Application of Intelligent Measurement and Control Technology in Grain Storage

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Abstract: It’s of strategic importance that China takes the grain as the reserve material. The final quality of the grain is directly related to its storage process. Proper storage measures and methods can extend the shelf life of the grain. In the process of grain storage, the technical indicators, such as temperature and humidity of the stored grain, indoor temperature and air humidity, should be strictly controlled. The intelligent network-based measurement and control system composed by the PCI bus-based intelligent network interface card, the measurement nodes with the neuron chip as the core and LON bus is used to perform real-time measurement on various condition parameters of the grain bin, and transmit the measurement results to the server over the network for controlling and regulating the device after the server processes the results to ensure the safety of grain storage. Copyright © 2014 IFSA Publishing, S. L.

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1. Introduction

It’s of strategic importance that China takes the grain as the reserve material. The grain reserve is an important element in the grain circulation. The final quality of the grain is directly related to its storage process. Proper storage measures and methods can extend the shelf life of the grain and delay grain aging, otherwise, there will be unexpected results causing incalcuable damage to the country's economy. At present, the varieties of China's grain reserve primarily include rice, wheat and corn, depending on the origins, for instance, the rice is the majority of the reserve for the regions to the south of Yangtze River, while the wheat and corn for the Northern Region. According to the storage quantity and sizes, the reserve can be divided into national, provincial and local levels, etc. Regarding the storage effects, larger grain storage units have comprehensive automatic monitoring and control facilities to control the changes in the grain condition, and thus have achieved better storage effect. While local grain reserve depots with limited capitals and scale failed to achieve ideal effect due to the climate change in recent years and the restrictions of other factors. Viewed from the storage scale, the majority of grain is stored locally. Therefore, it’s not only an economic issue but also a strategic issue to take good care of the grain reserve. Improving the technologies and conditions for local grain bins and the quality of stored grain can benefit the mankind.

1.1. Main Factors Affecting Grain Storage Technologies and Current Situation Analysis

Currently the main threats to the grain storage are aging and insects, especially the rice and corn aging
problem. Both the restrictions by objective conditions and the influence of subjective factors compromise the quality of stored grain. Moreover, stagnate grain storage technologies and backward measurement and control methods also result in worse grain storage quality [1].

The statistics shows that high moisture content of the grain entering the storage results in worse storage quality, mainly as follows:

1) Excessive grain pile breathing, prone to heating, condensing and mildew, declining storage stability.

2) Poor grain pile permeability, not good for ventilation, heat dissipation and the penetration of fumigation agents, causing difficulties in cooling grain piles and incomplete insect control with fumigation.

3) The environment of grain pile is easy to breed insects, speeds up the rate of insect growth, causing the gathering of grain insects.

Currently many local grain storages are still using simple technologies and functions which can only measure the room humidity and temperature but cannot detect various factors affecting the stored grain safety, such as grain moisture content, mold, insects, etc.

The surveys from relevant departments indicate that mildew and insects are very harmful to the stored grain. In China, the annual post-harvest losses are up to 8 % where the losses due to insects account for 3 % ~ 5 %. Insects and mold not only cause the grain weight loss, but also seriously affect the grain quality, lead to grain discoloration, flavor reversion and even produce toxicity in the grain, causing poisoning and lesions to the people and animals who eat them.

1.2. Evolution of Storing Technologies

The grain storage can be divided by temperature technologies into low temperature storage and quasi-low temperature storage. Generally the quasi-low temperature storage means the grain temperature is controlled under 200 °C, while the low temperature storage refers to the technology keeping the grain temperature under 150 °C. The low temperature storage can inhibit the grain breathing, reduce the grain dry matter loss, kill insects and inhibit bacteria, as well as reduce the use of chemicals. It can also effectively delay grain aging, ensure the grain safety and health, the edible and nutritional quality of grain and oil, which are unmatched by other storage technologies, however, the cost is relatively high.

In addition, the grain storage measurement and control system used in our country has simple functions that can measure the room humidity and temperature only but cannot detect various factors affecting the stored grain safety, such as grain moisture content, mold, gas composition, insects, etc. They have incompatibility, poor anti-lightning and fumigation corrosion resistance, and incomplete grain condition control functions. As one of the important modern grain storage technologies, the development trends of the grain condition measurement and control system are grain condition monitoring and control product serialization and standardization, comprehensive data detection, integrated digital and intelligent sensors, data transmission by carrier and wirelessly, automatic grain condition control, intelligent data analysis, and simplicity of use [1, 2]. Therefore, it's inevitable to find an intelligent, low-cost grain storage automatic measurement and control system to solve the problems.

