Microcontroller-Based Optical Displacement Weighing Scale

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Abstract

Electronic weighing systems are used in industries and business establishments for weighing and segregating materials accurately for process scales. Thus, the aim of this research is to design and implement a microcontroller based optical displacement weighing scale. The electronic weighing system comprises the basic load cell suitable signal conditioners and output recorders/indicators giving both the analog and digital output for further processing. The signals from the load cell are amplified and fed to analog/digital converter, which provide an output in the digital format for display printing/processing etc. The strain gauge based load cell is the most popular weight transducer used in the electronic weighing system.

1. Introduction

Electronic weighing systems are used in industries and business establishments for weighing and segregating materials accurately for process sales [4]. The main advantages of an electronic weighing system when compared with mechanical weighing systems are:
(a) Compactness and small size independent of capacity.
(b) Ruggedness and high dependability.
(c) High speed of response and rapid weighing.
(d) Good accuracy.
(e) Excellent flexibility to monitor multiple loads.
(f) Analog and digital with print-out facility remote indication and parallel display.
(g) Online processing through computer.
The electronic weighing system comprises the basic load cell, suitable signal conditioners and output recorders/ indicators giving both the analog and digital output for further processing. The signals from the load cell are amplified and fed to analog/digital converter, which provide an output in the digital format for display/printing/processing etc. The strain gauge based load cell is the most popular weight transducer used in the electronic weighing system [2].
Weighing scales normally used for weighing smaller weights ranging from probably mgs up to a few kgs. The design of a simple electronic weighing machine presented here can weight heavy object in kilograms from 1 kg to 150kg full scale range white 0.1kg deviation and display weights in kg on LCD.

1.1 Strain Gauge

A strain gauge is a device that is used to measure the strain that occurs in an object. The device was invented in the year 1938 by Edward E. Simmons and Arthur Ruge. The device is still being used in many electronic circuits mainly as the principle sensing element for sensors like torque sensors, pressure sensors, load cells and so on [1].

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Although strain gauges are available in many shapes and sizes, the fundamental working of this device is the same. They also vary in both shape and size according to their field of application. A strain gauge consists of a foil of resistive characteristics, which is safely mounted on a backing material. When a known amount of stress in subjected on the resistive foil, the resistance of the foil changes accordingly. Thus, there is a relation between the change in the resistance and the strain applied [6]. This relation is known by a quantity called gauge factor. The change in the resistance can be calculated with the help of a Wheatstone bridge. The strain gauge used is connected to the Wheatstone bridge with the help of an adhesive called cyanocrylate.

The property of the strain gauge not only depends on the electrical conductivity of the conductor, but also in the size and shape of the conductor used. As a matter of fact, the electrical conductivity also depends on the electrical conductance of the foil. This, in turn depends on the material of the conductor. The electrical resistance of the foil changes according to the change in the foil when it is stretched or compressed [4].

The stretching or compressing is considered normal as long as there is no permanent change in the original appearance of the foil. Stretching causes an increase in the resistance from one end to another. Compressing causes a decrease in the resistance from one end of the conductor to another. Basically, the conductor will be a long strip with parallel lines with the condition that a little stress in the path of the orientation of the parallel lines will cause a resultant bigger strain multiplicatively over the effective length of the conductor. Thus a larger resistance change will be obtained. The force applied to change elongate or shorten the strip can also be calculated with the help of the obtained output resistance. An ideal strain gauge resistance varies from a few 3 ohms to 3 kilo ohms when it is unstressed. This value will change by a small fraction for the full force range of the gauge. It also depends on the elastic limits of the foil material. If there are forces applied to such an extent that they lose their original shape and size, the strain gauge will

no longer be fit to use as a measuring device. So measurement of small fractional changes in the resistance must be taken accurately in order to use the strain gauge as a measuring device [5].
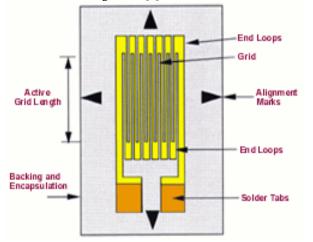

