# Design of Data Acquisition Terminal for Sisal Rope Core Production Workshop Based on Internet of Things Technology

Xin Ming

mingxin_66@sohu.com

Guangxi Vocational and Technical College, No. 19 Mingyang Avenue, Jiangnan District, Nanning City, Guangxi Province, China

**Abstract.** To solve the problem of low production efficiency of original sisal rope core production enterprises and break through the bottleneck of sisal rope core production capacity, a digital data collection terminal for sisal rope core production based on Internet of Things technology is designed. This terminal node can collect two voltage signals, two current signals, and two switch signals without changing the original equipment control circuit. Based on this, real-time data of each process link in the production of sisal rope core can be obtained, and it can be accessed through a 5G network cloud database. These information, as basic data, can provide decision-making basis for production scheduling and scheduling for management personnel, improving production efficiency and capacity.

**Keywords:** Sword hemp rope core production, Internet of Things, digital collection

## 1 Introduction

The cultivation and processing of sisal has always been a dominant characteristic industry in Guangxi, with the planting area of sisal in Guangxi accounting for over 80% of the national planting area. The rope core made of sisal is one of the raw materials for steel wire rope core, which can maintain the structural integrity and uniform performance of the entire rope in both dynamic and static states. And steel wire rope is a key component of important equipment related to life and production safety, such as elevators and lifting machinery. The domestic rope core market alone has a demand of about 48000 tons per year, with an annual growth rate of 15%. According to statistics, various sisal processing plants in China produce approximately 36000 tons of sisal rope cores throughout the year, with a market gap of approximately 12000 tons, which is becoming increasingly large. With the recognition of high-quality rope core products in the international market, the market for sisal rope core will be even broader[1].

One of the main products of a certain sisal product Co., Ltd. in Guangxi is sisal rope core. After several years of development, the company's annual production capacity of sisal rope core reaches 4000 tons. After on-site research, it was found that a major factor restricting production capacity is the low level of informatization in production process management, as well as the lack of efficient scheduling and decision-making, while the existing quantity of raw materials, personnel allocation, and actual operating rate of equipment remain unchanged.

BDEDM 2024, January 12-14, Ningbo, People's Republic of China

DOI 10.4108/eai.12-1-2024.2347223

To address the aforementioned issues, this article designs a digital data acquisition terminal for sisal rope core production based on Internet of Things technology. This terminal can collect data from various process steps in the production process of sisal rope core and submit it to the cloud database, providing managers with real and reliable basis for production and operation decisions.

The application of Internet of Things technology in the industrial field has been very extensive.

Prakash Vijay studied the use of shared databases, standard methodologies, and cross functional domain data exchange to handle internal factory transactions in complex and information physical fields such as industrial IoT and smart factories [2].

Mantravadi Soujanya applied a two-year period to track the role of Manufacturing Execution Systems/Manufacturing Operations Management (MES/MOM) in an IIoT driven manufacturing enterprise. They implemented autonomous MES/MOM data model design in the Smart Production Lab at Aalborg University, which is a reconfigurable information physical production system. And applied to practical production cases [3].

Jagtap Sandeep proposed a water monitoring system architecture based on the Internet of Things for real-time monitoring of water demand, addressing any water inefficiency issues in food production processes. They deployed the water monitoring system in a food and beverage factory to analyze the water usage throughout the entire production process, thereby solving the problem of excessive water waste during the production process[4].

However, the application of data collection systems based on Internet of Things technology in the field of sisal rope core production is still in a blank state. Therefore, this data collection terminal was designed.

## 2 System requirement analysis

The production process of kenaf rope core includes softening, carding, drawing, spinning, shearing and winding, soaking, strand making, rope making, weighing, warehousing, and other processes, which are distributed in 7 different production workshops. Except for warehousing, each process has its own production equipment according to different process requirements, and data collection nodes need to collect key parameters of different mechanical equipment in each link of the entire process.

Due to the small number of mechanical equipment in each process, ranging from a few to dozens, and the number of data acquisition terminals in the entire system reaching hundreds, a data transmission scheme based on Internet of Things technology is adopted.

This design mainly studies a distributed data acquisition terminal that can be applied to the above scenarios and adapt to different types of devices. This terminal needs to meet the following parameters.

(1) Power supply voltage: DC 12 V.

(2) Communication network: 5G.