2. Hardware System Structure

Through in-depth research, an intelligent network-based grain condition measurement and control system composed by intelligent measuring nodes with Neuron Chip as the core and LON (Local Operating Network) bus network was developed. The intelligent measuring nodes of the system are constituted by the neuron chips [3]. The intelligent network-based measurement and control system has been gradually playing an important role in the modern intelligent measurement and control system thanks to its ease of installation and construction, flexible operation, reliable operation, cost-effective performance, low maintenance cost, etc.

2.1. Intelligent Measurement Control System Structure

The system consists of PCI intelligent network interface card (PCI bus), LON bus network server and intelligent measurement nodes with Neuron chip as the core. The structure is shown in Fig. 1.

![Fig. 1. Intelligent Measurement Control System Structure Diagram.](image-url)
2.2. Neuron Chip Based Intelligent Measurement Node

The intelligent measurement node takes TMPN3150B1AF Neuron chip manufactured by TOSHIBA Japan as its core [3]. The Neuron chip is a multi-processor chip jointly manufactured by Motorola and TOSHIBA. The intelligent measurement node is provided with complete system resources are provided and 3 pipeline CPUs are internally integrated, one for executing the user-written programs, the other two for performing network tasks. Communication protocols and microprocessors for control are integrated effectively to realize communication, control, dispatching and I/O functions. It is also provided with the components including high-precision 16-bit Δ-Σ AD7706 A/D converter from TI Corporation, 78KBPS twisted pair transceiver FTT-10A from Echelon, threshold voltage detector, photoelectric coupling PS2501, DC-DC power module, etc. Its hardware composition is shown in Fig. 2.

2.3. Signal Acquisition and Measuring Methods

The signal acquisition and measuring circuit is as shown in Fig. 2. Δ-Σ AD7706, the latest product manufactured by TI Corporation, is a high precision, wide dynamic range, 16-bit resolution Δ-Σ A/D converter with the voltage 2.7 V ~ 5.25 V, and 4-way single-ended or 3-way differential input channels. It can be directly connected to the sensor and low voltage signals, provided with internal buffer of optional high input impedance, and fuse current source that allows open circuit or short circuit of the sensor circuit. Besides, Δ-Σ AD7706 has 8-bit programmable digital interface and 2-way programmable constant current source. It has the internal programmable gain amplifier PGA (optional gain magnification 1, 2, 4, 8, 16, 32, 64, 128), supports both the internal reference voltage of 2.5 V or 1.25 V, and the external differential input reference voltage. It exchanges the information with CPU through SPI bus. Δ-Σ AD7706 works in the way of 3-way differential. The neuron chip sends the start operation command word to Δ-Σ AD7706 and selects one of the analog signal input channels via its IO8, IO9, IO10 (SPI communication interfaces) and IO6, IO7.

When the system is required to measure certain signals, the server will initialize each intelligent measurement node according to the task requirements. Each intelligent measurement node completes the measurement task independently as required, and transmits the preprocessed signals to the server which perform the signal storage, analysis and display. The server, in the modular way, can process both the signals of same type such as grain ambient temperature, humidity, grain moisture content, mold, gas composition, etc. separately and the signals of different types for analysis and judgment of some related events, and it can output the analysis and measurement results. For different analytical purposes, different analysis modules are required to meet different requirements.

For example, when the first-way differential input signal is ±19.5 mV, PGA can be set to 128. Δ-ΣAD7706 internally amplifies ±19.5 mV to ±2500 mV in order to perform A/D conversion. The converted digital is sent by the neuron chip by the read operation command word to Δ-Σ AD7706 and selects one of the analog signal input channels via its IO8, IO9, IO10 (SPI communication interfaces) and IO6, IO7.

In Fig. 2, the pre-amplified measuring signals of different types are MM1, MM2, MM3, such as grain moisture content, ambient temperature, humidity, gas composition, mold, etc. These signals are converted to electrical ones by a special sensor. The MAC processor of neurons chip is connected to the twisted pair transceiver to constitute LON bus. The processor expands EEPROM by using these three buses in order to store LON system programs. The neuron chip selects one of the input channels through the input/output port IO6 - IO10, starts A/D converter, and reads 16-bit A/D sampling results via SPI bus. The photoelectric coupler is used to isolate the analog measurement circuit and the neuron chip, improving the system anti-interference ability.
while VREF+ and VREF- are differential reference voltage inputs. In this application, VREFOUT is connected to VREF+, while VREF- is grounded. The internal reference voltage (2.5 V) is used. VRcap pin is externally connected to a 0.1 μF monolithic capacitor for filtering the internal reference voltage.

