The Intelligent Detecting Robot

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Abstract— **With the current advanced SOPC technology carrier, intelligent detection robot system is designed. Using the DEII board of ALTERA company as the robot's control core, we realize the robot's navigation and positioning, environmental information detection and the function of information transmission. Detection robot system transmits the position and spot environmental information to the PC monitor, this can help operators to judge the scene of the accident situation for effective rescue work.**

Keywords— **Detecting robot; FPGA; DEII; GPS; EC**

I. INTRODUCTION

At disaster sites or unknown environment, these places may have something harmful to human life, such as high temperature, toxic gases and factors, etc. But sometimes in order to rescue or fulfill a important tasks must go into these places, can used the detect robot to ensure the safety of people's life. Intelligent robot system has a reliable detection and navigation system, can reach the location where people appoint, and returns the real time environmental information, and provide a reliable basis for people's follow-up work.

Altera presents an advanced embedded system solution, using the System on a Programmable Chip which is based on Nios II embedded soft core. It has flexibility, customizability, and the ability of hardware and software collaborative design. Because it can quickly and efficiently help users to realize the design of intelligent system software algorithm and hardware development, so it has been widely used in the modern intelligent system.

This article is about using embedded system technology for a detection robot system design. The intelligent detection robot in this paper, can navigate to the intended target range, detect the site, and return the reliable real time environmental information, provide the reliable basis to the detect personnel, and ensure to complete the subsequent rescue mission. This design has a certain engineering significance.

II. INTELLIGENT DETECTING ROBOT SYSTEM

Detection robot is an army ground mobile robot which is used to entering the unknown place where staff cannot access or high risk area to carry out the detection task. Navigation and positioning system is one of the core unit in a detection robot. Because it has built-in navigation and positioning system, the robot can arrive at the appointed place by using the navigation in the unknown environment, and using all kinds of sensor to detect the environment around the robot, collect environmental data and transmit scene image data for the latter part of the rescue work probe.

This system uses GPS, EC and photoelectric encoder as the navigation sensor. In navigation, GPS detects robot's location information, EC measures robot's heading angle, incremental photoelectric encoder measuring detection robot's walking distance. This system can transmit remote robot's position information and the site environmental information to the rescue center displayed in the upper computer, and help rescue personnel to effectively determine the scene of the actual situation.

A. Detecting Robot design

Intelligent detection robot system's hardware structure can be divided into five parts: (1) MCU-DE2 Board, responsible for communications with each sensor and information processing of the whole system. (2) Navigation unit, it is comprised of GPS, EC and photoelectric encoder. (3) Obstacle avoidance unit, it is comprised of ultrasonic ranging and infrared distance measurement system. (4)Detection unit, it is comprised of all kinds of sensors and wireless data-transmit module. Its task is to transmit environmental information to detect personnel and the main control unit. (5) Manipulator, consisting of four degrees of freedom manipulator, Responsible for fetching and obstacles of the object. Detecting robot overall design as shown in figure 1.

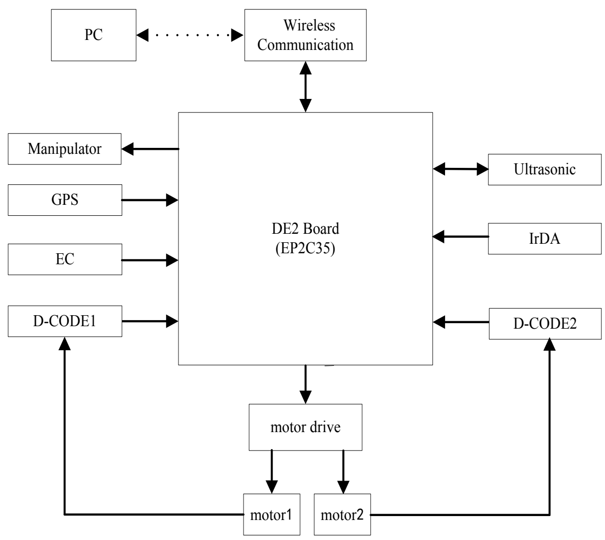

Fig.1. Detecting robot overall hardware design

B. Task scheduling of embedded real-time operating system realize

Due to deal with many tasks, such as EC information processing, GPS information processing and photoelectric encoder information processing, etc. so the software of robot system is very complex. So the system need to use the embedded real-time operating system to reasonable allocate system task, optimize the system performance.

Because ALTERA company has put its full ported to NIOS II, so NIOS-II is more convenient in use. Therefore the allocation under the NIOS II IDE software, the C standard library can be used.