(3) Digital quantity acquisition channel: 2-way isolation.

(4) Voltage acquisition channel: 2 channels 0-5 V, with an error of ± 1%.

(5) Current acquisition channel: 2 channels 4-20 mA, with an error of ± 2%.

(6) Supported protocol: Modbus RTU.

## 3 Design of data acquisition terminal circuit

The perception layer consists of terminal nodes distributed in various workshops of the factory. They collect key data from various production processes through sensors or data interfaces, unify data from different devices into a fixed format, and send it to the backend through 5G network modules, achieving the most primitive data collection.

In order to meet the data collection needs of different types of equipment in the factory, the perception layer data collection terminal is fully self-designed. Each terminal node consists of three modules: the main control module, 5G communication module, and data acquisition module.

### 3.1 Main control module

The STM32F103CBT6 chip is used, which has 128K Flash and 20K RAM, providing ample space for program operation [5]. Equipped with a built-in 12 bit ADC and a dedicated timer for power-off wake-up, it is very practical for applications such as data acquisition terminals that require low-power operation. The DMA channel supports modules such as ADC serial port, which can effectively reduce the computational burden on the CPU. Most importantly, this chip has powerful computing power for the CM3 core, which can meet the requirements of this application scenario.

### 3.2 5G communication module

Select WH-GM5 from IoT company. The module software has complete functions and covers the vast majority of conventional application scenarios. Users only need to set up simple settings to achieve bidirectional data transparent transmission from the serial port to the network. And it supports custom registration packets, heartbeat packet functions, and supports 4-way Socket connections, allowing for faster transmission of user data to the network.

### 3.3 Data acquisition module

In order to adapt to the diverse types of production equipment in the sisal workshop, the data acquisition module is independently designed and can be compatible with collecting the following types of data.

(1) Analog data types: voltage of 0-5 V and current of 4-20 mA. For example, in the oil immersion process, the liquid level in the oil tank is [6].

(2) The input data of the switch node includes signals such as the operation status of each equipment, start stop status, and the number of yarn bundles produced by the winding

machine.

(3) Private protocol data: For example, diameter data output by sensors for measuring the core diameter of sisal rope.

### 3.4 Overall circuit design

The digital input and analog input circuits are shown in Figure 1, and the PCB circuit board is shown in Figure 2. CN1 is a 5V power interface, powered by a 12V DC/0.5A DC power supply.

CN3 and CN4 are two input terminals for voltage signals, providing a 12V power supply to external sensors and collecting 0-5V voltage signals from sensors. The two input signals are divided by R34, R35, R49, and R50, and then passed through a follower composed of U5 and U8 operational amplifiers to send the final voltage signal to the AD pin of the microcontroller.

CN2 and CN5 are two input terminals for current signals, providing a 12V power supply to external sensors. At the same time, they collect 4-20 mA current signals from sensors. After sampling R2 and R31, the two current input signals are converted into voltage signals and input into the same phase terminals of the operational amplifiers U9 and U7. Adjust SW1 and SW2 to work together with R14 and R28 to set the amplification factor of the operational amplifier to 10 times. Finally, the 4 pins of U9 and U7 will output a voltage signal of 0.4-2 V to input to the AD pin of the microcontroller. The microcontroller can calculate the current input values of two terminals by measuring the voltage value[7].

