Design of Solar Charger in Agricultural Monitoring Device

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Abstract -- **Agricultural monitoring devices are electrically powered, but agricultural areas are broadly spread out geographically where electricity supply is not often available, hence the need for solar charger is clear. In this paper polycrystalline silicon solar energy cell boards are designed to be controlled through a LM2596 switching regulator modules. Output voltage and charging status from a Holzer current sensor are detected by using SCM STC89LE52RC and analogue-to-digital conversion chip ADC0832. The collected data are processed and displayed on an LCD screen. Experimental tests show that the charger can be used for normal USB charging, real-time voltage and current parameters are displayed on the LCD during charging, at the start and finish with interim state of charge indicated through the LED.**

Keywords -- ***Polycrystalline silicon solar energy cell board; Single Chip Microcoputer; Charger; liquid crystal display.***

I. INTRODUCTION

Agricultural monitoring devices are generally inactive, the device is in a sleep state most of the time with very little power consumption. Solar energy is very rich as a renewable source [1,2,3], the use of solar energy for agricultural monitoring devices saves electricity and the cost of wiring, as well as avoiding the risk of outages which can paralyse the system, hence the use of solar energy for agricultural monitoring devices is feasible and desirable.

II. THE GENERATION PRINCIPLE OF SOLAR BATTERY

Sun light is absorbed through the solar panel, solar radiation is converted directly or indirectly into electricity using the photoelectric effect or photochemical effect [1]. Solar cell devices respond to light and convert the energy of sunlight into electrical energy. There are many kinds of materials which can produce photovoltaic effect, such as: monocrystalline silicon, polycrystalline silicon, amorphous silicon, copper indium selenium, gallium arsenide power, etc., they have the same basic principles. Now on the light power generation process is described with crystal silicon as an example [2].

Phosphorus can be doped in the P type crystal silicon in order to obtain the N type silicon, thus the P-N junction is formed. The new hole electron pairs are formed when the sun light in the semiconductor P-N junction, the hole flow from the N area to P district, electrons flow from the P area to N district under the P-N node action of electric field, and current is formed when the circuit switched on, this is the working principle of the photoelectric effect of solar cell.

When light irradiates the surface of solar cell, silicon material absorb a part of photon, the photon energy transfer to the silicon atoms, It make the electronic transitions become free electrons, the potential difference was formed in P-N junctions. When the external circuit is switched on, there will be a current flowing through the external circuit to produce a certain output power under the action of the voltage, the essence of this process is: the photon energy conversion into electrical power.

III. DESIGN OF THE HARDWARE

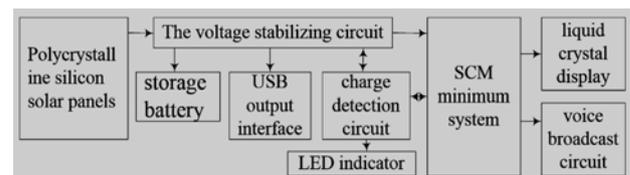Solar charger schematic diagram shown in Fig.(1).

Fig. (1). Solar charger schematic diagram

It comprises a solar panel, storage battery, USB output interface, a voltage stabilizing circuit, SCM(Single Chip Microcomputer) minimum system, charge detection circuit, liquid crystal display, LED indicator, voice broadcast circuit, etc..

A. The solar battery panel

The solar battery board is divided into crystalline silicon panels, amorphous silicon cell board, chemical dyes panels, flexible solar panels. The crystal silicon cell plate is divided into single crystal silicon solar panels and polycrystalline solar panel. The photoelectric conversion efficiency of monocrystalline silicon solar cell is about

15%, sturdy and durable, the service life of up to 15 to 25 years, but the production cost is big,it can not be widely used. The production process of polycrystalline silicon solar panels are basically the same with single crystal silicon solar cell board, the photoelectric conversion efficiency is about 12%, the production cost is cheap, the material is simple, saving power consumption, the total cost of production is relatively low, so from the price, polycrystalline silicon solar energy cell board is slightly better than the single crystal silicon solar battery board[3]. This design uses polycrystalline silicon solar panels.

