Design and Development of Signal Conditioning Card for Load Cell

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***Abstract*—In industry environment the most commonly measured parameters are strain, force and pressure. The most commonly used sensing devices in order to measure above parameter are strain gauge load cell. There are different types of strain gauges are available resistive, capacitive, piezoelectric transducer type and semiconductor type strain gauges are there.Strain gauge sensor is a passive transducer that converts the mechanical elongation, displacement produced due to force or load acting on them into change in resistance, capacitance and inductance value. They are low impedance devices, they required exact excitation (input) value because there signal (output) will be in milli volt range, the typical load cell will be having four strain gauges which are all arranged in Wheatstone bridge manner with impedance of 270 ohms or 350 ohms. The load cell will be having six wires, two of them for "excitation" voltage, two of them is for giving "signal" and two of them are for "sens", in order to maintain the excitation voltage as the output from load cell are in milli volt range they need to be conditioned for next stages with low cost, high precision, reliability, amplification and noise reduction capability. The low output signal after amplification is to be send to filtering, analog to digital conversion then the output is programmable controlled by microcontroller ATmega 168p then they again converted to analog signal using digital to analog converter (DAC) because the next level will be of analog component in industry that is programmable logic controller(PLC) in order to display the weight and to send the packed things to suitable place.**

Keywords: Load cell; sens; PLC;strain gauge; signal conditioner.

I. INTRODUCTION

Measuring the parameters like strain, force and pressure is very important in industrial environment because, if it is a product based industry if the measurement is not correct it may leads to loss of money they have invested or if any industry is based on producing the animal feed for example if it is a poultry based, then for getting a protein rich egg, food feeder should be in measurable amount if it is less or more also there will be a loss in production. [1]

There is a need in constantly monitoring the weight, here for measuring any load, load cell are used. Load cell are the type of transducer or a sensor which converts the load or any force applied on them into electronic signals. The electronic signals refer to change of voltage, current or frequency it depend on the load applied. The most commonly used load cell is resistive strain gauge based load cell.

In industry load cell may be present at some place and the monitoring of weight will be in some other place there will be copper wire connectivity between them which may be of 80-100 meter in length. The applied voltage to load cell while reaching it there may be a resistive voltage drop in excitation voltage to load cell hence, there is a need for conditioning the applied voltage. The signal conditioner may be used in order to amplify any signal, filtering, interfering with microcontroller, analog to digital conversion (ADC), protection,linearization and for error compensation. The signal conditioning is a technique of making any signal from transducer or sensor to suits for processing by data acquisition equipment.

II. SYSTEM FLOW

In industrial environment weighing of a definite amount of thing is done automatically by the use of load cell. Fig (1) shows the product flow in industrial environment. [4]

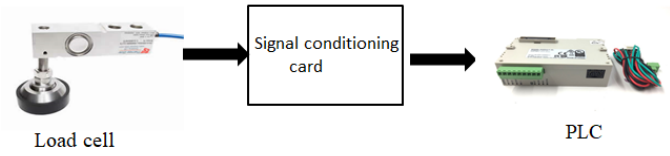

Fig. 1. Product flow of load cell signal conditioner

When the weight is applied on the load cell, correspondingly its internal resistance changes and the input excitation of load cell needs to be maintained using signal conditioning card and the milli volt output of load cell needs to be amplified in signal conditioning card, then the signal from signal conditioning card is given to programmable logic controller (PLC) in industry.

III. PROPOSED SYSTEM DEVELOPMENT

The proposed system of signal conditioning make easy in product weight measurement and in packing system. The signal conditioning card development was having the purpose

of maintaining the excitation voltage to the load cell, improving the resolution of ADC and maintain the output of DAC8760 of (-10 to +10V) because, its next stage is PLC which required the same range as mentioned. The below Fig (2) provides the theoretical approach for designing the signal conditioning card for the load cell using printed circuit board(PCB).

