ISSN : 0974 - 7435 Volume 10 Issue 23

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(23), 2014 [14600-14605]

The research of CO_2 concentration monitoring system based on USB technology

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ABSTRACT

According to China's actual conditions, which mean comparatively poor economic conditions of farmers and the weak infrastructure in countryside, the controller, with lower cost and better performance, has been developed in order to enhance the level of greenhouse production management and automation. The main design feature of this system is to gather the information of CO_2 concentration, through the analysis and comparison between the collected parameters and system setting. When the collected parameters do not conform to the requirement, through opened or closed of the control module to achieve the automatic adjustment of CO_2 concentration in greenhouse. At the same time, this system chooses the USB interface chip CH375B which supports Host way and Slave equipment way. Insert U disk in the USB port, we can take the information of CO_2 concentration gatherer, collecting site, collecting time and so on for the form of TXT at any time, kept and extracted data conveniently, giving the staff bring greatly facilitate to take date in different environmental conditions

KEYWORDS

CO_2 concentration; USB; CH375B; Automatic control.

INTRODUCTION

The basic conditions for survival of plants are water, sunlight and carbon dioxide. According to the determination of carbon dioxide in air is about 0.03% (300-500 ppm). Cultivated in the open air, the plants to absorb carbon dioxide in the air at will. In winter closed in Green House, in order to maintain a certain Temperature, can not a lot of ventilation, and air is difficult to exchange outside the greenhouse, plants absorb carbon dioxide every time, resulting in lower threshold of s carbon dioxide concentration in greenhouse, so that plant physiology response to the unbearable life insurance in the state, cannot grow normally. Especially in the daytime, the sun came out, crop chlorophyll cells to carry out photosynthesis, light up to 1000-3000 LUX, crop start absorb carbon dioxide in large quantities, in this period, carbon dioxide from the atmosphere cannot be added in time, Plants stop the photosynthesis due to the lack of carbon dioxide plant , the result is bound to affect yield and quality long time , It is proved that CO_2 concentration increase has become a limiting factor in greenhouse, so the need to manually replenish the CO_2 concentration is very important., the key to high and stable yield. However, need to be noted that there is a saturation of carbon dioxide for plants, when the carbon dioxide concentration too high, stomata will close portion, so that affected photosynthesis. Therefore, the precise control of CO_2 concentration on the promotion of plant growth and development is great significance. [1]

Currently the detector of carbon dioxide in domestic market generally have the function of measurement data, real-time display, data storage, set the acquisition parameters by PC, PC online processing collected data. Haven't Integrated control functions and the communications technology of host computer and detector mostly use RS232, limiting the flexibility and portability of the detector, so this design was developed mainly for fill the gap of the defects of carbon dioxide based on USB technology concentration monitoring system. The system uses the MSP430F149 microcontroller as a core control chip, through the USB interface chip CH375B [2] can not only set the recording parameters and read the data from the computer, but also can set the acquisition parameters and extract any data ,automatically storing data to TXT files without computer. Also has intelligent monitoring, through a comprehensive comparison of CO_2 concentration, the use of fuzzy control algorithm for greenhouse CO_2 concentration adjustment.

OVERALL DESIGN OF SYSTEM

This system detected the concentration of carbon dioxide in the greenhouse, through the automatic acquisition and intelligent control, data was stored into the permanent memory directly; can achieve 24 hours uninterrupted real-time monitoring and effective control. Main functions are as follows:

(1) Automatically collect carbon dioxide in the air and light intensity by Carbon dioxide sensor.

(2) Show the time and the system configuration and other information collected by sensor real-time.

(3) Through the key module set the concentration of carbon dioxide, the upper and lower limits of light intensity, the interval parameter of data storage.

(4) Carbon dioxide density, illumination, time, system disposition and so on carry on the classification to save, are advantageous for the user examination historical data.

(5) Via USB-Slave (USB device mode) computer can set or achieve carbon dioxide concentrations and illumination settings and data acquisition parameters extraction.

(6) Turn on carbon dioxide generator for the plant to provide high concentrations of carbon dioxide base on the carbon dioxide concentration and light intensity, when the concentration reaches a certain level, close the carbon dioxide generator.