Solar panels include toughened glass, EVA (ethylene-vinyl acetate copolymer), battery plate, back plate, aluminium alloy protective laminate, wiring boxes, silica gel, etc.. Toughened glass's role is to protect the power subject (such as battery piece), require high transmittance (more than 91%), super white steel processing. EVA is used to bond the fixed glass and power generation subjects (such as battery piece), bond package power main body and the back plate. The main function of battery plate is to generate electric. The backplane is the role of sealing, insulation, waterproof (generally used TPT, TPE and other materials), it must be resistant to aging. Aluminium alloy protective laminate seals play a supporting role. The junction box protect the entire power system as a current transfer station role. Silica gel is the role of the seal, which is used to seal assembly with aluminium alloy frame, assembly and wiring box junction.

In order to estimate the parameters of solar photovoltaic products, if it is used for 5 hours a day and the output power of 100W. First, power consumption is calculated every day (including the loss of inverter): if the conversion efficiency of the inverter is 90%, when the output power is 100W, the output power of the actual needs should be:

$$P = 100 \div 90\% = 111 \text{ (W)} \tag{1}$$

If 5 hours per day is used, then the power consumption E is:

$$E = 111 \times 5 = 555 \text{ (Wh)} \tag{2}$$

Secondly, Solar panel output power: the assumption that the daily effective sunshine time is 6 hours, charging efficiency and loss during the charging process are considered, the actual use of the process of charging the solar battery board rate is about 70%, the output power of the solar panel:

$$P = 555 \div 6 \div 70\% = 132 \text{ (W)} \tag{3}$$

The final choice of charging controller and battery: The maximum output current of the 132W solar energy cell board is 7.7A, so the charging current of the charge controller should be at least 8A.If the 12V battery is used, the depth of discharge is 50%, then the capacity of the battery should be:

$$C = 555 \div 12 \div 50\% = 92.5 \text{ (Ah)} \tag{4}$$

If 24V battery is selected, then the capacity of the battery should be:

$$C = 555 \div 24 \div 50\% = 46.3 \text{ (Ah)} \tag{5}$$

Estimation and detection of solar energy cell: the rated power output of the solar cell has a relationship with the conversion efficiency, the conversion efficiency of the battery components per unit area is high, the output power is bigger. The conversion efficiency of solar cell is in commonly 14～17%, the output power of the battery piece per square centimeter is 14～16mW, solar cell module output power per square meter is about 120W. The basic calculation formula is:

$$P = VI \tag{6}$$

In formula (6): P indicates power, V indicates voltage, I indicates current.

The use of energy consumption is:

$$E = P \times t \tag{7}$$

In formula (7): E indicates energy consumption, P indicates power, t indicates time.

B. The Design of Voltage Stabilizing Circuit

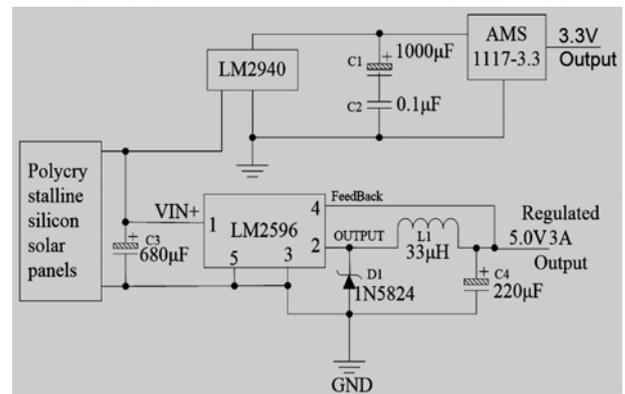The design of voltage stabilizing circuit shown in Fig.(2).

