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A Research of Anemometer based on ARM and ZigBee

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Abstract

This project is a research of wind speed measurement system, with a high-precision, low-power, whose control core uses the Samsung S3C2410 32-bit microprocessor with high performance, low power consumption. The system adopts the LCD, and can display the current value of wind speed and wind direction which can be transmitted by ZigBee. The system can set up two limit of wind speed corresponding to two alarms, two relay outputs, and any configuration. The system has simple operation, eye-catching display, reliable performance, and can be widely used in meteorology, civil aviation, highway, construction, energy and other industries.

Keywords: *sensor, s3c2410, wind speed, wind direction, Zigbee*

1. Introduction

Wind as a natural phenomenon, it is one of the most important factors that affect climate change. It is full of a vast reservoir of energy, which can have a significant impact on human activities. Now, around the world is more and more attention to the observations of wind parameters. The measurement of Wind direction and wind speed is used to measure the instantaneous value of the local wind direction and wind speed, which can be used to compute the average wind speed, maximum wind speed, maximum wind speed and other data.

The measurement of Wind direction and wind speed can be widely used in meteorology (such as typhoon data to provide accurate reference data), the Civil Aviation (takeoff and landing to provide a reliable wind data), roads, bridges (for the construction of highways, bridges provide a basis), the new energy (wind power generation pre-wind data) and other industries and broad prospects.

The measurement of Wind direction and wind speed is composed of the sensor of wind direction and wind speed and data acquisition. The sensor of wind direction and wind speed converts the two physical of wind direction and speed to electrical signals. Data acquisition is used to process, compute, store electrical signals.

2. Design Principle and Characteristics of Wind Direction and Wind Speed Sensor

The sensor of wind direction and wind speed can be divided into three categories. First category is propeller wind direction and wind speed sensor; second one is the wind speed is three cups of type, wind direction and wing wind direction and wind speed sensor; the last one is ultrasonic wind direction and wind speed sensor. Propeller type wind sensor accuracy

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is poor dynamic performance; ultrasonic wind sensor applications are not very mature. Considering of the measurement of performance, reliability, price and other factors, this design uses three cups of wind speed sensor, the wing type wind sensor. The shape of the sensor is shown in Figure 1.

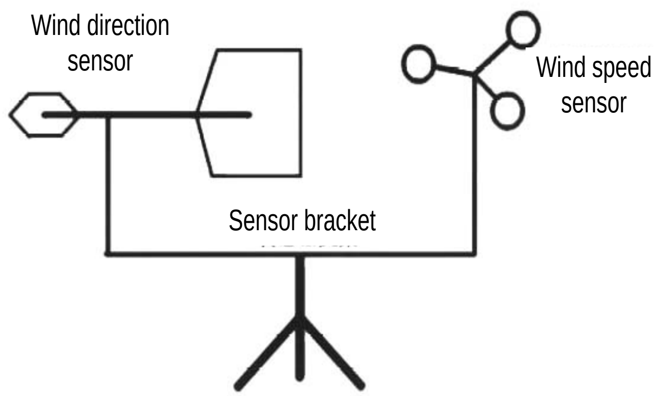

Figure 1. The structure of the sensor

Wind cup wind speed sensor working principle as follows: the sensing element of wind speed sensor is the three cups rotating frame, the signal conversion circuit is switching circuit for the Hall. Effecting on the horizontal wind, the wind cups rotates, then it drives the spindle to rotate the bar magnet plate which formats of 18 small magnetic field. The wind cups rotate a ring that can induce 18 pulses signal from the Hall switch circuit and the frequency increases linearly as wind speed. The calibration equation: V = 0.1F (V: wind velocity, unit: m / s; F: pulse frequency, Unit: Hz.).