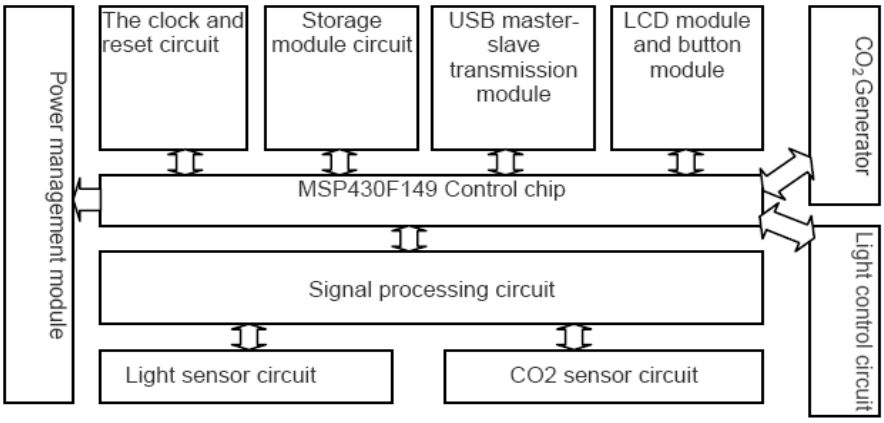

Figure 1 : The system hardware structure

MAJOR FUNCTION MODULE DESIGN

Low power system design

The system selected MSP430F149 as system microcontroller chips. CPU contains a 16-bit register is used to reduce instruction, operations between registers and register Can be completed in one clock cycle. CPU is rated operating current is 0.1 ~ 400μA, rated voltage of 1.8 ~ 3.6V, wake up from standby mode to Wake-up mode less than 6μS, start more quickly. At the same time enriches interrupt ability reduced the inquiry need; Suitable for the work situation which needs long time power supply. The chip has Multichannel, high-speed A / D converter module (ADC12), multiple timers and PWM function, multiple I/O has a rich interrupt capability. Manchester in-house data encoding, decoding, encoding and decoding microprocessor does not need to develop rules, to realizing the miniaturization and low-cost nodes [3-4]. For most environment need collect concentrations of carbon dioxide, can satisfy the requirements.

Acquisition circuit design of CO_2 concentration

The system uses a solid electrolyte type carbon dioxide sensor MG811, which is based on the principle of solid electrolyte batteries made of gas sensors. The device filled with cation solid electrolytes between the electrodes. It is the cathode of lithium carbonate, and gold-plated material, and only gold-plated anode material, with stainless steel net to do the column size package. [5] In order to reduce the impact, MG811 is filled with adsorption material between the inner and outer layers of stainless steel mesh. Sensor 6 pin through the foil 0.1mm wire connected to others. The 6th pin attached to the anode and the cathode connected to pin 1, Pt heaters connect to the 2nd, 5th pin, the internal thermal resistance and the sensor is connected with 3rd, 4th pin. The hardware circuit diagram is shown in figure 2.

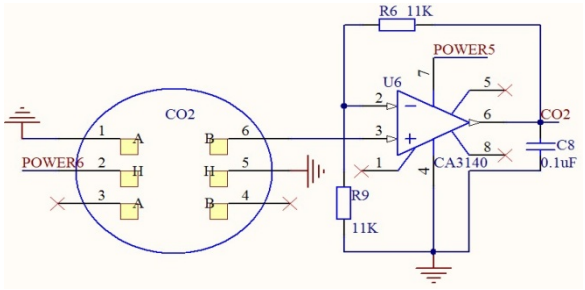

Figure 2 : CO_2 concentration acquisition module hardware circuit

At a certain temperature, when the sensor placed under test atmosphere, the solid electrolyte battery electrode react, the sensor sensitive electrode and reference electrode potential difference between the Nernst equation found by measuring the output voltage signal across the sensor to achieve detection of gas concentration.

When the device exposed to carbon dioxide it will have the electrochemical reaction, the reaction is as follows:

Negative pole : $2Li^+ + CO_2 + 1/2O_2 + 2e^- = Li_2CO_3$ (1)

Positive pole : $2Na^+ + 1/2O_2 + 2e^- = Na_2O$ (2)

The total electrode : $Li_2CO_3 + 2Na^+ = Na_2O + 2Li^+ + CO_2$ (3)

The potential difference between sensitive electrode sensor and reference electrode (EMF) to conform to Nernst equation:

$$EMF = Ec - (R \times T) / (2F) \ln (P(CO_2)) \quad (4)$$

P (CO_2)—The CO_2 partial pressure
Ec—constant
R—gas constant
T−Kelvin（K）
F—Faraday constant

Based on the properties of the better linear relationship between EFM and the concentration of CO_2, as shown on (4), the concentration of CO_2 can be measured by the value EMF that is produced by monitoring between the positive and negative instead of the absolute value of EMF.

△EMF cannot be affected by the range of temperature between -10℃～+50℃, even if the absolute value of EMF is increased with temperature, and then △EMF is constant.