We use NIOS-II to achieve the system task scheduling, including task switching and task management. According to the specific circumstance of the detecting robot, we create eight tasks in this system.

Task 1: Gps_task completes GPS information collection。

Task 2: Ec_task Completes magnetic sensor SPI communication and the heading angle calculation of detection robot.

Task 3: Hongwai_task completes infrared distance information collection and processing.

Task 4: US_task completes ultrasonic ranging information collection and processing.

Task 5: Human_task completes the human body infrared module data collection, and to judge whether have injured personnel in the detecting area.

Task 6: Jixieshou_task completes D-H modeling and inverse of the robotic hand, make robotic hand arrive at any point in the degrees of freedom.

Task 7：Car_control_task completes the control of mobile robot's drive motor. According to the navigation information and obstacles information, we can realize robot's move function. Set the task priority to 10.

Task 8：Pc _task transmits the information to upper computer， and to display the detected environment information and navigation information on the PC screen. If the detection robot navigation failure，we can control the robot move through remote operation by receives control signals from the PC.

III. INTELLIGENT DETECTING ROBOT'S SOPC

According to the need of the detecting robot system design, we use Quartus II and SOPC Builder to build a SOPC system based on FPGA. The system uses NIOS II embedded processor as the kernel, Using the AVALON bus with each IP core, on-chip and off-chip peripherals connected。Build a SOPC system based on FPGA can realize the coordinated design of hardware and software, make multiprocessor cooperation can greatly enhance the integration of the system and increase the system's control and processing capacity.

Intelligent detecting robot's SOPC Builder implementation of Nios II processor as shown in figure 2.

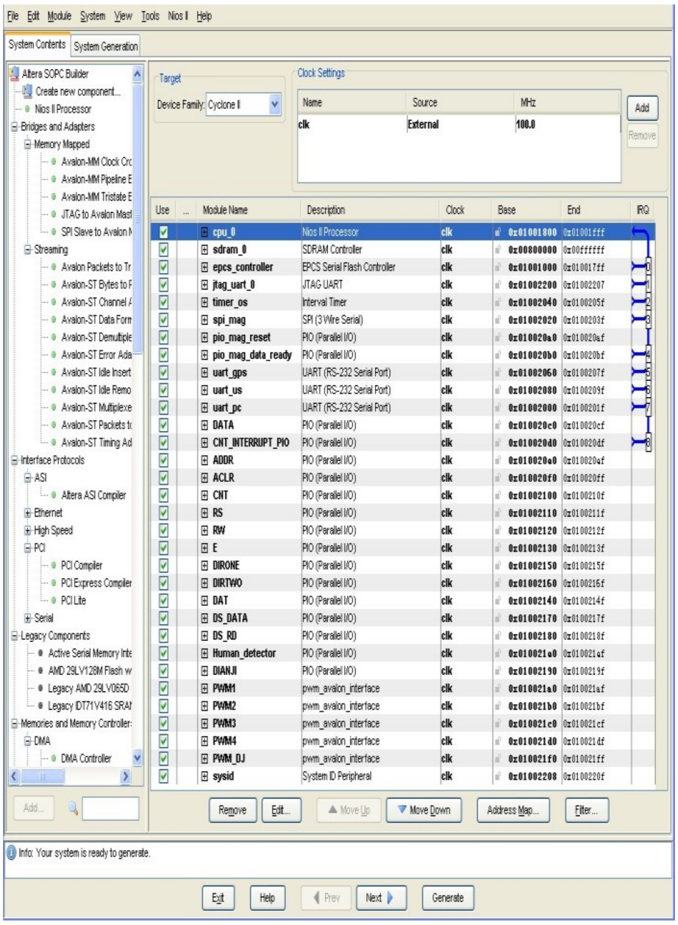

Fig.2. System's SOPC Builder implementation of the Nios II processor

As shown in Fig 2, on the basis of adding standard processor and peripherals kernel, in order to meet the needs of the whole system, we customized user peripherals based on Avalon, such as PWM, etc. We also customize user command base on IP. System uses data cache with 32 bits of 4K bytes and address cache fast type (f) CPU of 4K bytes. In order to facilitate debugging and reduce system resource, we add simple Level JTAG debugging and online software breakpoint debugging module for CPU.

Because magnetic sensor communicates with Nios II CPU is through the SPI interface implementation, so EC unit in this system need a SPI core.