Fig.(2) . The voltage stabilizing circuit

Due to the electrical charging part circuit access (USB load) moment will have a larger current change, it will have a certain impact on the MCU system, in order to guarantee the stability of the system, the power of the interference to a minimum, LM2940 is used after stabilizing to supply system power separately , LM2940 is linear three terminal regulator which have a fixed and low voltage output, it compared with LM7805 of the traditional ST 78 series voltage stabilizing chip, LM2940

have lower voltage difference of input and output, conversion efficiency is higher, in good heat dissipation condition, rated output current can reach 1A, when the output current is 1A, the minimum voltage difference of input to output is less than 0.8V; and the maximum input voltage is 26V; working temperature is -40 to +125℃; it contains static current reduction circuit, current limit, overheat protection, reverse connection of power supply and load inverse insertion protection circuit, it can be protect the safety of controlling circuit effectively when the solar battery board reverse connection.

LM2596 is used in the power supply of charging circuit [4], Voltage regulator module LM2596 is launched by the United States National Semi-conductor Corporation, it is a down voltage switching integrated circuit of 3A output current, it contains a fixed frequency oscillator (standard is 150kHz) and the reference voltage regulator (standard is 1.23V), it have a protection circuit, overheat perfect the turn off circuit, current overload limit, etc.. The module only needs few peripheral circuit, voltage stabilizing circuit can be highly efficient and stable. For 5V DC voltage regulator circuit, the short-circuit current can reach 3A, Schottky diode 1N5824 is used for freewheeling diode in circuit, maximum continuous current may be to 5A, It also has a 2A margin when LM2596 at 3A output current, it can ensure the security of the system and the reliability under full load.

C. SCM Minimum System

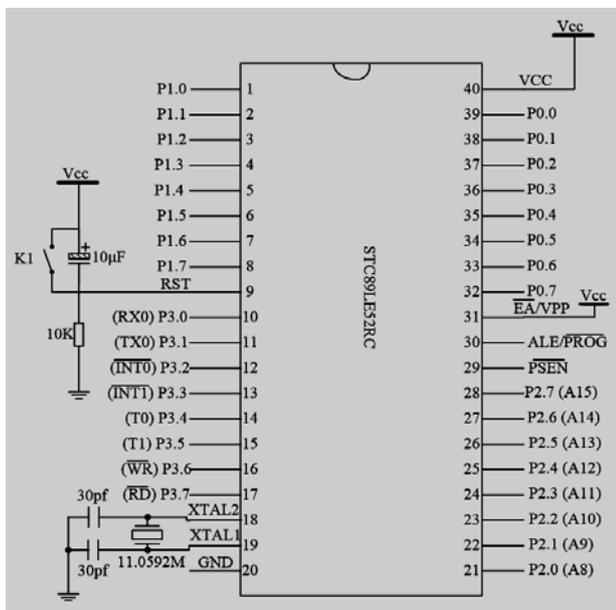Design of SCM minimum system as shown in Fig.(3).

Fig.3. SCM minimum system

STC89LE52RC microcontroller of STC technology company is used for the main controlling chip ,it is a kind

of CMOS 8 bit microcontroller with low power consumption and high performance, with 8K Flash memory in programmable system, using the traditional MCS-51 kernel. It has 512 bytes of RAM, 32 I/O ports, general watchdog timer, built-in 4kB EEPROM, MAX810 the special reset circuit, 3 general purpose 16 bit timer / counter, 4 external interrupt port, a structure of seven level Four interrupt vectors (it is compatible with the 5 vector 2 level interrupt architecture of traditional 51),a full duplex serial port [5].In addition, static logic operation of STC89LE52 can be reduced to the lowest 0Hz,It supports 2 power saving modes through software selectable.

In idle mode, the CPU will stop working and only allow RAM, serial port, timer / counter, interrupts to work. In the power down protection, the contents of the RAM will be saved, the oscillator will be frozen, all work of MCU will stop, until the next interrupt or hardware reset date of arrival. The maximum operating frequency is 35MHz. Instruction code is compatible with the tradition 8051 microcontroller core , the 12 clock / machine cycles and 6 clock / machine cycle can be arbitrary choice, the MCU adopt 3.3V level format with lower power consumption than the traditional 8051 MCU.