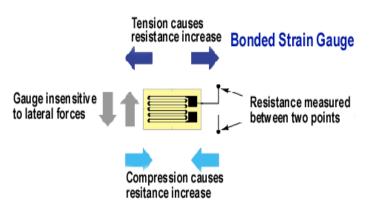**Fig.1**: Strain Gauge Working Principle

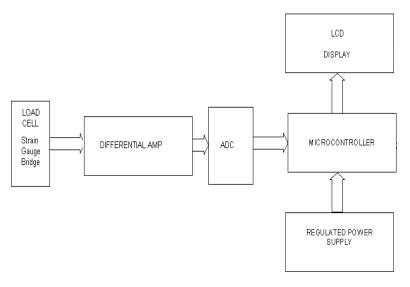**Fig.2**: Force Applied to Change/ Elongate/ Shorten a Strip

Fig.3: Block Diagram of Weight Sensor

2. Materials and Methods

Each individual module was designed separately. After successful simulation and testing, they were put together to create the finalized version.

2.1 The Load Cell

The typical "weight" sensor is in reality a force sensor made up of strain guages and some fairly solid material. This combination is usually called a load cell. The mass of the object to be weighed generates a force (using the earth's gravitation) which distorts the material of the load cell. The strain guages attached to the load cell change their resistance in proportion to the distortion. The strain guages are usually connected in a bridge configuration, as shown in Figure 4, with RA and RD increasing resistance (expanding) when weight is applied and RB and RC decreasing resistance (compressing). A configuration of this type yields four times the output of a single strain gage while being very immune to temperature changes. If the distortion stays in the Hooke's region (i.e. no permanent deformation of the solid material occurs), the bridge differential voltage Vd will be proportional (or at least proportional for all practical purposes) to the weight.

Load cell sensitivity is typically specified in as mV per V at full scale. The mV number refers to the bridge differential voltage Vd while the V number refers to the excitation voltage Vexc. It is clear that the higher the excitation, the more differential output at a given weight will be generated. Excitation voltages are typically 5V to 20V. For example, if a load cell is specified as 1.875mV/V and 20Kg full scale, the output at half scale load (10Kg) will be 4.6875mV (5V * 0.5 * 1.875mV/V) if the load cell is operated at 5V excitation voltage.
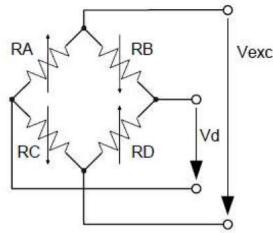

Fig.4: Sensor Bridge Configuration

The load cell depicted in Figure 4 generates the differential output given by:

$$Vd = V_{RARC} - V_{RBRD} = s * f * V_{exc} \qquad (1)$$

Where, s is the sensitivity in mV/V, f is the force (weight) applied as a fraction of the full scale, and Vexc being the excitation voltage. In absolute terms, the common mode voltage Vexc/2 rides on both signals V_{RARC} and V_{RBRD} that form Vd when the load cell is at zero load. This common mode voltage has to be eliminated by the signal conditioning circuitry which has to act as a differential amplifier.

Another aspect is that due to minute inaccuracies of the load cell or due to mechanical structures added to the scale ("tare", such as a bowl for containing the weighed material or parts), a residual differential voltage ("offset at zero load") will be present that will have to be eliminated by either the signal conditioner or by the application following the signal conditioner. The process of removing the zero offset is usually referred to as auto-zeroing. Since Vd will typically be in the micro-Volt or low milli-Volt range, amplification or gain will have to applied in conjunction with the elimination of the common mode voltage in order to lift the output signal into the input signal range suitable for the ADC.

An important consideration for selecting the op-amp is the input offset voltage which must be low. We cannot allow an input offset voltage of more than a few mV, since after amplification with gains between 10 and 100, this would result in an offset output voltage that would restrict the useable signal range ($\pm$250mV).

