DESIGNING ONE CHANEL WIRELESS LOAD CELL INDICATOR

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Abstract

This paper describes wireless load cell indicator design for one channel. A strain gauge (also written as strain gage) is a sensor used to measure the strain or stress of an object. In some application to measure the strain or stress of the object we need long distance such as 100 m measurements. Due to this reason we need wireless device to transmit this data of measurements. The output signal from this is sensor is very small in order microvolt and the radio transceiver also can make interference to the strain gauge signal. The main purpose in this research is how to design electronic circuit to measure the small strain gauge signal then transmit it with high resolution and low EMI. In our research design we used ADC 24 bits to read the analogue output from strain gage sensor. The method in this research is to using high resolution ADC and low EMI. We also used radio transceiver with specification of half-duplex, baud 19200 bps and the 500 m of maximum distance range with 100 mW of power. From the experiment with the calibrator input, we get that the data is not interference by the radio. The error is under 0.1%. In the future works the authors will try to design the wireless indicator load cell for more than one channel.

***Key Words**: ADC 24 bits, wireless, indicator, load cell, calibration*

1. Introduction

In recent years the area of sensors has become increasingly important due to of their varied applications in many areas. The term sensor is a broad terminology which encompasses a wide variety of devices. The present paper deals with wireless indicator load cell design. Basically, a strain gauge is a device used to measure the linear deformation (mechanical surface strain) occurring in a material during loading. In addition to their fundamental use for measuring strains as such, strain gauges are also used for measuring other physical quantities such as pressure, load, displacement, torque, and so on.

The origin of strain gauge goes back to Robert Hooke (1935-1703) whose famous law states that, within certain limits, stress is proportional to strain[1)]. Later, Robert Young (1773-1829) provided a quantitative relation between stress and strain in a bar under simple tension (or compression) by his modulus of elasticity equation:

$$\sigma = E \, x \, e \tag{1}$$

Where E is the modules of elasticity, σ is the stress and $\in$ is the strain.

Poisson (1781-1840), a French mathematician, extended the laws of elasticity from uniaxial to two and three-dimensional aspects which involved another well known material constant, now named Poisson’s ratio. Although mathematicians of the last two centuries worked out a great deal of theory, it is comparatively only at a later stage that strain measurement has been done on a large scale. Nowadays the strain gauge is used in broadly application, such as instrument to weigh a rocket body, to measure thrust force of the rocket motor, even from an instrument to weigh a packet until a sensor to detect a building structure deviation.The main purpose this research is how to measure the small signal output from sensor strain gauge and how to transmit it around distance 100m and low EMI. We know that the signal output from sensor strain gauge is very small in order microvolt. It takes high gain to can measure it. With the high gain, the noise also will be increased and this is new problem. Due to this case, we need to use ADC with high resolution and low EMI. In this research we used the ADC CS5530 with resolution 24 bits and low EMI. We also used the radio transceiver which can transmit and receive data around 500m and low power 100mW.

2. Strain Gauge Sensor and Radio Modem

There are many application of strain gauge sensor and radio modem in our daily live such as strain gauge sensor for measurement of stress and strain a metal, radio modem for transfer data digital.

2.1. Strain Gauge Sensor

Strain gauge sensor is a sensor whose resistance varies with applied force; it converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured [2)]. Resistance strain gauge has been used for nearly 60 years. As a kind of high accuracy mechanical sensor, it has been applied to aerospace, rocket, dam and other fields. At the same time, its measurement accuracy has been generally recognized by the road researcher, and used in pavement as a traditional strain measuring element.

Resistance strain gauge can convert surface deformation into electrical signals. The signal output can be measured by electronics device. In this research we use ADC 24 bits to read the analogue output from strain gauge sensor. Strain gauge sensor is shown in Fig. 1.