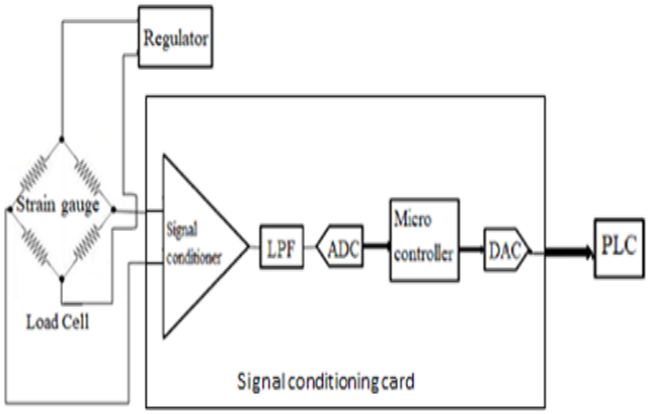

Fig. 2. Theoretical approach for accurate weight.

The main purpose of signal conditioning unit is to get the proper excitation voltage to the load cell with no resistive voltage drop in copper wire which is connected between load cell and weight monitoring side, to improve the resolution from 16bit to 18 bits in ADC so that we can weigh in terms of 1grams and maintain the output of DAC of (-10V to +10V). Before input giving to the load cell it is voltage regulated and given as "excitation" to load cell.The output of load cell is in (0-30) milli volt range that is called ''signal'' which is amplified in analog to digital converter and the digitized output is given to microcontroller (ATmega168p) in which the obtained data isprogramed. The output of microcontroller is given to digital to analog converter (DAC) and its output needs to maintained in the range of (-10V to +10 V) and its next stage will be programmable logic controller (PLC). Then the analog counts can be seen in PLC in an industrial environment.

IV. SYSTEM ANALYSIS AND DESIGN

To design and develop the PCB, hardware and firmware used in this project are:

A. Hardware design and implementation

The hardware used are load cell, dual power operational amplifier, analog to digital converter (ADC), micro controller, digital to analog converter(DAC).[5]

B. Load cell

A load cell is a transducer that converts force into electrical signal. The most of the weighing equipment uses the weight stone bridge type load cell sensor, whose output voltage is in proportional to applied weight over it, the load cell consists four strain gauges which are resistive type when the load applied on the load cell correspondingly there resistivity changes which leads to change in output voltage .The typical load cell diagram is as shown in fig 3under resistive load cell single pointed load cell are used and its specification is as shown in fig (3b). [2]

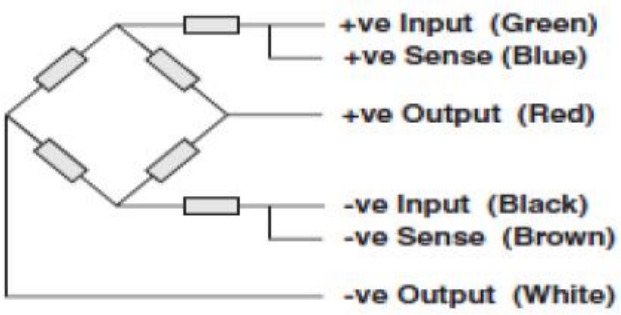

Fig. 3. Typical load cell diagram.

TABLE I. SPECIFICATION OF SINGLE POINT LOAD CELL

parameters	value
Type	Single Point Load Cell
Material	Aluminum Alloy
Suggested Platform Size	350 x 350 mm
Applications	Weighing Scales, Retail, Bench & Counting Scales
Rated Load	40 Kg. Max
Rated Output	2.0mV/V+/- 5%
Excitation Voltage	5-12V DC
Cable	420mm(3mm dia 4 wire shielding cable)
Operating Temperature	-20 °C to +65 °C
Zero Balance	1% F.S.

C. MCW03 – 24D12

The MINMAX MCW03 is a isolated 3W DC/DC converter module with fully regulated wide range which is able to provide the voltage output in 2:1 range. It is very compact DC/DC converter which can be used in many space critical applications in battery power and instrumentation. It is having the features like it operates with a temperature range of -40°C to +85°C, input voltage of 18-36 vdc, provide output voltage of 12V or -12V, maximum output current of 0.125Amps, output power of 3 watts, it gives overload protection, we can control on and off remotely. Here in this project it is using in order to convert the industrial power supply of 24V to 12V so that it can be given analog components used to design the card.