The sensing element of wind direction sensor is called the wind vane components. Angular transformation adds photoelectric circuit to the Gray code disk. The shaft and the encoder rotate when vane components rotate. Every rotation of 2.8125 °, seven photoelectric conversion circuit located on both sides of optoelectronic devices produces a new seven parallel Gray code which can be inverted output by the shaping circuit. Sensor has advantages of the dynamic characteristics, good linearity, high accuracy, high sensitivity (3 °; 0.1 m / s), high (≤ 70 m / s) wind strength, wide measuring range (0 ~ 60 at m / s), mutual change, reliable, anti-lightning interference ability and many other excellent performance. Wind cup is maken of special plastic injection molding; wind vane tail board is maken of the quality of light, high strength, good rigidity non-metallic materials that formed of high temperature and pressure conditions. So, the sensor has excellent of light weight, good strength and strong wind resistance.

3. Hardware of Data Acquisition

The hardware circuit of data acquisition is cored of the measuring instrument to the wind direction and speed, which adopt with the mature, reliable technology. The data acquisition hardware consists of controller circuit unit (CPU), wind direction and wind speed interface circuit unit, the power conversion unit, a data storage unit, RS-232 communication unit.(Shown in Figure 2).

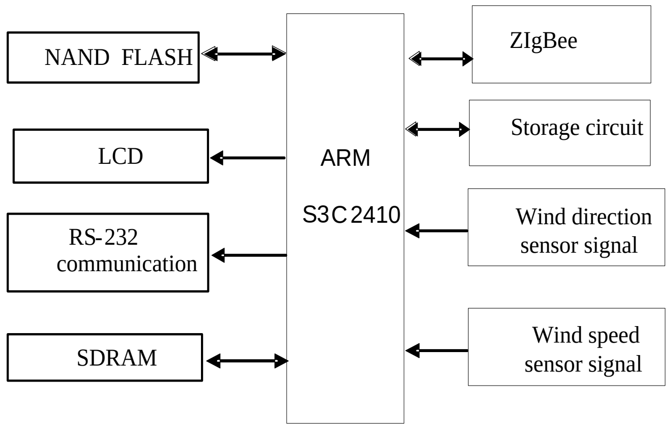

Figure 2. The structure of the hardware

3.1. The CPU S3C2410

In the system we choose the MCU S3C2410 which is made by SAMSUNG CO. This product is designed to provide hand-held devices and general applications with cost-effective, low-power, and high-performance microcontroller solution in small die size. To reduce total system cost, the S3C2410X includes the following components separate 16KB Instruction and 16KB Data Cache, MMU to handle virtual memory management, LCD Controller (STN & TFT), NAND Flash Boot Loader, System Manager (chip select logic and SDRAM Controller), 3-ch UART, 4-ch DMA, 4-ch Timers with PWM, I/O Ports, RTC, 8-ch 10-bit ADC and Touch Screen Interface, IIC-BUS Interface, IIS-BUS Interface, USB Host, USB Device, SD Host &Multi-Media Card Interface,2-ch SPI and PLL for clock generation. The S3C2410X was developed using an ARM920T core, 0.18um CMOS standard cells and a memory complier. Its low-power, simple, elegant and fully static design is particularly suitable for cost- and power-sensitive applications. It adopts a new bus architecture called Advanced Microcontroller Bus Architecture (AMBA). The S3C2410X offers outstanding features with its CPU core, a 16/32-bit ARM920T RISC processor designed by Advanced RISC Machines, Ltd. The ARM920T implements MMU, AMBA BUS, and Harvard cache architecture with separate 16KB instruction and 16KB data caches, each with an 8-word line length.

By providing a complete set of common system peripherals, the S3C2410X minimizes overall system costs and eliminates the need to configure additional components.

3.2. Interface Circuit unit of Wind Direction and Wind Speed

The output characteristics of Wind direction and wind speed sensor as flow: the wind 7 Gray code, the wind speed for the pulse-frequency signals. Interface circuit provides 5 V DC power for the sensor. Wind speed pulse is through the interface unit of the RC filter, Schmitt trigger shaping, and then sent to the counter of 74HC393 to count. Wind 7 Gray code level signal is driven by the interface circuit 74HC245 plastic to control circuit unit. Winds Gray code can be computed into the instantaneous wind direction data by CPU.