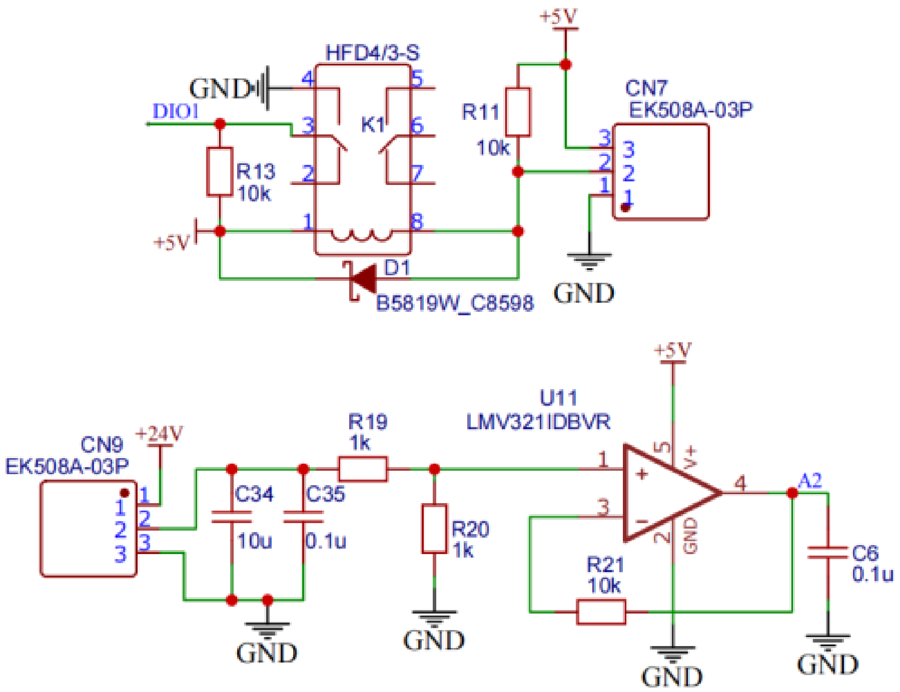


**Figure 1** Circuit diagrams for digital and analog inputs.

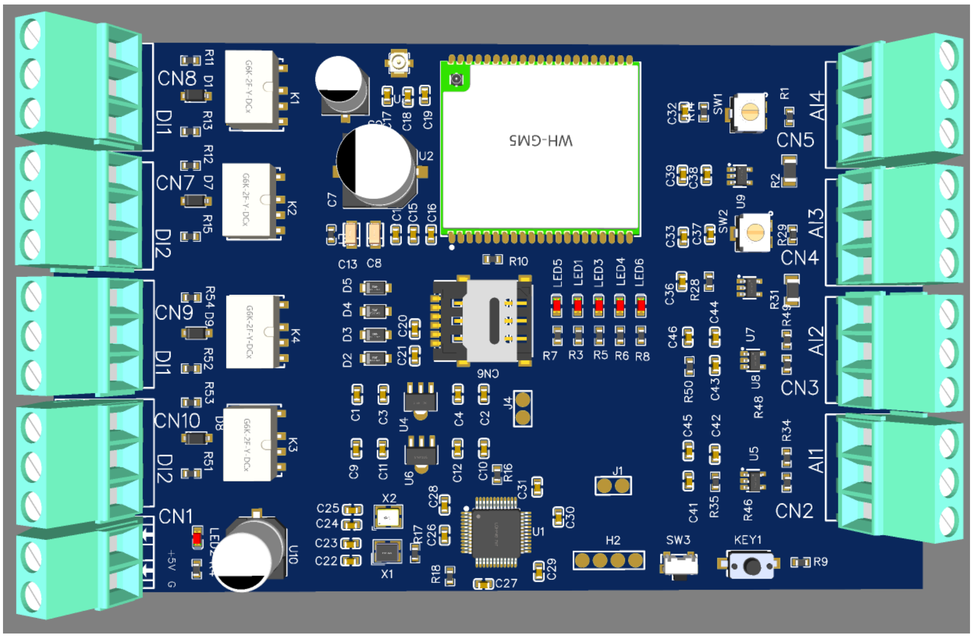


**Figure 2** PCB diagram of data acquisition module.

CN7 and CN8 are two digital input ports. The external digital input signal is connected to the coil control circuit of relays K1 and K2. The relay contacts are pulled up by resistors R13 and R15 and then input to the IO pin of the microcontroller. The relay plays an isolation and protection role.

U2 is a 5G data transmission chip WH-GM5, with a nominal module power supply voltage of 3.8 V, a floating range of 3.4~4.2 V, and a peak power consumption current of up to 2.5 A. In order to ensure stable and reliable data transmission, special treatment is required for the power supply of this module. The main measure is to ensure reliable filtering of the power pins, so several capacitors need to be connected in parallel near the power pins of this module to eliminate the influence of large current pulses when the module sends and receives data. 470 is used in the circuit μ F. 220 μ F capacitors in parallel to filter out low-frequency interference, 22 μ F. 0.1 μ F. 1nF and 100pF capacitors are connected in parallel to filter out high-frequency interference. Meanwhile, considering that the application scenario of this circuit board is in a sisal factory, the electromagnetic environment is relatively harsh due to the movement of various equipment's start stop motors, and magnetic beads are also connected in series at the power supply end to enhance the stability of the module [8].

