Development of Controlling and Monitoring System for a new grain yield monitor

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Abstract. *Based on an impact flow sensor, a Grain Yield Monitor was developed at the Research Center for Precision Agriculture (PAC) of China Agricultural University. The system can collect 4 analog signals (grain flow, grain moisture content, grain temperature, and header up/down signal) and 2 digital signals (ground speed and RPM of driving shaft of elevator), and can receive DGPS signal at the same time. It stores these signals to CF card once per second. A liquid crystal display and a touch screen were integrated to input and output signals. Since grain flow is not continuous, it was difficult to increase precision of the monitor with low sampling frequency (<10 Hz). However it* *was impossible to increase sampling frequency of grain flow signal by main ECU since it must have enough time to perform other task. Hence, in order to improve S/N ratio, a new AD collection board was designed to collect grain flow signal at a high frequency (250 Hz). After sampling it calculated the mean of 250 data obtained in a second, and then sent the mean to main ECU. It was observed that the data recorded in main ECU were stable and reliable after using the new AD collection board. Experiment result shows the system can be used in yield monitoring practice.*

Keywords. Yield monitor; Precision agriculture; AD; MCU; ECU.

Introduction

In the recent years, information collection in the field becomes more and more important technology in precision agriculture. Especially yield information is one of the most important which helps farmers to input suitable materials to the field to save money and improve benefits. And yield monitoring is the most important practice used in the development of precision farm management. They provide a method to determine the amount of variability in a field as well as an assessment tool for how precision management practices are affecting yield. Now Grain crops and cotton have commercially available yield monitor systems on the market and have years of experience in their development. For example AFS (CASE-IH), PF advantage (Ag Leader), GreenStar (John Deere) etc. But they are all very expensive to farmers and not suitable for harvesting machines in China. There are some reports about the yield monitor system in China, but there are no such products made.

So, a new grain yield monitor was developed at the Research Center for Precision Agriculture (PAC) of China Agricultural University. The yield monitors are a combination of several components as shown in Figure 1. They typically include several different sensors (grain flow sensor, header height sensor, elevator speed sensor, ground speed sensor, moisture and temperature sensor) and other components, including a GPS receiver, a liquid crystal display, a touch screen, and an intelligent controller which controls the integration and interaction of these components.

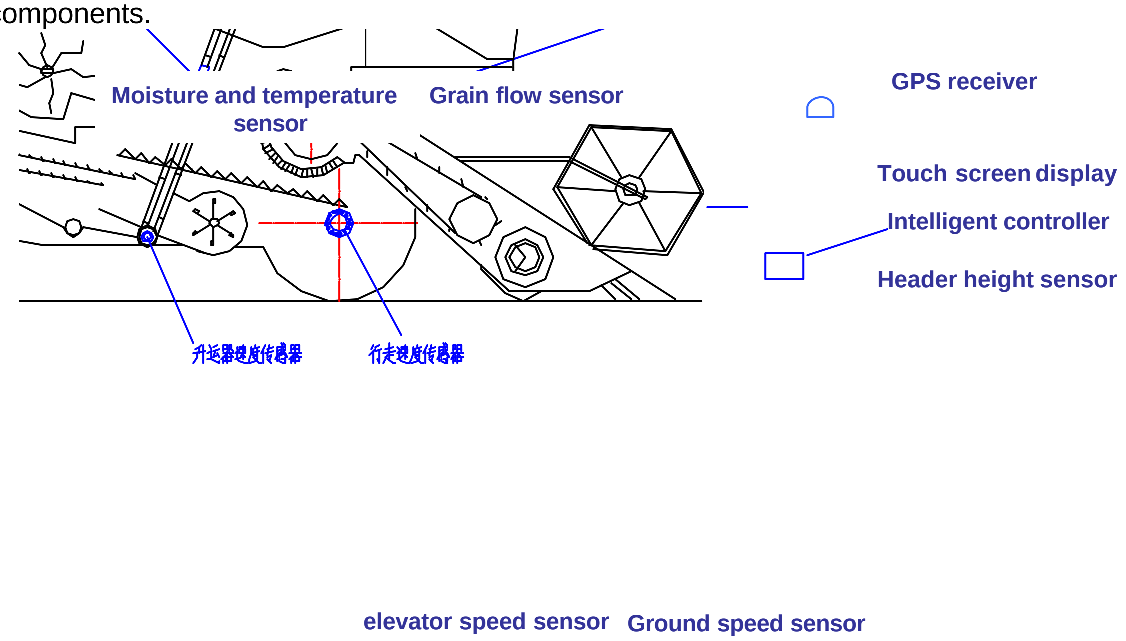

Figure1. Components of grain yield monitoring system on a harvesting combine

System Description

System requirement

Based on our design, there were four analog signals, grain flow, header height, grain moisture, and grain temperature and two digital signals, ground speed and elevator speed, in the yield monitor developed. Hence, at least four analog channels were needed to collect them and an A/D converter was needed to transform signals from analog to digital.