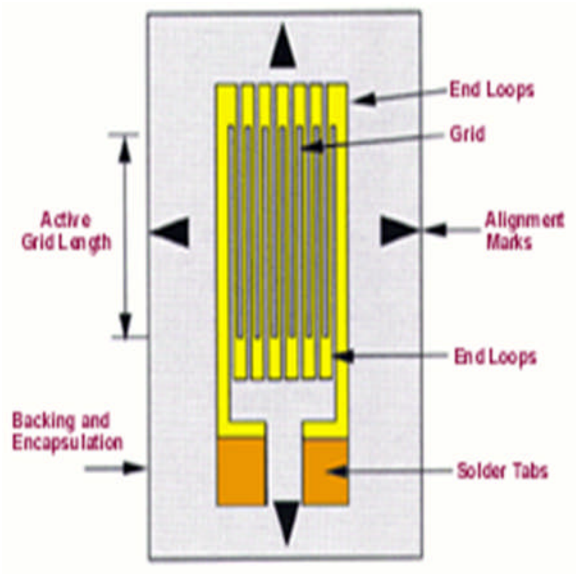
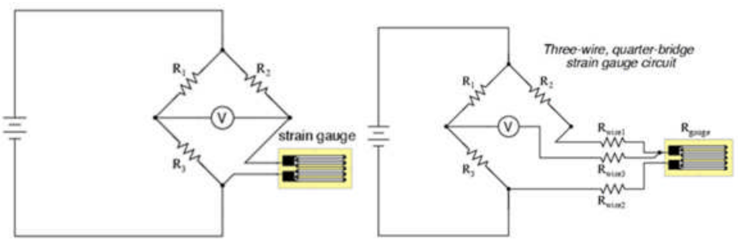
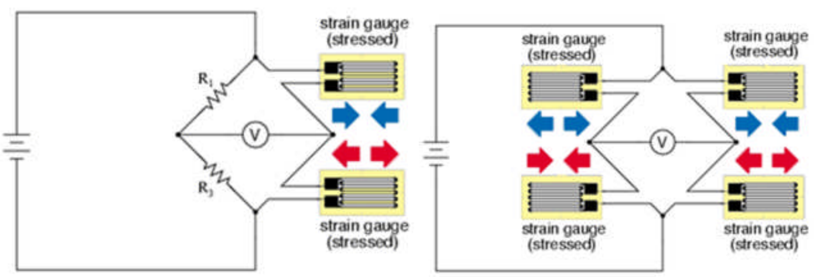


Fig. 1.Strain Gauge Sensor [3].

There are many kinds of type bridges to implement strain gauge circuit depend on the application. There are the first is quarter-bridge strain gauge circuit, the second is three-wire quarter-bridge strain gauge circuit, the third is half-bridge strain gauge circuit and the fourth is the full-bridge strain gauge circuit. Fig.2 shows all of the basic strain gauge circuit.



a). Quarter-bridge b). Three-wire quarter-bridge



c). Half-bridge d). Full-bridge

Fig. 2.Basic Strain Gauge Circuits[3].

2.2. Radio Modem

A radio modem transmits data several kilometers over a wireless connection to another radio modem over a point to point or multi point link. Radio modems are independent or mobile and satellite network operators and no cost is thus associated with transferring data. Private radio modem networks can use either unlicensed (e.g. ISM) or licensed frequency bands (UHF, VHF). This research we use the radio modem or radio transceiver with specification carrier frequency 433 MHZ, interface TTL, baud rate 19200 bps and power consumption is 10 mW with maximum range 500 m. Fig. 3 shows the radio transceiver.

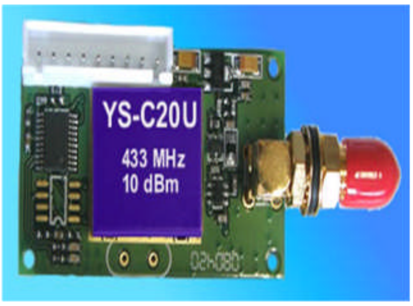


Fig. 3.Radio Transceiver.

3. Design Hardware and Software

The project was run on PC and a wireless load cell indicator, using software architecture with visual Basic for communication between computer and load cell indicator. In the following sections, detail about the design hardware and software used in the system will be presented.

3.1. Hardware of Load cell Indicator

The output of strain gauge sensor is very small around µvolt. This reason because the change of the resistive strain gauge sensor also very small in order µOhm. So it takes good amplifier to read this small output, or we can use the high resolution of ADC such as use ADC 24 bits. In our design we use ADC with resolution 24 bits. It means that 2^{24} equal with 16,777,216 point ADC. So this ADC can read the smallest output around 0.003 µvolt is equal with 1 (one) point ADC. The series ADC is cirrus logic CS5530. The CS5530 is a highly integrated ΔΣ Analog-to-Digital Converter (ADC) which uses charge-balance techniques to achieve 24-bit performance. The ADC is optimized for measuring low-level unipolar or bipolar signals in weigh scale, process control, scientific, and medical applications. The ADC includes a very-low-noise, chopper-stabilized instrumentation amplifier (12 nV/$\sqrt{Hz}$@ 0.1 Hz) with a gain of 64X. There are three-wire serial interface which is SPI and a Schmitt-trigger input on the serial clock (SCLK) for interface between microcontroller and ADC[4]. Fig. 4 shows the diagram of ADC CS5530.