3.3. The Data Storage Unit

In order to meet the demand for data storage, circuit design extends a data storage circuit that is used to store data of wind direction and wind speed. The data is contained Average wind direction and wind speed, maximum wind direction and wind speed, great wind direction and wind speed and the space occupied by the extreme time. A record occupies of 15 bytes and is stored every 10 min. So one day it stores about 2160 bytes of data. The design storage capacity is up to 30 days of data, 2160 × 30 data storage capacity is about 64 k bytes. Therefore the need to expand data storage capacity is above of 64 kB. The final design is used the AT29c010 to achieve function. The AT29c010 the data capacity is up to 128 k bytes, which can store data for more than 10 years. These properties suggest that the chip meets the circuit design requirement.

3.4. The Power Conversion Unit

The main function of the power conversion unit provides the power of 10 ~ 14 V DC control circuit unit, wind direction and wind speed interface unit, wind direction and wind speed sensors, a data storage unit, the power supply voltage needed by the RS2232. The design uses MAX738. The MAX738 is a PWM type DC / DC module, the switching frequency can reach more than 200 kHz. Chip input voltage is 18 V DC, output voltage is 5V DC ± 5%, the maximum output current is 500 mA, the efficiency can reach more than 85%. The MAX738's peripheral circuit is very simple, which only several capacitance and inductance can complete the function. The design requirement meets in the system.

3.5. The RS-232 Communications Unit

CPU chip with SCI interface adds an RS2232 driver chips, it can be completed RS2232 standard communication interface circuitry. The design uses MAX232 to complete this function. The MAX232 is designed specifically for EIA / TIA - 232E communication interface, no external ± 12 V power supply, no external components, reducing the board area. MAX232 as for low voltage, the internal integration ± 15 kV ESD protection, low power, high speed (up to 1 MBps) RS2232 driver chip is a high cost performance. It is fast and reliable transmission of data. The Circuit of RS-232 is shown in Figure 3.

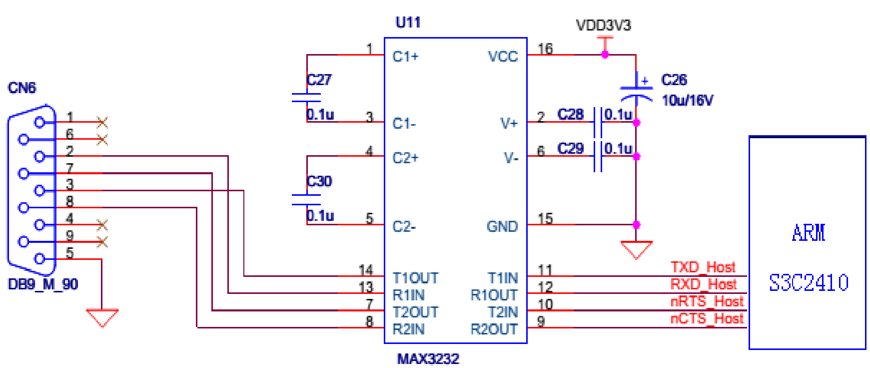

Figure 3. The Circuit of RS-232

3.6. ZigBee module

In the wireless transceiver module system we use the CC2430 chip which is made by Chipcon Company in November 2003. The chip answers for IEEE802.15.4 agreement with the 2.4 GHz band, and provides packet processing, data buffering, pulse transmission, data encryption, data identification broadcasting channel access, connectivity and reliability of packet timing information support. These features reduce the load of the MCU, and the CC2430 adopts the SPI interface connecting the MCU.

The CC2430 uses a 7 × 7 mm QLP-48-pin package, and can be carves up three modules according to their function, they are receiver circuit, transmitting circuit and communication circuit, we requires only minimal external components, and its use can be realized. The circuits are introduced as follows:

Receiver circuit: Low noise receiver circuit includes amplification, frequency conversion, filtering, A/D converter, automatic gain control, digital demodulation and the final restoration of the transmission to the correct data. The data received by the CC2430 will be stored in the receiving Storage (RXFIFO, and the total of 128 Bytes), and the SPI interface users can read the data in the RXFIFO.