In order to meet the needs of system communication between various modules, this system need 3 UART core. All UART core set similar. GPS receiver requires 19200 serial baud rate. In our design, set serial baud rate between ultrasonic and FPGA is 9600, wireless data communication module's serial baud rate is also 9600.

A. GPS packet receiver module design in FPGA

The uBLOX company's LEA-5A is a GPS receiver plate of ultra-low power consumption in this system. Have a orthogonal MCX connectors to connect to the active antenna. It also has some digital interface, such as USB, UART and

I2C, etc. Due to the convenient operation, combination of high performance and flexibility, so it can satisfy the quick and easy plug-in system integration which request cost effective. It supports multiple data formats，such as NMEA, UBX and RTCM. It has 4 Hz positioning data update rate. UBX data format and 4 Hz data update rate can satisfy the needs of the algorithm in this system.

In this system, while it is possible to directly use UART IP core in the SOPC Builder to receive GPS message data, but receive 70 Byte data of a frame will generate 70 interrupt information, this will increase the burden of mobile robot navigation system. Therefore, this system improved the GPS message receive mode, using Verilog language to design GPS_UART message receiving module, so that each receives 70 Byte data of a frame only generates an interrupt, and receiving process with other tasks concurrent execution in the system. In this way we can effectively reduce the burden of the NIOS II, obviously improve the efficiency of the system.

After fully consult the UART communication protocol, designed the GPS_UART packet receiver module, as shown in figure 3.

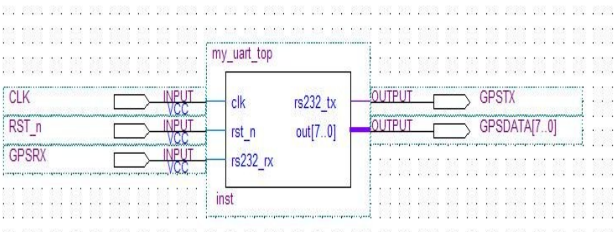

Fig.3. GPS packet receiver module design by Verilog

B. EC communicates with the FPGA kernel design

This system uses the PNI 11096 three-axis EC module to measure geographic magnetic field strength, through the correct solution to get the heading Angle of the mobile robot.

PNI 11096 use 3.3 V power, the sampling frequency can be set, the fastest can reach 2000 times per second, with a standard SPI communication digital interface. The sensor’s heading accuracy is ±1° .

In the communication interface design of EC and FPGA, FPGA using SPI to communicate with EC. Using SOPC Builder configuration wizard, constructed a SPI core for FPGA to communicate with EC in the NIOS II soft core processor. As shown in figure 4. The FPGA is the MASTER, the EC is a SLAVE, SPI clock frequency is 200 KHZ, data width is 16 bit.

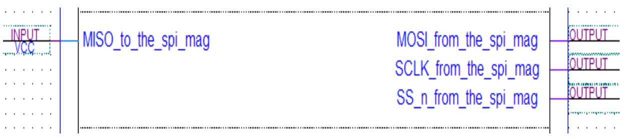

Fig.4. SPI core for the FPGA to communicate with EC

C. Unit interface communication protocol

EC unit transmits data to Nios II by SPI protocol. The protocol timing diagram is shown in figure 5. SS is a chip select signal of SPI interface. SPI protocol is activated when it is pulled low. The meaning of serial data input signal MOSI is master output and slave input. The meaning of serial data output signal MISO is master input and slave output. SCL is the serial clock signal of the SPI interface, its maximum working frequency is 1MHZ. SCL rising edge latches data in data transmission, high bit before, and low in the back.

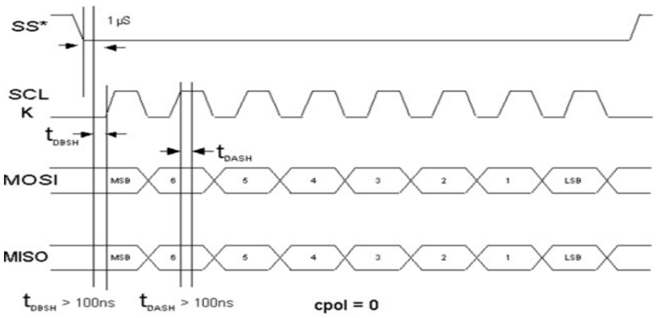

Fig.5. SPI Timing diagram interface of EC unit

EC unit communicates with Nios II soft core processor through RESET, DRDY two PIO control signal lines and SPI interface. A communication operation timing diagram is shown in Figure 6. After the EC unit is powered on, first pull chip select signal SSNOT low to activate the SPI communication interface. Then setting reset signal and set it to low lever after keep it more than 100 ns. The data acquisition channels, sampling period and sampling resolution of the magnetoresistive sensor are set by command word in the next 8 clock cycles. We can collect the EC data information of the selected channel after DRDY signal into a high level.