The reset trigger of the MCU requires high level for over two cycles , which takes about 2 ~ 3 μs, automatic power on reset and manual button reset can be designed , the power on reset is the use of capacitor in the just power on transient state corresponds to the conduction of the properties, the RST pin of MCU to high level, the function of 10uF capacitor is slightly prolong the charging time of capacitor, the time of high level is more than 30 s, and then the capacitor after a full charge equivalent to cutoff, The RST pin is connected to ground through the 10kΩ resistor, it equivalent to connect a low level, so that it is equivalent to the RST pin a pulses of high level more than 30 s, it make the reset of MCU can be to normal work. Need to press the button when manual reset, RST is directly connected to the Vcc, loosen the button connected to ground through the 10kΩ resistor, it is equivalent a low level, the time remained at least more than 100ms when the button is pressed (assuming 10 times can be pressed per second), this is equivalent to the completion of a high level pulse , which makes the MCU can normal reset.

Crystal's role is to produce the original clock frequency, numerical of crystal oscillator commonly is 12MHz and 11.0592MHz. The baud rate formula is:

$$B = \frac{f}{2} \times 16 \times (65536 - t) \qquad (8)$$

In formula (8): B indicates baud rate, f indicates Crystal oscillator frequency, t indicates time.

If the MCU is connected to a external crystal for 11.0592MHz, the baud rate generator is T/C2, the calculation result is:

$$9600 = \frac{11.0592 \times 10^6}{2} \times 16 \times (65536 - t) \qquad (9)$$

Calculation formula (9):

$$t = 65500 = 0xffdc \qquad (10)$$

The obtained t is an integer, transmission error can be eliminated, so the design is use of passive 11.0592MHz crystal. The starting capacitor of crystal adopt two 30pf/63V ceramic capacitor .

D. The design of charging circuit

The design of charge detection circuit is shown in Fig.(4).

The parameters of charge state are mainly the terminal voltage of solar panel and the charging current value. Because the output voltage of polysilicon solar panels has a relationship with the light intensity,the light intensity is stronger, then the output voltage value is close to the rated voltage of the solar battery board,this part of the value can reflect the intensity of the light.The charging current magnitude response speed of the charging,in the electric power controlling range,the output current is greater then charge faster, conversely the more slowly [6].
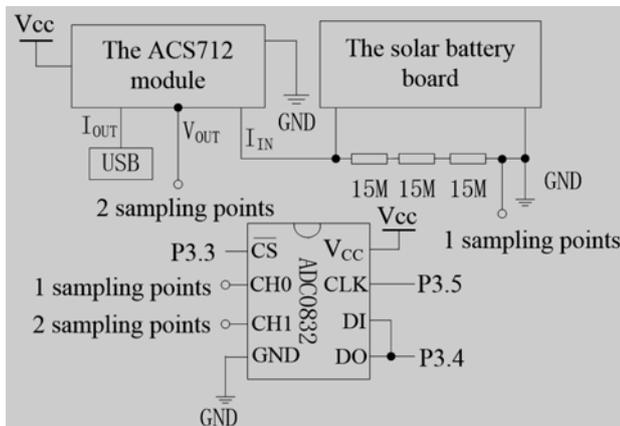

Fig. (4). The charge detection circuit

As a result of the analog-to-digital conversion chip ADC0832,it can measure the voltage range is 0 ~ 5V, and the output voltage range of the solar battery board is 0 ~ 12V, so three 15MΩ/0.25W precision carbon film resistor is used in the form of series pressure to obtain the voltage component , the component is the 1/3 of testing voltage value, change the range is 0 ~ 4V,it has solved the voltage under test beyond measurement range.

A new linear current sensor ACS712 module is used as a current information collection, the device has a built-in precision low bias linear Holzer sensor circuit, the output voltage proportional to current detection, and with characteristics such as low noise, fast response time, convenient use, high performance price ratio, etc. The

module is in series to the circuit being measured when used, the output voltage will produce corresponding change according to the size of electric current flows. Its output voltage of VOUT end is V_{CC} / 2, variation is 185 mV/A, measuring range is $\pm$5A (reverse current may be measurable) in the case of no current flows through.