Two Hall sensors were used to measure ground speed and elevator speed. Each sensor always generated a square wave with a frequency in direct proportional to the speed measured. There would be at least two 16-bit counters needed to record two speeds.

The system utilizes an RS-232 serial interface (a common interface for data transfer in the personal computer industry) to communicate data from a DGPS receiver.

User interface is important in the system. One input keyboard and one output screen would make the system easy to use.

Data storage devices are also necessary. In order to make the system running more than one day, storage space should be large enough to save all data mentioned above at one-second interval.

System design

The key step of the design is to choose CPU. It should integrate some key components of the system and would be possible to fit the future needs, such as to communicate with other electrical control unit (ECU) mounted on the machine. The chosen CPU is P80C592, which integrates a 10-bit ADC with 8 multiplexed analog inputs and an on chip CAN protocol controller.

Signal conditioning is needed to prevent the CPU from damage by input analog signals. Input signal must be filtered.

Two digital signals in pulse form should be count once per second. The easy way to do this is to use a chip--Intel 82C53 which has three 16-bit counters. The electric level transforming circuit is also needed.

The user interface consists of a touch screen and a liquid crystal display. The touch screen is used to input some parameters for system setting. The liquid crystal display is used to show the data related to yield. CPU controls these two devices through its RS-232 serial port.

The GPS receiver output its positioning signal in RS-232 serial communication mode. Therefore a universal asynchronous receiver/transmitter, PC16552D, is embedded in the system. It has two independent serial channels and can meet the demand of GPS signal communication.

The storage media should have enough space to log all yield data. The chosen storage device is Compact Flash card. More than 30 hours of yield data can be logged at one-second interval on a 2-Mb card. The format of saving data in the card is ASCII text which is suitable for PC reading.

The system can be viewed in the following diagram (Figure 2)

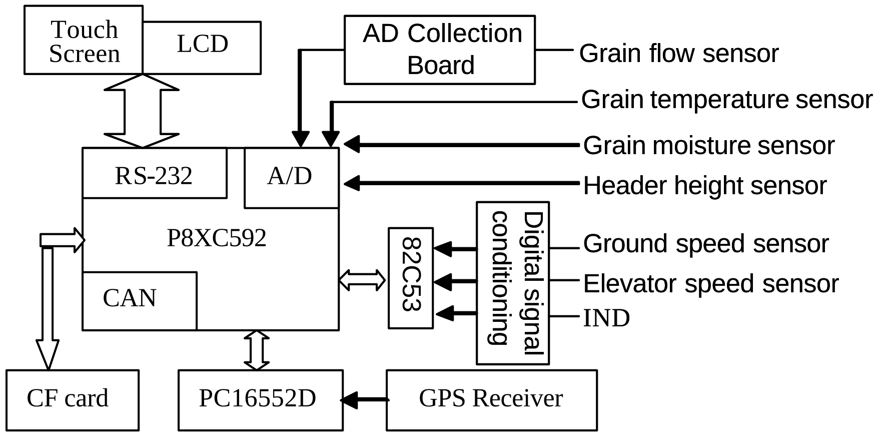

Figure2. System Architecture

Special Features

After several experiments, some problems were found. The grain flow signal had some noise and the system could not sample the signal correctly. A series of experiments were designed and conducted, and finally the reason was found. The grain flow is not continuous and the valid frequency is higher than sampling frequency, so it is difficult to increase precision of the monitor at a low sampling frequency (<10 Hz). However it was impossible to increase sampling frequency by main ECU since it must have enough time to perform other task. In order to improve S/N ratio, a new AD collection board was designed to collect grain flow signal with high frequency, as shown in Figure 3. An ATmega128 was used as MCU in the AD board. It is an 8-bit Microcontroller with an 8-channel, 10-bit ADC. One channel was used to sample the flow signal at 250Hz frequency. After sampling it calculated the mean of 250 data obtained in one second, and then sent the mean to main ECU in analog signal through a series of transforms . These transforms include D / A converting, voltage amplifying, and voltage- current transmitting.

