Average value - weight	199,6 g	173,8 g	150,1 g	127,2 g	102,7 g	75,3 g	50 g	25 g
RMS	±0,129099	±0,129099	±0,095743	±0,457347	±0,216025	±0,170783	±0,095743	±0,129099

of self-supply of the system as well as to the lack of protection of the wiring of the load cell.

6. Literature

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