The LM358 OP-Amp by National Semiconductors was selected for very low input offset and low offset voltage drift with temperature, another important consideration, especially for industrial applications. While the commercial scale might operate in constant temperature, an industrial scale will often be exposed to the elements. While the auto-zero mechanism will provide for a good reading at zero load, it may take considerable time for the load to be applied (think of a truck that has to be driven onto a truck scale, which may take minutes), and consequently temperature drift will occur.

$$Gain = 1 + RF/R \qquad (2)$$

NB: The gain of 50 translates a 50 mV full scale bridge output to a nominal 5 V output.

2.2 The Output Interface Design (LCD DISPLAY UNIT)

The LCD is finding widespread use replacing LEDs. They have the ability to display numbers, characters, and graphics. Incorporation of a refreshing controller into the LCD, relieve the CPU of the task of refreshing the LCD and ensure ease of programming for characters and graphics.

2.3 The Power Supply (AC-DC)

This module will consist of a center tapped transformer that will step down the AC voltages from 220V to 12 Vrms. Then this will pass through a Full Wave Bridge Rectifier and a filtering capacitor to achieve close to DC voltage level.
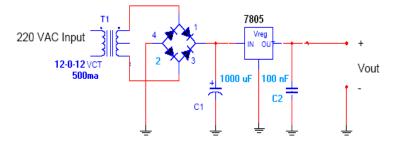

Fig. 5:AC/DC Converter Schematic

2.4 Transformer Rating for Power Supply

In the above diagram we have transformer rating of 0.5A (500mA) 12V secondary voltage. For the power supply this is a small transformer available at the market. To achieve the peak value of the output dc signal, we must multiply the transformer secondary rms voltage value by $\sqrt{2}$, and subtract the voltage drop on diodes (there are two diodes on the current's path).

$$VDC_{peak} = 12 \cdot \sqrt{2} - 1.4 = 17 - 1.4 \simeq 15.6V$$
(3)

2.5 Power Supply Rectifier Diode Rating

With the full wave bridge rectifier, the current rating should be at least twice the load current maximum i.e. 2 x 0.5A or 1A good type to use is 1N4001 - 1N4007 rated 1A, 1000PIV, since we don't anticipate drawing the maximum current.

2.6 Power Supply Filter Capacitor Rating

The value of the filter capacitors for the smoothing of the rectified voltage to minimal allowable ripple voltage can be computed using formula. Vr, value depends directly on the load current and inversely on the size of the capacitor. It can be estimated with this design formula:

$$V_r = \frac{I}{2 \bullet f \bullet C}$$
(4)

Where, f is the line frequency (50 Hz/60Hz) and C is the capacitor capacity, its main parameter, usually measured in microfarads, nanofarads and picofarads. For example, we have a 12VAC transformer, a diode bridge rectifier, and a maximum load current of 0.5 Amperes. Let's assume that the circuit we are going to feed requires that Vripple is not more than 2 Volt. We use the previous formula but reordered in this way.

$$C = \frac{I}{2 \bullet f \bullet V_r} = \frac{0.5}{2 \bullet 60 \bullet 2} = 2.1 \bullet 10^{-3} = 2100uF$$
(5)

The nearest available size is 2200uF. Now we need to know what is the maximum voltage that the capacitor is going to be exposed to. We must consider the worst case, this is the Vrectified peak in no-load condition, which means without deducting the voltage drop on diodes:

$$V_{max} = V_{peak} = V_{rms} \bullet \sqrt{2} = 12 \bullet 1.41 \simeq 17Volt$$
(6)

Available commercial values are 16V, 25V, 35V, 50V, 63V. Well, 25V is ok for us. So, our capacitor is completely defined as "Electrolytic capacitor 2200uF x 25V". However a 1000uF/25V capacitor can be used with increased ripple voltage.

2.7 The Regulator

Voltage regulator ICs are available with fixed (typically 5, 12 and 15V) or variable output voltages. They are also rated by the maximum current they can pass. Negative voltage regulators are available, mainly for use in dual supplies. Most regulators include some automatic protection from excessive current ('overload protection') and overheating ('thermal protection').