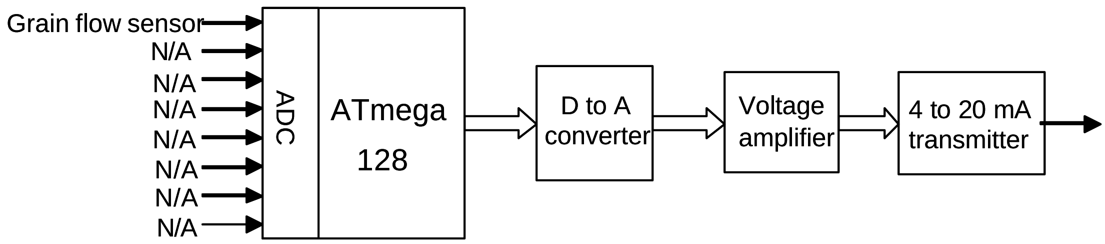

Figure3. The AD board Architecture

System Testing

A Laboratory apparatus was developed to simulate the working principle of combine harvester. It was designed to imitate elevator section on an actual combine. It consists mainly of flow rate controller, grain hopper, elevator duct, receiving container and a scale. All sensors were installed on it.

Figures 4 and 5 show the test results of grain flow sensor. Figure 4 is the results without AD board. Figure 5 is the results with the AD board.

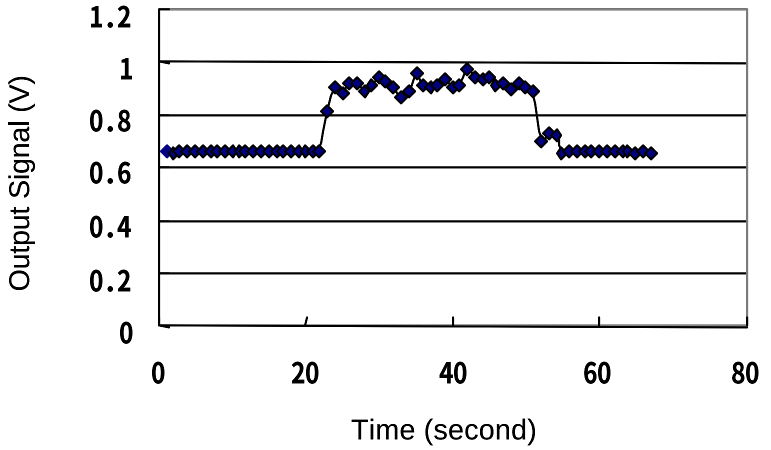

Figure4. The Output of flow sensor without new AD board

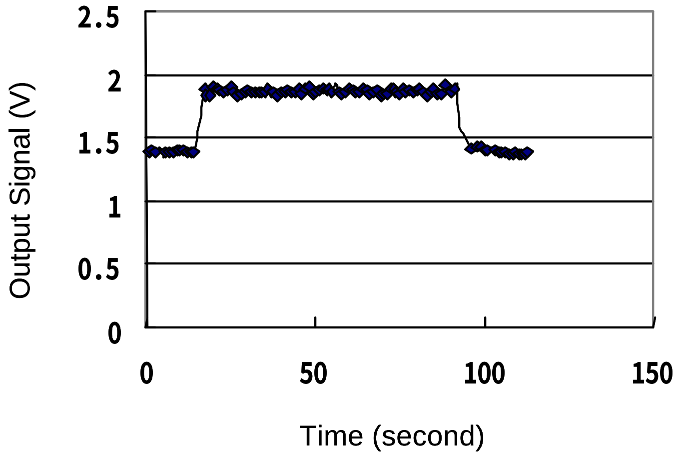

Figure5. The Output of flow sensor with new AD board

Comparing the two figures, it is obvious that the flow signal sampled by new AD board is more reliable and credible.

In 2004, a first prototype of the PAC Grain Yield Monitor was field test in Hebei province. This harvest season is from June 10 to June 19. During these days the field test results were consistently positive.

Accuracy was documented by comparing actual and predicted load weights. When field-tested on a harvester, results were positive, with an average absolute error of 2.89%. Some test results are shown in Table 1.

Table1. Error between the yield monitor weight and the scale weight

Number	Monitor Weight (kg)	Scale Weight (kg)	error
1	277.1	277	0.04%
2	328	324.3	1.14%
3	311	341.1	8.82%
4	309	318.4	2.95%
5	311	315.7	1.49%
average absolute error 2.89%			

Conclusion

Three years of design, fabrication, testing, and modification of the PAC Grain Yield Monitor gave very promising results leading up to 2004. Both laboratory experiments and field tests show that the system with the new AD board can finish the yield-monitoring task. It runs normally and stably. The accuracy of the system depends on appropriate installation, calibration, and operation. And the cost of the system is very low comparing with the commercial products on the market.

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