△EMF= EMF1- EMF2 (5)

EMF1—350 ppm of carbon dioxide in the EMF values;
EMF2—the EMF value of the measurement of carbon dioxide.

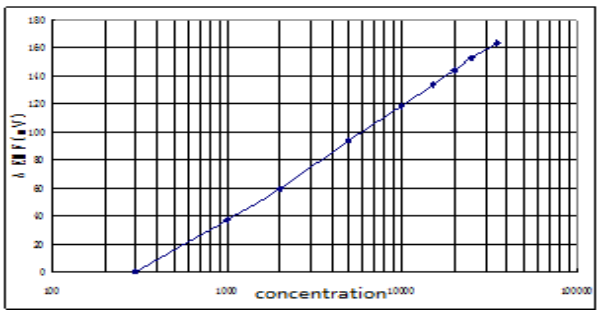

Figure 3 : The relationship between CO_2 concentration and delta ΔEMF 4 Tables

USB interface module design

The system selected CH375B as interface chip; the chip supports Host mode and Slave mode device, which integrates PLL frequency multiplier, USB Interface Master SIE, data buffer, passive parallel interface, asynchronous serial interface, command interpreter, Protocol Processor witch control transmission, and Generic firmware program and so on. By the USB-Host interface, 8K cache 6264, and the FAT file system embedded in MSP430F149 [6], to achieve the set acquisition parameters, carbon dioxide concentration, light intensity and other data and extract collectors, collection sites , acquisition time and other information, and stored in U disk as TXT file. When the recording time or memory is full, the data automatically stored into the U disk, away from the conditionality of depend on computer.

By the USB-Slave PC could set parameter of achieve the concentration of carbon dioxide and data extraction. Just connect the system with the computer can display on your computer in real time parametric curve, the collected data can be stored as EXCEL file to facilitate the users to save and process the data.CH375B has 8 bit data main lines and reads, writes, selects patches and interrupt out, could connect on integrated circuit /DSP/MCU system buses conveniently. In the computer system, the software builds with CH375B provided Simple and easy to use operation connection, is similar to the read-write hard disk's document when communication with the local microcontroller. CH375B is built-in USB communication lower protocol, therefore, when use CH375B, you do not need to understand any USB agreement or the firmware program, design the USB connection product just need to call drivers[7]. Hardware schematic diagram is shown in Figure 4.

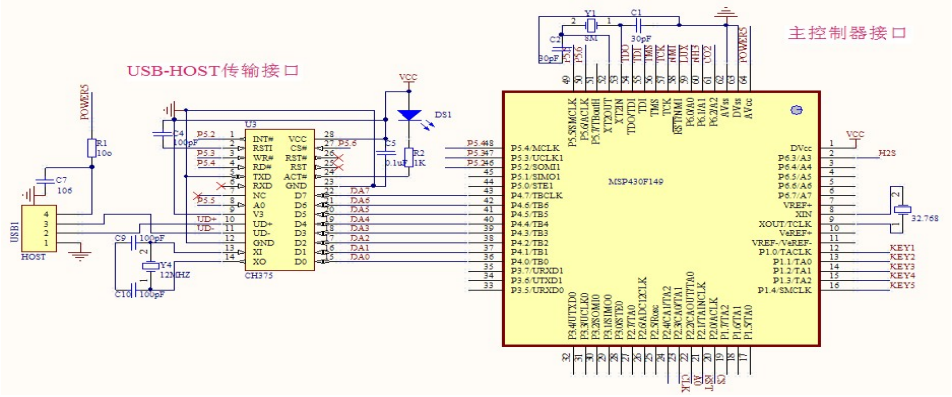

Figure 4 : USB hardware principle diagram

Illumination acquisition circuit

The system uses the principle of photodiodes short-circuit current and light intensity was proportional linear relationship, the light intensity signal is converted to analog current signal, and then converted to a voltage signal, through the "analog-digital conversion circuit" converted to digital signal ,able to be processed by microcontroller. Light collection module circuit shown in Figure 5.

The instrument used to measure the object witch near the peak wavelength of visible light at 540nm, using silicon photodiode 2DU6 and high input impedance of the OP777 op amp design "current-voltage conversion circuit", the short circuit current Isc amplified photodiode converts the analog voltage 0-5V U0. 2DU6 external circuit connection for zero bias voltage, that is no voltage across the diode optical source, when there is light exposure to the 2DU6, in the 2DU6 very near the surface of the internal P to stimulate the electron - hole pairs (photo carrier), stimulate the electron-hole pairs,

respectively, including the electric field to the N-type drift region and P-type area, when the PN junction at both ends of short (RL = 0), the photo-voltage close to zero, flow short-circuit current across the PN junction formed by the OP777 "current-voltage conversion circuit," Zoom into 0-5V analog voltage.