The module adopts a SIM card interface that complies with the ISO 7816-3 standard. The CN6 is a Nano SIM card holder, which supports the smallest physical phone card currently available, with a card size of only 2.3 mm × 8.8 mm ensures the compact size of the circuit board. In order to avoid damage to the USIM card and chip caused by human static electricity caused by frequent insertion and removal of USIM cards, four TVS tubes D2, D3, D4, and D5 have been added to the circuit as ESD anti-static measures to protect the entire circuit from static electricity.

The microcontroller U1 and the 5G module U2 transmit bidirectional data through a serial port.

## 4 Terminal data transmission

The data collection terminal node collects on-site data and converts it, and then sends the relevant information to the cloud database through transparent transmission. In order to unify the standards of all nodes, an improved Modbus RTU protocol is used to bi-directional transmit data between the 5G network and the backend cloud configuration end.

Based on the characteristics and application scenarios of this data collection terminal node, the improved Modbus RTU protocol mainly refers to the following two aspects:

(1) Tailoring the standard Modbus RTU protocol to support a subset of the standard Modbus RTU protocol [9];

(2) Several custom instructions have been extended to address the characteristics of the 4G network transport layer.

### 4.1 Trimming modbus RTU instructions

This data collection node has 4 analog inputs and 2 digital inputs. Therefore, the instructions involved mainly include reading discrete inputs and reading input registers.

The instruction format for reading discrete inputs is shown in Table 1.

**Table 1** Read Discrete Input Request and Response Format.

| | Equipmen | function | Register Start | | Register unit | | crc check | |
|---|---|---|---|---|---|---|---|---|
| reques: | 0X02 | 0X02 | 0X00 | 0X00 | 0X0 | 0X02 | 0X40 | 0X15 |
| | Equipment No | function code | Byte count | | Data | | crc check | |
| answer1: | 0X02 | 0X02 | 0X01 | | 0X00 | | 0XA1 | 0XCC |
| answer 2: | 0X02 | 0X02 | 0X01 | | 0X01 | | 0X60 | 0X0C |
| answer 3: | 0X02 | 0X02 | 0X01 | | 0X10 | | 0XA0 | 0X00 |
| answer 4: | 0X02 | 0X02 | 0X01 | | 0X11 | | 0X61 | 0XC0 |

Cloud initiated data request frames: 0X02, 0X02, 0X00, 0X00, 0X00, 0X02, 0X40, 0X15

The first byte of the request frame is the address code, which is 0X02; The second byte is the function code, where 0X02 represents reading discrete inputs; The 3rd and 4th bytes represent the starting address of the register to be read, which starts from the 0X0000 address; The 5th and 6th bytes represent the length of the unit to be read, which means reading 0X0002 units. In this application, the terminal node only has two discrete data inputs, with addresses 0X0000 and 0X0001; The 7th and 8th bytes are the CRC checksum values, with the low byte followed by the high byte.

The table lists the response frame data for four scenarios where the values of the two switch input ports are 00, 01, 10, and 11, respectively. Taking response frame 4 as an example, 0X02, 0X02, 0X01, 0X11, 0X61, 0XC0, the meaning of each byte. The first byte of the response frame is the address code, which means the address of the upload node is 0X02; The second byte is the function code, which means that the uploaded data is discrete input information; The third byte is the length, which means the data is only 1 byte; The fourth byte represents the data content, and in response 3, it represents the case where both digital input modules are 1. At this time, the data of the two discrete nodes is mapped to the 0th bit and the 4th bit of a byte with other bits being 0. Therefore, the fourth byte of data is 0X11; The 5th and 6th bytes are CRC checksums.

### 4.2 Extended modbus RTU instructions

The Modbus RTU protocol itself is a half duplex bus protocol. In order to avoid data confusion, a question and answer method is adopted on the bus. Based on this, the server can manage multiple slaves and devices simultaneously, achieving active collection and control by the host. Under normal circumstances, the server can achieve millisecond level polling control.

In the scenario of this application, 5G network is used to transmit data. Due to traffic limitations, network latency, server concurrency, and other reasons, it is impossible to achieve millisecond level polling read and write. According to different working conditions, the polling data period is generally set to be between 1-10 minutes. However, there may be a situation where the server fails to read the changing data in a timely manner when the terminal node collects it. By the next reading week, the node data has changed, greatly reducing the real-time and reliability of the system[10].