### 2.4. LON Bus

LON (Local Operating Network) bus is a comprehensive monitoring network launched by Echelon Corporation in 1991 and it offers powerful means for the smart distributed system (SDS) [3]. Its supports give birth to a new generation of low-cost monitoring and control intelligent network device. To support LON bus, Echelon Corporation developed LonWorks technology which offers a complete development platform for LON bus design and productization, including all hardware and software necessary for design, configuration, installation, maintenance and control. LonWorks technology primarily consists of the following components:


### 3. Measurement and Control System Software Programming

#### 3.1. Measuring Program Flowchart

LonWorks technology uses a dedicated hardware programming language Neuron C for programming. Neuron C is ANSI C based and expands ANSI C [3]. It supports the event-driven task scheduling mechanism: when a given condition (called as event) is true, a set of codes (called tasks) related to this condition are executed.

In Δ-ΣAD7706 chip, there are 8 registers which can be directly read and written and used to configure their working states and enables the direct configuration of data formats, PGA, channel selection, etc. Δ-ΣAD7706 also provides 128 bytes of RAM which is read and written through the instructions directly. Its measuring flow is shown in Fig. 3. The configuration data definitions are not provided.

After the register configuration is completed, the multiplexer register MUX can be configured to select the differential input channel and start A/D conversion. In addition, Δ-ΣAD7706 signal turning valid indicates the data conversion is completed, and the result is stored in 16-bit data output register DOR and can be read through dedicated instructions via SPI interface.

### 3.2. Self-made Synchronous Communication Protocol

We designed a PCI bus based LON smart card which organizes all measuring intelligent nodes together to form LonWorks control network. The host computer software transmits MMi input range, upper and lower alarm points, tasks to be completed at the measuring node and other configuration information as well as the return data request information to the signal measuring intelligent node via the smart card. When the node receives the configuration information, it will save the configuration information in EEPROM variable parameter area. The configuration information won’t be lost in case of power failure. When the node receives return data request information, it will transmit the measured data to the host computer for processing via the LON smart card. The formats of the data to be transmitted are shown in Table 1.

![Fig. 3. Measurement Program Flowchart.](image)

<table>
<thead>
<tr>
<th>Byte No.</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Data length</td>
</tr>
<tr>
<td>2.</td>
<td>Command flag</td>
</tr>
<tr>
<td>3.</td>
<td>Group No.</td>
</tr>
<tr>
<td>5.</td>
<td>Measure data 1</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>N</td>
<td>Checksum</td>
</tr>
</tbody>
</table>

Where the command flag 0xF0 indicates that the host computer transmits the configuration information to the node. The command flag 0xF1
indicates the return data request information is transmitted.

The data transfer between LonWorks nodes is mainly realized by the network variables. After the network variables are defined, the data transfer can be realized by binding network variables with LonBuider or LonMaker during the network installation. It's not necessary for the applications to consider sending and receiving issues. Network variables greatly improve the node product interoperability by assigning specific network interfaces to the node.

However, the use of network variables requires binding network variables with LonBuider or LonMaker from Echelon. One LonBuider emulator costs tens of thousands of dollars, and LonMaker software is also costly. They can only be installed on a machine, which invisibly increases the costs of development and application. For the above reasons, we decided to transmit the data by explicit message. When using explicit message for data transmission between nodes, the transmission is carried out in broadcasting manner so that other nodes, such as the PC, can receive the data sent from a certain node at the same time. The data will be processed only when the received node number is the same as the node number preset in the PC. Compared to the master-slave communication method, this communication method can significantly reduce the network traffic and improve the communication transmission efficiency without the need of using LonMaker and LNS DDE Severs, which minimizes the system cost, eliminates the need of using LonMaker for network variable binding when replacing modules, and facilitates the repair and the replacement. This method is more suitable for China's national conditions, but its disadvantage is making LonMaker a closed system.

4. Conclusions

This paper researches on the highly cost-effective multi-parameter network-based grain condition measurement system constituted by intelligent signal measuring nodes with TMPN3150B1AF neuron chip as the core and LON bus which is used as the network platform. The industrial intelligent Distributed Control System concept is introduced into the actual application of the grain storage monitoring and has achieved good effects.

References