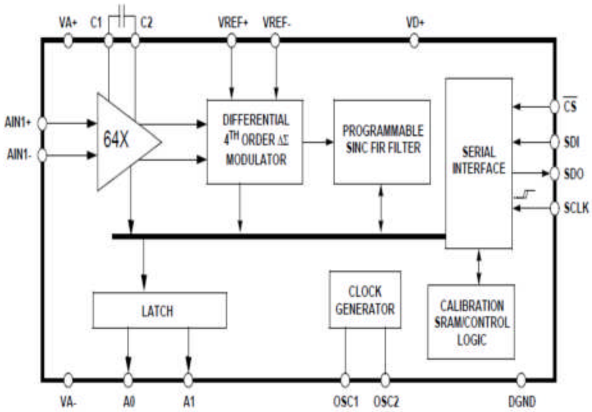
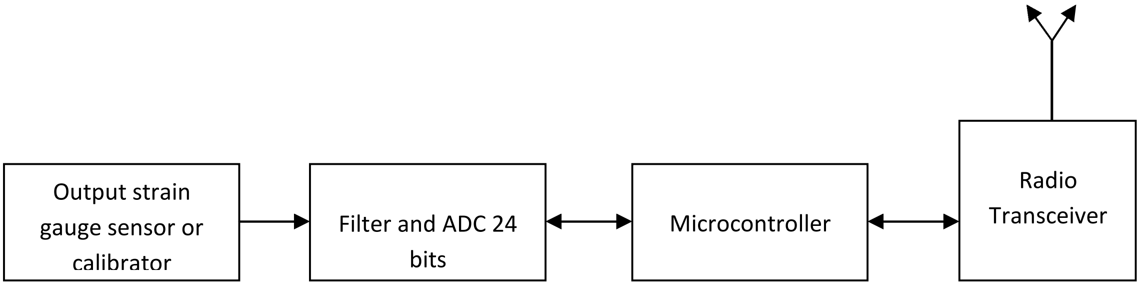
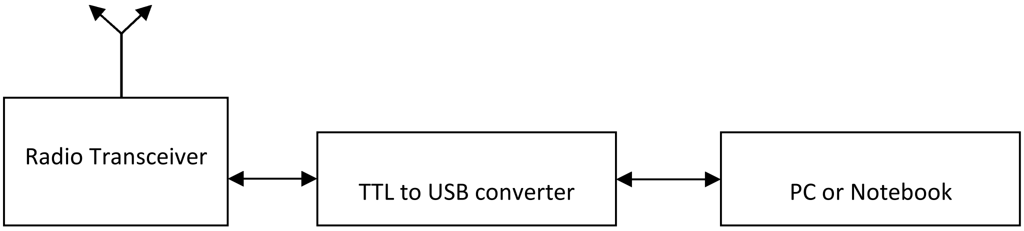


Fig. 4.Diagram ADC Cirrus CS5530

The microcontroller ATmega8A-AU is used in this research for communication with ADC module and radio transceiver. This microcontroller has 8 kb flash memory which is enough to implementation the algorithm. A block diagram for this design in side of load cell indicator and computer can be shown in Fig. 5. The radio transceiver in computer side can be connected directly with computer via converter TTL to USB.



a). Load Cell Side



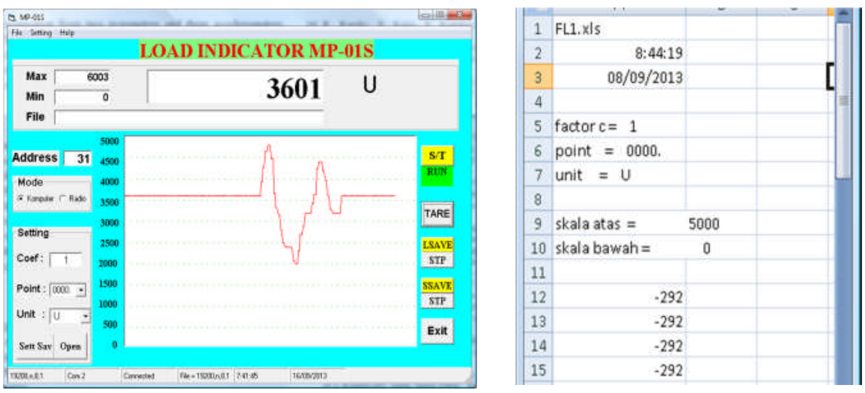
b). Computer Side

Fig. 5.Block Diagram of The Hardware

3.2. Software Design

The system was developed in two kinds of the software, the first is the software for microcontroller with using BASCOM (basic compiler) and the second software is visual Basic for display data and interface computer with radio transceiver. The BASCOM is commonly and easy software to do program for Atmel microcontroller series. This software has two versions that are free or trial and pay. The algorithm in the microcontroller program can interface with ADC to get the result conversion data analogue and interface with the radio transceiver. The process is the first microcontroller communicate with ADC then the data is sent to radio, sometimes the microcontroller also get interrupt command from the computer side to tare or reset ADC to get the zero data.