D. Precision operational amplifier

The precision operational amplifier is a device with low offset, low noise, chopper less, or many application offset nulling and frequency compensation can be made through this device. The true differential input, with a wide input-voltage range and outstanding common-mode rejection, provides maximum flexibility and performance in high-noise environments and in no inverting applications. Low Circuits

bias currents and extremely high input impedances are maintained over the entire temperature range.

E. Analog to digital converter (ADC)

It is an analog front end module for measuring pressure and in weighing machines.[1] It can accept the low voltage signal from the transducer and provide the serial digitized output. They are used as external ADC in order to increase the resolution to 18bits so load cell can measure in terms of 1grams. It is having the features like,

- An output count up to 2, 30,000.
- It is having a gain of 2ppm/C.
- It is having a frequency rejection below 150dB.
- It is having an internal offset/tare DAC of 6 bits.
- It is having the reference voltage from 1V to 5V.

F. Microcontroller

Microcontroller is one of the main functional elements in this piece of work. Microcontroller used here isATmega 168p which belongs to Atmel family. They are used in order to reduce the count from ADC which is 24 bitsto 16 bits so that it can be given to next stage which is DAC and for communicating between ADC and DAC using SPI protocol. [6]

G. Digital to analog converter (DAC)

The DAC used here is of 16 bit which is of high precision and low cost they are designed in order to meet the industrial processor control systems. Implementation of hard ware is done on printed circuit board (PCB) as shown in fig (4).

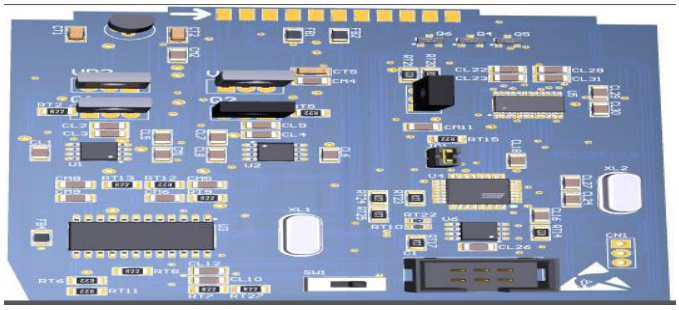

Fig. 4. Hardware module on PCB.

The required hardware components for signal conditioning card aredesigned. Both the analog and digital sectionsare present on same hardware module; each components are designed and there 2D and 3D models where generated, after arranged them in a précised way the 3D model of the card look like as shown in above figure , this designed card is inserted between load cell and PLC.

V. FIRMWARE FRAME WORK

The software used here is ATmel studio. It is the integrated development platform (IDP) for developing and debugging of all types AVR and SAM type of microcontroller. The Atmel studio version 7 provides the programmer an easily handle able environment so that it can write, debug and compile with the basic language like C, C++ or assembly language and it is easy to overcome the error if presented.

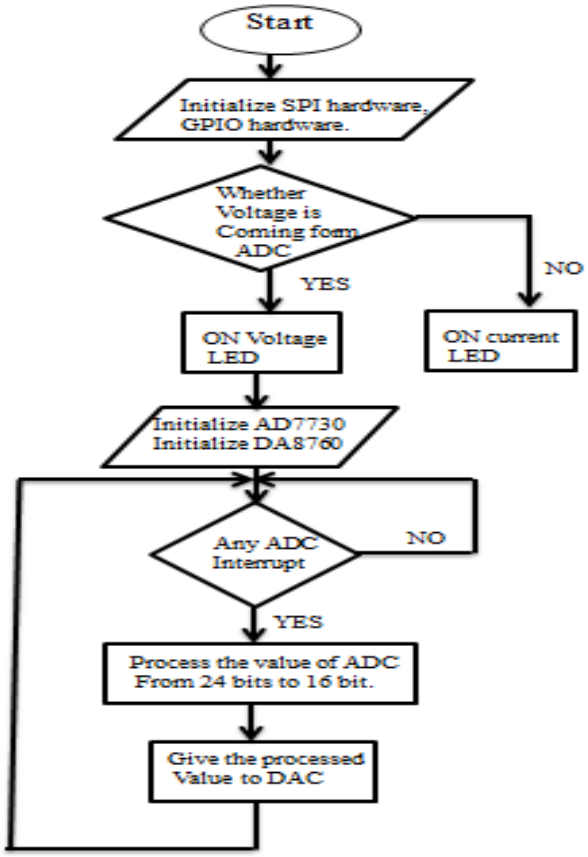

Fig. 5. The overall program flow of the project.