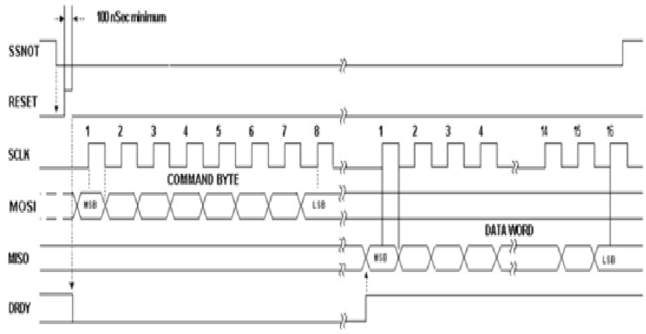

Fig.6. Data transmission sequence diagram of EC unit

D. The combination of ultrasonic and infrared range finders

In the serial mode, FPGA inputs 0X55 through Trig/TX pin in the baud rate of 9600. The ultrasonic ranging module US-100 outputs two bytes distance value to FPGA through Echo/RX pin. The output signal of infrared distance measuring sensors is analog voltage. We can acquire obstacle distance information in the program through transform by conversion chip PCF8591.

According to the principle of ultrasonic distance measurement and infrared range, we find that in the case of a long distance the precision of ultrasonic sensor is better than the infrared sensors. But in close distance, the measurement accuracy of infrared sensors is better than ultrasonic sensor. This is because the ultrasonic sensor collection data delay more time and length period. So we use ultrasonic sensors and infrared sensors to measure distance at the same time. According to the results of different measurement, choose different sensors' measured values as obstacle distance information.

Through the testing experiment find that when the detecting distance is within 250mm, ultrasonic ranging performance was disappointing and the more distance closer, the more error large. When the detecting distance is more than 250mm, the error of ultrasonic distance measurement is less than infrared distance measurement. So we use the distribution of observation weight method for the combination of sensor data. When the detecting distance is within 250mm, infrared distance measurement weights is 0.9, ultrasonic ranging weight is 0.1; when the detecting distance is greater than 250mm, infrared distance measurement weight is 0.2, ultrasonic ranging weight is 0.

E. The experimental of the system

In the experiment, in order to help the rescue workers take the suitable measure and strategy, detecting robot will need to collect information and returned to the host computer. The PC interface uses MFC which program by the Microsoft Visual C++ 6. Mainly used to display some information, such as latitude, longitude, temperature, obstacle, human body infrared and video, etc. We can control the car manually or automatically control by itself through the monitoring interface. There have a map to display the trolley real-time position and attitude through the monitoring interface in our design. And we can set the target point and the trolley route. The monitor interface of the detecting robot as shown in figure 7.

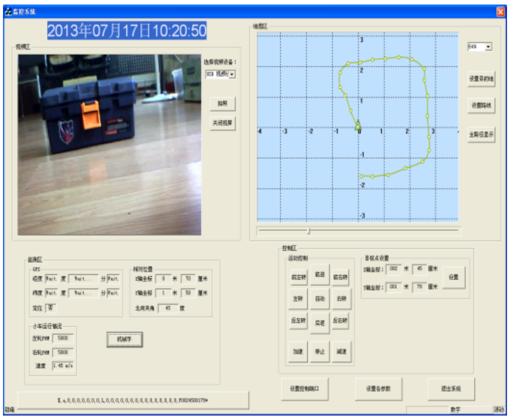

Fig.7. PC monitor interface

Detection robot will make course aimed at target point after initialization, then move toward the target. If robot encountered obstacles in the process of movement, it can quickly avoid then adjustment and continued move toward the target motion. We shielding the GPS module in the process of movement until the robot can reach the purpose area. Due to the target point is measured by GPS receiver, so there will have an error between the target point and the position where the robots eventually stop in the experiment. But after many experiments, found that the error is acceptable.

IV. Conclusions

The intelligent detecting robot in this system can move to the preset purpose area by its autonomous navigation. It can return reliable real-time environmental information after detection for the scene. Including image information and data information. Data information includes the current location of robot, heading angle, obstacle distance and temperature information. This information provides a reliable basis for detecting personnel, guarantee the completion of the rescue and rescue mission. Hence, this system has a great practical significance.

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