To address this issue, Modbus RTU will be used as an extended application. According to preset rules, when there is a data mutation, upper and lower limit crossing, or sleep wake-up situation, even if no data request instruction is received from the server, the terminal node can actively upload data in the form of Modbus response frames. Due to the fact that 5G network communication belongs to full duplex, protocol expansion will not affect the normal polling of the server and will not cause bus confusion. This not only ensures the normal response of polling data, but also avoids losing critical data of terminal nodes, ensuring the reliability of terminal data collection nodes.

## 5 Conclusion

The terminal node was installed on site in the rope core production workshop, and 8 tests were conducted on three types of signals: voltage input, current input, and digital input. The test data is shown in Table 2:

**Table 2** Test result statistics table.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Input Voltage(V) | 4.97 | 3.01 | 1.54 | 2.68 | 3.76 | 0.84 | 4.21 | 1.66 |
| Measure Voltage(V) | 4.98 | 2.99 | 1.55 | 2.67 | 3.78 | 0.84 | 4.23 | 1.67 |
| Voltage Error | 0.20% | -0.66% | 0.65% | -0.37 % | 0.53 % | 0.00% | 0.48 % | 0.60% |
| Input Current(mA) | 10.6 | 6.3 | 18.8 | 15.6 | 9.7 | 11.8 | 14.4 | 7.3 |
| Measure Current(mA) | 10.4 | 6.2 | 18.6 | 15.4 | 9.6 | 11.9 | 14.2 | 7.4 |
| Current Error | 1.89% | 1.59% | 1.06% | 1.28% | 1.03 % | -0.85 % | 1.39 % | -1.37% |
| Input Digital Signal | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| Measure Digital Signal | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| Digital Signal Error | none | none | none | none | none | none | none | none |

The test shows that the voltage, current, and digital signals collected by the data collection terminal node are all within the allowable error range.

The designed terminal node has been applied in the production workshop of a sisal processing plant, and the terminal node can use Modbus RTU extension instructions to report production data of various process links in real time. In the context of intelligent manufacturing and industrial big data, the application of this terminal device realizes digital monitoring and evaluation of the production process of sisal rope core, providing decision-making basis for managers, and ultimately achieving the goal of optimizing resource allocation, improving production efficiency, and increasing production capacity.

## References

[1] Ming Xin, Qin Xiufeng, Mo Jianheng (2022) Design of a sensor for measuring the core diameter of sisal hemp rope Equipment Manufacturing Technology (8), 52-55.

[2] Prakash Vijay et al. Cloud- and Edge-based ERP systems for Industrial Internet of Things and Smart Factory[J]. Procedia Computer Science, 2022, 200 : 537-545.

[3] Mantravadi Soujanya et al. Design choices for next-generation IIoT-connected MES/MOM: An empirical study on smart factories[J]. Robotics and Computer-Integrated Manufacturing, 2022, 73

[4] Jagtap Sandeep et al. An Internet of Things Approach for Water Efficiency: A Case Study of the Beverage Factory[J]. Sustainability, 2021, 13(6) : 3343-3343.

[5] Tabi Fouda Bernard Marie,Dezhe Han Bowen An.(2019).Microcontroller design for security system: implementation of a microcontroller based on STM32F103 microchip..IJES(5),541-550.

[6] Anonymous.(2008).Keithley Expands 3700 System Switch/Multimeter Line with Plug-in Cards.Wireless News

[7] Yang Xu, Xu Qiaoyu, Wang Military Commission,&Zhou Xinwen (2021) Design of a voltage acquisition module with adjustable fir filtering parameters Journal of Henan University of Science and Technology: Natural Science Edition, 42 (2), 7.
[8] Su Huiyong,&Liu Wei (2022) A method for connecting 0~20ma transmitters to 4~20ma acquisition modules New industrialization (001), 012
[9] Kekre Akshay M. Kothari Ashwin.(2022).MODBUS-TR: Advanced MODBUS-RTU Protocol for IoT with Auto-discovery and Triggers.Wireless Personal Communications(3),2769-2780..
[10] Morris, T. , Vaughn, R. , & Dandass, Y. . (2012). A retrofit network intrusion detection system for modbus rtu and ascii industrial control systems. IEEE, 2338-2345.