First we have to initialize SPI and GPIO hardware, and then we have to check whether ADC output is voltage or current. It can be seen by glowing of their corresponding led's. Initializing AD7730 and DAC8760 and check any interrupt is coming from ADC, if it is coming then process the value of ADC from 24-bits to 16 bit so, that the value can be given to DAC. If there is no interrupt occurrence then wait until it obtains from ADC.The overall flow is as shown in fig (5).

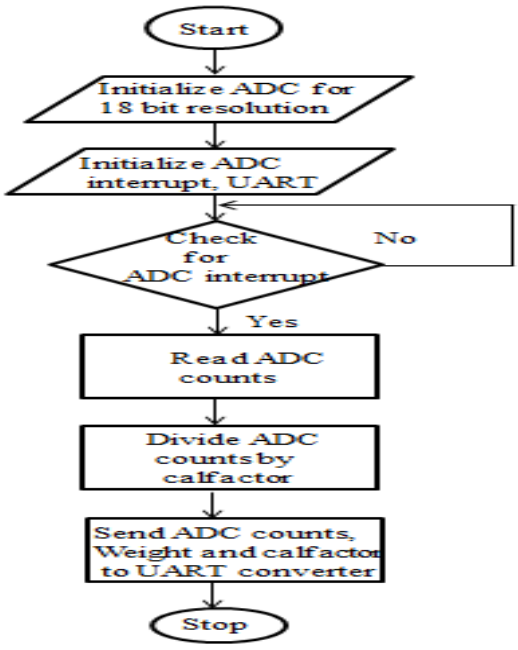

Fig. 6. Entire flow of the conversion of ADC count, calfactor and weight on terminal window (PC).

First we have to initialize the GPIO and SPI hardware to communicate between ATmega 168p with AD7730 and DAC8760, here ATmega 168p microcontroller act as master and both AD7730 and DAC8760 act as slaves. By defining the switch in PCB board we can select 2mv/v or 3mv/v rating load cell are using .while programing we have to make ADC and DAC data register to zero in order to avoid the previously stored data. By sending write command to AD7730 by use of SPI protocol in microcontroller then checking the output is in terms of voltage or current it can be seen by blinking of LEDs. If any of the interrupt (counts) generated from ADC as it is 24bit resolution ADC to send the data to DAC8760 via microcontroller it need to be down converted to 16 bit as the DAC resolution is 16 bit, the communication between ADC, microcontroller and DAC occur serially. The overall flow is as shown in fig (6).

VI. EXPERIMENTAL RESULT AND ITS ANALYSIS

Fig. 7. This is the hardware signal conditional model.

The signal conditioning for load cell, for maintaining the constant excitation voltage to load cell and providing the output voltage in range of (-10V to +10V) out of DAC8760 which is input to PLC in industry environment is as show in above fig (7).

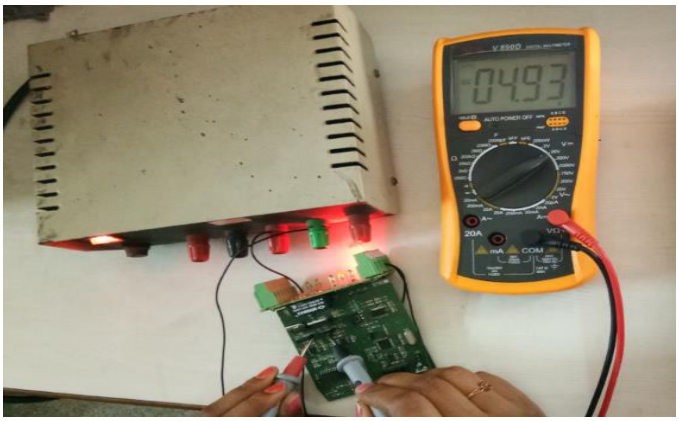

Fig. 8. Results for maintaining excitation voltage to load cell.