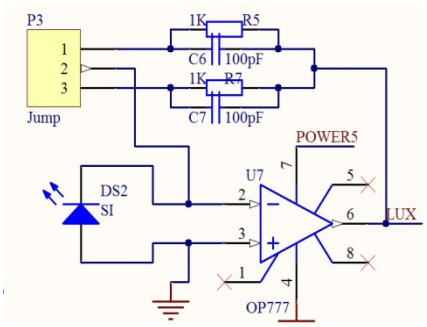

Figure 5 : Illumination acquisition circuit

This voltage "A/D conversion module" transforms into [0,255] after the MSP430F149 integration the digital signal to send in the monolithic integrated circuit P0 pin, the digital signal may obtain the illuminance size in MSP430F149 after the return to original state computation, may realize different scope illuminance gathering

This voltage is sended in the P0 pin, after transformed into [0,255] by the "A/ D conversion module" of MSP430F149, the digital signal obtain the illuminance size in MSP430F149 after the return to original state computation, realize different scope illuminance gathering.

THE DESIGN OF SYSTEM SOFTWARE STRUCTURE

Control flow of carbon dioxides

The CO_2 concentration and the light intensity in greenhouse are controlled by CO_2 and light parameters from the sensors .Control functions are as follows:

1. Through the button module set carbon dioxide concentrations accord the characteristics of plants. Select as the following table:

2.Through the key module Settings upper and lower limit for plan needed plant light intensity of t light compensation points, lower limit is light compensation point, upper limit is light saturation point of plants (normally, illumination achieve 1000-3000LUX, plant begins a large number of absorbing carbon dioxide).

3. The acquisition of carbon dioxide concentration and light intensity compared with the set value:

a) When the light intensity higher than the lower limit, and the same time carbon dioxide concentrations below the set conditions, CPU will control the start of carbon dioxide generator, increase the concentration of carbon dioxide greenhouse. When carbon dioxide concentrations are higher than set conditions, the carbon dioxide generator will be off. b) When the light intensity below the lower limit, CPU will control the turn on incandescent circuits to improve the light intensity inside the greenhouse, when higher than the set lower limit, the detection of carbon dioxide concentration set point, follow step1, when the light intensity above the set upper limit, the control circuit off incandescent.

TABLE 1 : Typical needed for plant growth in different periods of CO_2

Cultivar	*seedling stage (ppm)*	*flowering period*	*fruiting period*	*Fruiting peak period (ppm)*
cucumber	1500	2500	3500	4500
pepper	1500	3000	3800	4600
Zucchini	1000	2000	2800	3500
watermelon	1500	2600	3700	4800
tomato	1200	2200	3400	5100
kidney bean	900	1800	2400	3300
potato	1800	2900	4200	3800
strawberry	1200	2600	3600	4600
grape	1400	2800	4100	5500

In system software design, follows the following three principles: The software architecture is clear, the flow is reasonable and succinct; each function modulation, is advantageous for the management and maintenance; the procedure execution controlled through scans the flag bit by the timer interruption [8]. The monolithic integrated circuit repositions carry

out the initialization when power up and reset, then enters idle mode, waited the timer interruption scanning's flag bit, if the flag bit is 1, judges the pressed key and the connection condition, call the corresponding module function. Completes the parameter establishment and store, start luminance gathering procedure, stores the data into FM31256, at the same time LCD to demonstrate, when presses down Start-stop button or the memory record is full, and when the USB storage device inserts, luminance, acquisition time, gather, Sampling site and so on stored into USB storage device according to a certain form If connect the instrument with computer, the parametric curve could be displayed on the computer real time, may to the gathering data storage also could be saved as Excel files, Facilitate the users to save and process data.

Data transmission and analysis

By data analysis can display the recorded data, PC could read the data in detector or data stored on the U disk real-time, and generate Excel files, get the maximum, minimum, average and variance of illumination in arbitrary measurement periods, and draw the light curve. Can check carbon dioxide concentration and light intensity values of any time, analyze the results and save, or print out.

CONCLUSIONS

The system based on USB technology of carbon dioxide concentration monitoring with automatic acquisition carbon dioxide concentrations and illumination intensity information, and through the conditional set realize adjustment of carbon dioxide concentrations and light intensity in greenhouse, conditional values set by the user according to need. Could gathering parameters without PC, real-time Settings, automatic control and data transmission, also can connect to the PC on-line detection and real-time processing, Convenient for data extracting in different conditions, and the Data are reliable , high precision and convenient to use.

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