Many of the fixed voltage regulator IC have 3 leads and look like power transistors, such as the 7805 +5V 1A regulator shown on the right. They include a hole for attaching a heat sink if necessary.
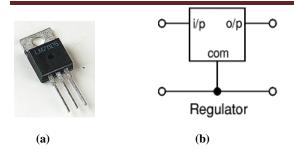
(a)   **(b)**

Fig 6: **(a)** Voltage Regulator **(b)** Circuit Symbol

3. Results and Discussions

3.1 Component Sourcing and Hardware Implementation

Gathering of components from the specification in the circuit design precedes assembly or construction of the project.

3.2 Strip/Vero Board Construction

This involves the actual construction, which is the hard wiring of the circuit already prototyped.

3.3 Input Interface Wiring Diagram

The circuit arrangement below shows the input bridge circuit of weighting machine interface implementation wiring diagram.
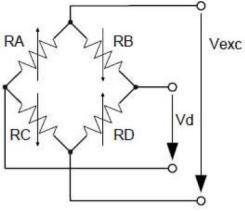

Fig 7: Sensor Bridge Configuration

Fig 8: Typical 3 Wire Strain gauge

3.4 Microcontroller System Wiring Diagram

Here we have the microcontroller system implementation wiring diagram. The display units are connected at port 1, set input at port 2 and finally the display drivers at port 0.

3.5 Output Display Interface Wiring Diagram

The 7 – Segments displays are interfaced at port 1 of the microcontroller. Four displays are multiplexed and driven with four transistors. A single display is shown figure 12.
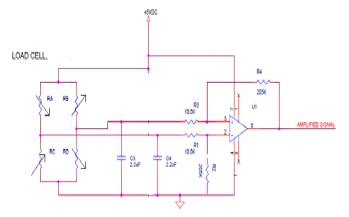

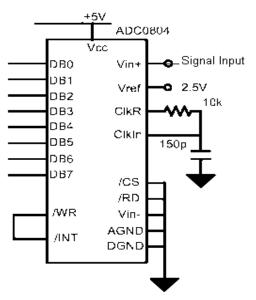**Fig 9**: The Differential Amp Circuit

Fig 10: Typical ADC0804 Wiring Diagram for Direct conversion

3.6 System Testing and Integration

Before you build your amp, in order to get a rough idea of how to set the gain, build the strain gauge circuit first, power it up, and use a multimeter to measure the output voltage from your strain gauge circuit with the maximum expected load applied. Then when you build your amplifier circuit you can select gain resistors that bring the amp's maximum output to 5V (the ADCs sample 0-5V), and you will get the most range out of your ADC.

The reason to do this is that the range and resolution of the ADCs is limited and discreet, so if you want to measure 0-150 kg, with the 8-bit resolution of the ADCs, you would at best be accurate to within a pound if your amp's output signal goes from 0-5V as the weight increases from 0-150kg. If you just half it or guess with the gain resistors, or start with pure trial-and-error and get bored and don't use the full range, you will throw away accuracy. Say you put

together an amp and it only puts out 0-2.5V, then you will be throwing away half the range and only accurate to within 1 kg for that same 150kg range.
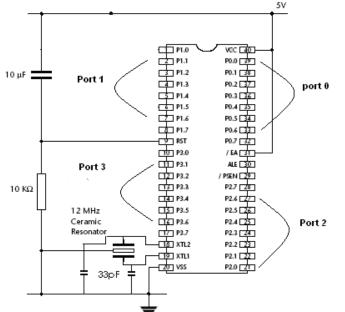

Fig 11: The Microcontroller System circuit

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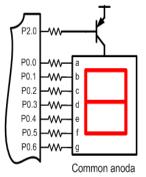

Fig 12: Driving 7 Segment common Anode Display

The Weighing machine operation is easy the user does not need to do anything but only place a sizable object on the machine or better still stand on the scale. Then observe the weight reading on display.

4. Conclusion

This research is basically designed to take weights in KG and display on LCD. Weighing scales normally used for weighing smaller weights ranging from probably mgs up to a few kgs. The design of a simple electronic weighing machine presented here can weigh heavy object in kilograms from 1 kg to 150 kg full scale range white 0.1kg deviation and display weights in kg on LED.

References

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