The program in computer can display the data, saving data, tare and setting some parameters. This program is build with use visual Basic 6. The saving file of the data is in the excel format. The all parameter of the measurement also saved in this file. Each process saving file, the name of file is automatically increased due to this software also need database to do it. We use Microsoft access for the database for this system. Fig. 6 shows the display of the software in computer and the example of data file.



a). Display Data real time b). Saving Data

Fig. 6. Display Data real time and Data File

4. Experiment and Result

This part describes the experiment and result of the design. In this experiment we used input calibrator as replace the real sensor strain gauge. Due to the main purpose this research is design electronic circuit to measure small signal which can be from the real sensor strain gauge or calibrator.

4.1. Calibration

Static calibration was performed by increasing the applied input from calibrator increasing from 0 mV/V up tp3 mV/V and then decreasing back to 0 mV/V, each increasing or decreasing is 0.2 mV/V. The standard output is 1 mV/V is 2000 µstrain. From the design we got that 1 mV/V is 2055 µstrain. So we must multiply the current data with coefficient value 0.973. The setup calibration can be seen in Fig.7. Table 1 is the result data of calibration.

Fig. 7.Setup Calibration

Table 1. Calibration Data

No	Input mV/V	1st	2nd	3th	Average	Default output	Error %
1	0	0	0	0	0	0	0
2	0.2	400	400	400	400	400	0
3	0.4	800	799	800	800	800	0
4	0.6	1200	1200	1200	1200	1200	0
5	0.8	1600	1600	1600	1600	1600	0
6	1	2000	2000	2000	2000	2000	0
7	1.2	2401	2401	2401	2401	2400	0,04
8	1.4	2801	2801	2801	2801	2800	0,035
9	1.6	3201	3201	3201	3201	3200	0,031
10	1.8	3601	3601	3601	3601	3600	0,027
11	2	4001	4001	4002	4001,3	4000	0,032
12	2.2	4402	4402	4402	4402	4400	0,045
13	2.4	4802	4802	4802	4802	4800	0,041
14	2.6	5202	5202	5203	5202,3	5200	0,044
15	2.8	5602	5603	5603	5602,6	5600	0,046
16	3	6003	6003	6003	6003	6000	0,05

The formula for calculation the error % is in Eq. (2).

$$error(\%) = \frac{(average - default)}{default} 100\% \qquad (2)$$

4.2. Experiment with Input from Calibrator

We didn’t use real strain gauge sensor to test the indicator but we used the calibrator as input sensor. The power supply for all the hardware is 5 volt. We used battery rechargeable for wireless indicator and USB port 5 volt for radio transceiver in the display system. Fig. 8 is the real experiment wireless indicator.

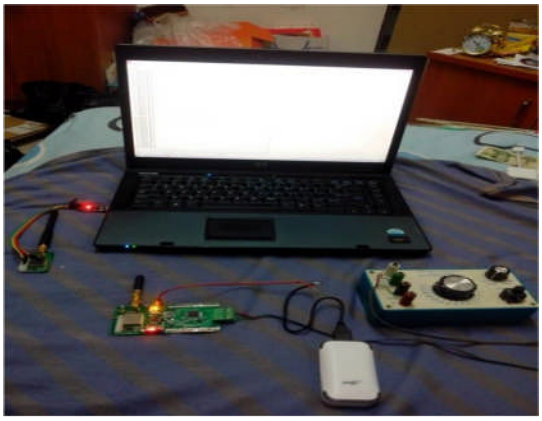


Fig. 8.Real Experiment

5. Conclusion and Future Works

This paper presented the design hardware and software of wireless load cell indicator with baud rate 19200bps and the range transmit data is up to 500m. The ADC (analogue to digital converter) module 24 bits is used and interfaced with microcontroller ATmega8A-AU. The ADC cs5530 is used in this research. This ADC has specification high resolution 24 bits and low EMI (electromagnetic interference), thus the ADC can convert the low signal around 0.29 microvolt to become 1(one) point ADC data. From the calibration we got the error is very small under 0.1% and the system circuit didn't get interference from the radio which is used to transmit the data. The experiment with the input from calibrator and the data is transmitted with radio transceiver and directly displayed in the computer as receiver also work very well.

In the future works the author will design the wireless load cell indicator more than 1 (one) channel. Due to this is possible to design wireless load cell indicator up to 10 (ten) channels or more.

Acknowledgments

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References

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3) www.sensorland.com/HowPage002.html.
4) www.cirrus.com/en/pubs/proDatasheet/CS5530_F3.pdf.

Discussion

Question:

1. Has it been tried/applied in the flight test aircraft or rocket? (Agus Bayu Utama, LAPAN)

Answer:

2. This design has several times used by the oil drilling rig for load test applications, and can be applied to the rocket or aircraft.