Sodar Wind Profiler Design Based on Embedded System

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Abstract. Sodar is a kind of remote sensing measurement device that detects targets by launching sound waves. In the application of atmospheric observation, it is mainly used for wind profile measurement at the bottom of the atmospheric boundary layer. Sodar is mainly composed of the main controller, power amplifier, backward wave amplifier and acoustic antenna. This paper designs a simple sodar with the main controller STM32F767ZI, and the use of RT-Thread embedded system realize the operational control and signal processing of sodar system. The main functions include the drive of transmission, echo acquisition and data transmission. At present, the software system has been developed, all modules work normally, it will be put into testing as soon.

1. Introduction
With the development of technologies, ARM-based microcontrollers are widely used in current control field. The good combination of embedded systems and Internet provides convenience for the intelligent detection of SODAR (Sound Detection and Ranging). The principle of acoustic remote-sensing tool is based on the detection of the backscattered signal from acoustic refractive index discontinuities or disturbances in the atmosphere. By analyzing the doppler shifting of the echo, sodar can obtain wind speed, direction and other related wind profile information. Compared to traditional acoustic remote-sensing tools using serial or USB-connected computers, RT-Thread real-time operating system offers many Internet-specific software packages, which are of great benefit to sodar to access the network in real time and simply. Besides, RT-Thread has a thin kernel that is ideal for small detection devices such as sodar.

The adoption of the operating system makes it easier for micro-control systems to perform complex tasks. RT-Thread, as an excellent domestic real-time control operating system, has the advantages of very small kernel, stable and reliable, easy to use and so on. In this paper, a method is presented for designing a sodar system based on the embedded system RT-Thread. Transmitting and receiving of the signals are discussed in detail in the program design, and network access is realized through LwIP which is a kind of efficient and simplified network protocol.

2. SODAR Systems
Driving signal of sodar is generated by D/A converter, and it will be transmitted by the acoustic antenna after passing through the power amplifier. While the backscattered echo signal is amplified by the small signal amplifier, then send it to the A/D converter. For echo signals, time is associated with radial distance. Radial wind speed will produce modulation on waveforms, hence by extracting the doppler frequency shift of the echoes can obtain the radial velocity. In order to get the retrieval data of the three-dimensional wind vector, such a transmit/receive module requires three sets, a simplified structure diagram as follows:
Figure 1. The system diagram for Sodar

The main function of the software system is to control the transmission of signal, to obtain and accumulate the echo signal and to communicate with the upper computer. The structure of the main control system is shown in Figure 2.

3. Procedure Design

The main program will wait for data from the host computer. When the communication task is completed, the main program receives the mailbox from the communication program and then parses the data. It performs the corresponding operation according to the setup information, responds to data from the upper computer, or is accomplished the detection task by the configuration parameters. It is worth mentioning that the configuration information of the program is a global variable that is accessible to all threads.

Firstly, the main program will release the semaphore when it executes the task of transmission. When the transmitter takes the transmit semaphore, it configures the peripheral according to the current parameters, after transmit complete, releases the complete semaphore and then suspends, waiting for the next trigger. Meanwhile, the receiver takes the semaphore that is completed from transmission, turns on the echo reception task, also configures the peripheral according to the current parameters and releases the received complete semaphore after the work is completed. Usually SNR of received signal is very low, to address this problem, coherent integration is employed in the design.
The accumulation of N times can increase the signal-to-noise ratio by N times. The main program will judge whether the number of accumulations has been reached, and if the requirement is not met, the transmit semaphore will be released again to trigger the task of emission until the end of the probe. For simple single-frequency pulse, the program will do simple data processing of the echo, including bandpass filter, windowed FFT, frequency offset of detection and rough calculation of wind speed or direction. The original data obtained by the probe is all sent to the upper computer for further processing. Program will evoke the data transmission by releasing the data transmission semaphore. The main process is shown in the following diagram:

![Diagram of transmit/receive process]

**Figure 3.** The program diagram of transmit/receive

The signal of the sodar is generated by the main control module, a built-in D/A converter of the main control chip STM32F767ZI is used in the design. In addition to the ability to send simple pulses, the program is designed to enable to transmit chirp signals for several seconds. With the help of the DMA(Direct Memory Access), signals can output directly from the RAM buffer to the DAC peripheral. DMA works in cycle mode and does not need to manually fill the DAC with values. For long pulses, there will be many points need to transmit, it means the entire table length is even longer than the main control module’s own RAM space so that allocating the required space directly to it will take up too much resources. In this paper, a fixed-length DMA Buffer is created, by configuring timer interrupts to detect if unsent buffer data is about to run out. For example, timer interrupt is triggered at the T1 moment, at the same time, the remaining data in the buffer reaches the threshold for updating at T2 moment, so the table generate function will be called to calculate until the T3 moment. DMA pointer will jump directly to the head when the end of the buffer is reached, as shown in the figure 4.
4. Communication with Upper Computer

FinSH is the shell of RT-Thread which provides a command-line interface for users. It is convenient to obtain the system operation performance through serial ports, debug program modules and change configuration parameters by using FinSH component in the RT-Thread system. A brief flow diagram is shown in the figure 6.

However, the use of serial ports cannot satisfy the requirement of a stable transfer over long distances and at high rates. The sodar data transmission interface designed in this paper is the RJ45 network interface. And LwIP protocol stack is adopted on the system, which is a kind of lightweight open source TCP/IP protocol stack for embedded system. Its optimized memory management
mechanism greatly reduces the time and resource cost. After configuring the TCP parameters in the LwIP stack, initializing the stack, then start two threads to process the transceiver and block on the mailbox to wait for data. A simplified block diagram of the data transfer is as follows:

![Data Transfer Diagram](image)

**Figure 7.** The diagram of data transfer

For echo transmission, once the data transmission application obtains the transmission semaphore from the main thread, it will package the data according to setup information and sends the mailbox to LwIP application. After the LwIP application obtains the mailbox, it parses the data and calls the internal processing function to complete the transmission. At the same time, LwIP app will feed an OK semaphore and then continue to suspend. In LwIP, the application that wishes to send data looks at the progress of transmission after it has obtained this semaphore to judge whether the data is continued to be sent. Finally, a Trans_OK semaphore will be sent by the application of data transmission to tell the main program that all transmissions are completed. Data Transmission is an application for transmitting the original data of echo, sending data far more than receiving, so the configuration priority of eth_rx within the LwIP module is higher than the configuration priority of eth_rx. The data received will be processed by the LwIP app sent to the main program via the mailbox. LwIP completes all the work from the application layer to the hardware layer in one process, figure 7 above represents a block diagram which is simplified.

5. **Conclusion**

The paper designs a software control system based on the RT-Thread embedded system for sodar. Using the peripheral resources on the low-cost STM32F767 chip to complete most of the control functions. In software design, tasks with high real-time requirements are handled by means of the lower layer of peripherals. For data transfer or other functions, enable the RT-Thread’s official software package, and then use some simple API from LwIP stack to get the job done.
Compared with traditional development, the use of embedded systems can shorten the development cycle to a certain extent. Also, existing common component packages can provide a data transfer between device and the upper computer conveniently in wireless communication. Furthermore, it is also easy to add subsequent features, such as the access of wireless 4G network. In short, the procedural framework provided in the paper has great benefits for the improvement of sodar system.

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