Transmitting circuit: Transmitter is based on the direct up-conversion, when the microprocessor data will be sent through the SPI interface to the transmitting memory (TXFIFO, and total of 128 Bytes), the precursor code and initial frame is automatically generated by the hardware. According to the IEEE802.15.4 standard, every four bit data whose spectrum is spread by the 32 yards Spread Spectrum Sequence is send to the D / A conversion, and then to the low-pass filter. And finally the RF signals are eventually modulated to 2.4 GHz, and be amplified to launch.

Communication circuit: The CC2430 is installed by the MCU through 4-wire SPI Interface (SI, SO, SCLK, CSn), and the interface is also used to send and receive data read and write. The CC2430 has thirty-three state 16 bit-registers and fifty orders registers and two 8 bit-registers used to access and receive RXFIFO and sent TXFIFO.

The typical application circuit of CC2430 that we use in the system showed in the Figure 4.

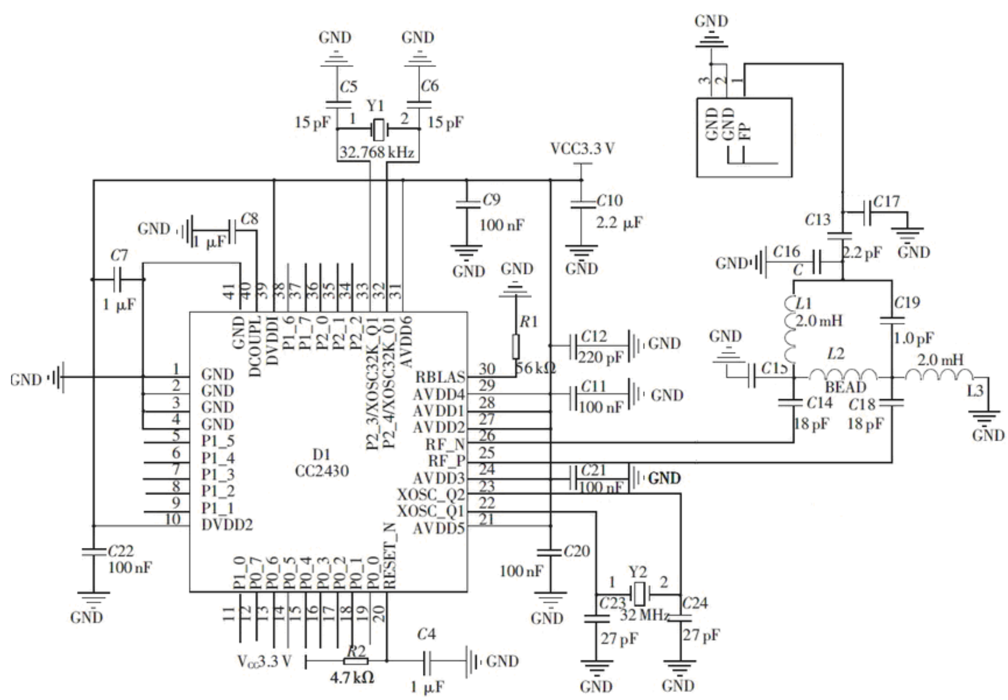

Figure 4. Typical application Circuit of CC2430

4. Software Design

4.1. Wind Speed Data Sampling and Processing

The wind speed value acquires one time every 100 ms and continues to the accumulated total of 1 s. The arithmetic mean calculated for 1 min wind speed sliding (the data operation per second) and each 10-min wind speed sliding arithmetic (1 min average data operation). Then selects of a maximum of 10 min average wind speed and a time, it is the maximum wind speed. Meantime selects of the maximum gust wind speed and a time; it is the maximum wind speed.

Sampling algorithm:

Use the following general formula, for different values of N calculates average wind arithmetic for 3 s, 1 min, 10 min.

$$Yn = (\ \Sigma y_n) / N \qquad n \leqslant N$$

$$Yn = (y_n - y_{n-N}) / N + Y_{n-1} \qquad n > N$$

Yn for n times the arithmetic mean; y_n for n-th sampling value; Σy_n for n = 1~n sum of y_n; N for the number of samples of the average range.