For any load cell Maintaing the excitation is very important because when a weight, force, strains is applied on a load cell, inside the load cell there are four strain gauges of 350Ω each arrange in Wheatstone bridge manner. The load cell work on piezo-resistive principle according to that by applying the load correspondingly mechanical elongation of the load cell occur, there will be decrease in the resistivity of load cell resistors, correspondingly its current varies and produces the voltage in terms of (0 to 30mv) which are unable to measure by the other devices, as it is a smaller voltage hence two operational amplifier are used to maintain the excitation voltage of 5V to load cell and also in the case where the load cell may be in some place and power supply may be other place between them a copper wire connectivity will be there which is of 80 to 100meter length there is also a chance of voltage drop in this case also there is a need of maintaining the constant excitation voltage.

Fig. 9. Signal from load cell and output voltage of DAC.

After the model is completely set, by providing the voltage from voltage supply, it will be regulated to provide required input voltage excitation of 5V to load cell. The output from load cell will be in range of (0-30mV), we are getting is 1.2mV by applying 5Kg of weight on load cell. After checking the output of load cell which is in the range of (0-

30mV) ,that is given to ADC where any –ve voltage coming from load cell inside ADC there will be a 6-bit DAC which will add a 1.25mv to output of load cell so that the load cell voltage remains in (0-30mV) range then counts from ADC is given to ATmega 168p microcontroller in order to program the ADC and the DAC to provide output of (-10 to +10V) so that we can display the counts in voltage and in terms of weight it will be displayed in industrial used programmable logic controller. We obtained here is -8.03V for 5Kg weight.

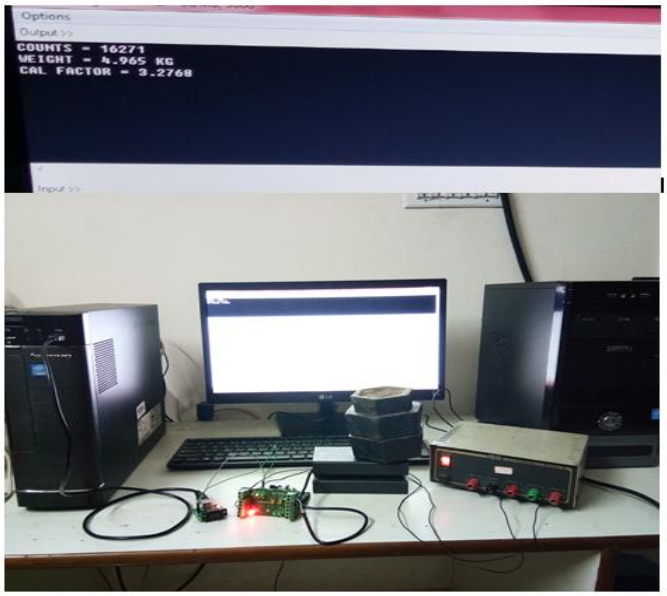

Fig. 10. Results for getting ADC counts in terms of 18 bits and displaying the weight in terms of 1 gram.

One of the objectives is to increase the ADC resolution to 18 bits in order to measure the weight applied on load cell to display the grams place also. So that we can measure in terms of 1gram, 2gram, 3 grams so on for this we have used ADC7730 which is of 24 bit resolution analog to digital converter, it is programmed to give 18 bits counts serially the counts will be send to microcontroller (ATmega168p). In signal conditioning card there is a 3pin berg connecter is present which will help in connecting external UART to USB connecter in order to display the counts, calfactor from ADC to personal computer by programing to UART, in personal computer counts, calfactor and by dividing counts by calfactor we can obtain weight applied on load cell all this values will be displayed in terminal window.

VII. CONCLUSION

Signal conditioning card is designed in order to measure the parameters like strain, force and pressure using load cell, maintaining the excitation voltage of 10V to load cell using dual power operational amplifier, increasing the external ADC counts with a resolution of 18-bits for weighing in terms of 1gram and amplifying the load cell output which is in milli volt range to (-10V to +10V) in order to give the input to next stage which is PLC.

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