The method for calculating 3 s, the average wind direction, wind speed (wind direction, wind speed and instantaneous values) is adopted of a step of 1 s to calculate the arithmetic mean of three sample values in the 3 s. N = 3. Wind adopted of 1 s step, the moving average method to calculate the instantaneous value of the arithmetic mean of three sample values within the 3 s, wind observations. N = 3.

1 min average wind direction, wind speed calculated in 1 s in steps of the moving average method to calculate the arithmetic mean of 60 samples within 1 min, is the wind speed observation of 1min average. N = 60. 1 s step, the moving average method to calculate the arithmetic mean of 60 samples within 1 min, which is 1min average of the wind observations. N = 60.

10 min average wind direction, wind speed calculation method 1 min step length, the moving average method to calculate the arithmetic mean of 10 within 10 min 1 min average wind is 10 min average wind speed observations. Take N = 10. The wind had zero processing method of calculation: $E = yn - Yn - 1 - 180° \leq E \leq 180°$, the wind do not need to have done zero processing; if E> 180 ° E, from minus 180 °; if E <- 180 °, then E plus 360 °; Yn values calculated with this value of E, if Yn> 360 °, then Yn minus 360 °; if Yn <0 °, Yn plus 360 °.

4.2. Data Quality Control

According to the level of quality, the data acquisition adopts to control techniques of data quality for reading the value of the wind speed and wind direction. The method of controlling data quality is as follows:

(1) Checking Questionable value

The purpose to check is whether or not the value is in the acceptable range. Each sample should be checked and its value in the associated sensor measurement range. If the sample value is not within the range, it should be discarded. And can not be used calculate the relevant parameters in the subsequent.

(2) Checking the suspicious change rate

The purpose of inspection is to check the rate of change value. This method is most suitable for testing high resolution of the sample which is close correlation.

The current sample compares with the previous sample that the difference is greater than a specific value; the current value should be treated as suspicious and can not be used to calculate the average value. However, it can still be used to check the consistency of the sample. This means that a new sample can still be tested by suspicious samples. Then its result is to produce a relatively large noise. One or two of the samples can not be used for calculation of the average. Assuming the number of samples generated five to ten per minute (The interval time of sample generated is to 6 ~ 12 second). The time limits (absolute) of sample should follow as the principles:

Wind speed: 20 m/s;

Wind speed and wind direction: there should be at least 75% of the sample that can be used to calculate the average value for 10 minutes. If the samples used to calculate the instantaneous value are less than 66%, the current value will not pass the standards of controlling quality. The relevant parameters can not be used to calculate in the subsequent, this value should be marked as missing one.

4.3. Storing Data

Data collection is used to store the data of wind direction and wind speed. The data memory shall have saved feature for the power-down, and can be read all stored data and information in the field.

4.4. Alarm

The acquisition provides a variety of alarm, the trigger conditions include the following: The main logger software has the strong winds alarm function, the system can achieve two alarm.

After the start of the first alarm, if the wind speed continuous below the first level of alarm for 15 min, and then send a report; if the wind speed is below the first level alarm 20 min, and then issued the alarm.

After the start of the second-level alarm, if the wind speed continuous below the first level of the alarm value for 20 min, then send a report; if the wind speed continuous below the first level alarm 25 min, then disarms the alarm.

Once the Alarm message is issued, which is waiting business processing system to read the alarm data. If no response, it will transmit the alarm message again after 1 min. It does not disarm the alarm until a response is received. Alarm message is issued, if the business processing system does not read the alarm message within 3 min or a new alarm occurs, and then the alarm message will be saved to the wind alarm file. When alarm business processing system reads the alarm data that is issued more than one, it will be issued one by one in chronological order.

The main program flow chart of software is shown in Figure 5.

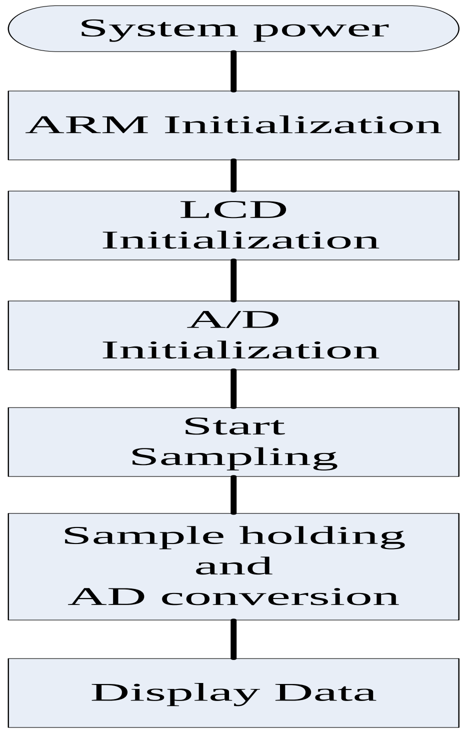

Figure 5. Software flow chart

5. Test results

The anemometer developed in this paper has been using actual measurement; the result is shown that it has high measurement accuracy within 0-60 m/s. Measurement data is shown in Table 1 and Table 2. The data tested show that measurement range is expanded and errors are within the allowable range.

Table 1. Measuring data of wind speed (0~ 30m/s)

Wind speed (m/s)	Measuring data(m/s)	Absolute error(m/s)	Wind speed (m/s)	Measuring data(m/s)	Absolute error(m/s)
0.1	0.1	0.0	16.0	16.0	0.0
0.4	0.4	0.0	19.6	19.6	0.0
0.8	0.8	0.0	21.0	21.0	0.0
1.4	1.4	0.0	23.8	23.8	0.0
1.8	1.8	0.0	24.2	24.2	0.0
2.0	2.0	0.0	25.0	25.0	0.0
2.6	2.6	0.0	26.0	25.9	0.1
4.0	4.0	0.0	27.6	27.5	0.1
6.0	6.0	0.0	28.0	27.9	0.1
8.0	8.0	0.0	29.5	29.4	0.1
12.0	12.0	0.0	30.0	29.9	0.1

Table 2. Measuring data of wind speed (30~ 60m/s)

Wind speed (m/s)	Measuring data(m/s)	Absolute error(m/s)	Wind speed (m/s)	Measuring data(m/s)	Absolute error(m/s)
30.1	30.0	0.1	46.0	46.1	0.1
30.4	30.3	0.1	49.0	48.9	0.1
30.8	30.7	0.1	51.0	50.8	0.2
31.4	31.3	0.1	53.0	53.2	0.2
31.8	31.7	0.1	54.0	54.2	0.2
32.0	32.0	0.1	55.0	54.9	0.1
32.6	32.6	0.1	56.0	55.9	0.1
34.0	34.1	0.1	57.0	56.8	0.2
36.0	36.1	0.1	58.0	57.7	0.3
38.0	37.9	0.1	59.0	59.7	0.3
42.0	42.0	0.0	60.0	57.6	0.4

6. Conclusion

The design of anemometer provides reliable parameters of wind speed measurements will serve large industrial and mining enterprises for adjusting equipment to provide reliable measurement parameters of wind speed, which can serve agriculture, weather station and other services. Relation different enterprises, the wind speed measurement of intelligence will greatly support equipment safety, increase production efficiency.

The control core of the design uses S3C2410, a low-price, low-power, high-performance, and high-processing speed(up to 200 MHz to 266 MHz) ,which provides a wealth of internal equipment, reduces the external devices of design and makes the design more conveniently and concisely for consumer. And we remain a lot of interface to extern the other external equipment such as video camera that can take the photo of the coating at some time. It is appropriate to be used in many fields.

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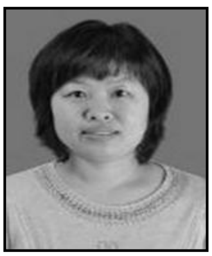

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