ADC0832 is a A/D conversion chip, Resolution is 8 bit and two channels, it was launched by the American national semiconductor Corporation. Analog-to-digital conversion chip for 8 bit resolution can be divided the reference voltage into 256 digital quantity, the measured voltage of input is compared to the voltage of recovery approximation method obtained the digital quantity, V_{CC} is used for reference voltage , when using 5V DC power supply, its range is 0 to 5V, If the measured voltage is more than 5V,You need to test the voltage divider, a voltage component is less than 5V, then the actual measured voltage is calculated in MCU. Because of its input and output level is compatible with TTL/CMOS microcontroller, and the data/instruction transmission can be used directly. The interface between ADC0832 and MCU under normal circumstances should be 4 data lines, which are DO, DI, CLK, $\overline{CS}$. But because of not effective at the same time the DI end and the DO end during the communication, and the all interface of MCU are bi-directional, the circuit in the design of DO and DI can be connected in parallel with a data line. When ADC0832 is in the non-working state, the input of $\overline{CS}$ should be high level, the chip is disabled, level of DO/DI and CLK can be any value. When converting for A/D is needed, you must first will enable $\overline{CS}$ end on a low level, and the need to maintain a low level until the end of conversion chip, at this time to start the trans formation work. At this time, the processor input clock signal to the clock input of chip, the data signal is selected by the DO/DI terminal using the input channel function in DI terminal. DI must keep high level at the first falling edge of the clock signal, it represents the beginning of the signal.2 bit data should be input to the DI end of the second and third pulse, it is used to select the channel.

E. Design of voice broadcast circuit

Design of voice broadcast circuit as shown in Fig.(5), SYN6288 Chinese speech synthesis module is used.

SYN6288 Chinese speech synthesis chip is a high-end speech synthesis chip [7], it was launched by Beijing Yuyin world science and technology limited company. SYN628 receives the text to be synthesized through the asynchronous serial port, a text to speech (TTS) conversion is implemented, Chinese speech synthesis effect is clear, natural, accurate; Any specified Chinese text and English letters can be synthesized. SYN6288 is a built-in push-pull (Push-Pull) DAC, the horn can be directly driven voice broadcast without requiring high power play.The power amplifier circuit can also be

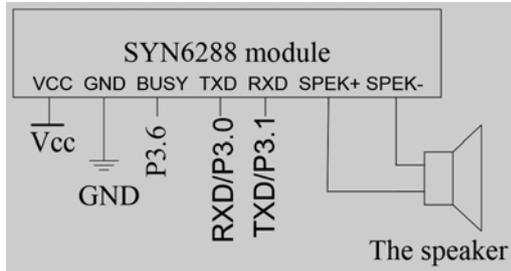designed, the speaker is driven voice broadcast with requiring high power play.

Fig. (5). The voice broadcast circuit

F. Design of State Display Circuit

Two ways to display the available charge state, one is through the LCD screen for various parameters (voltage and current) to display, the other one is using LED (light-emitting diode) display.
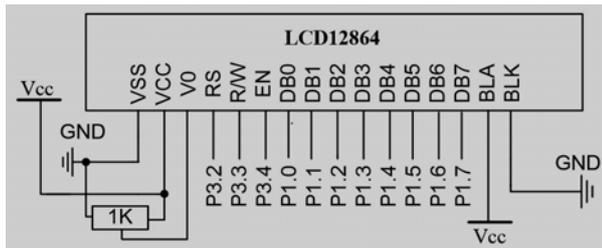Design of LCD12864 circuit as shown in Fig.(6).

Fig.(6) LCD12864 circuit

LCD12864 is a LCD display, the display resolution is 128× 64, 8192 Chinese characters of 16×16 point is built-in, and 128 ASCII character of 16 × 8 bit is set. Using the interface mode of the module is simple, flexible and convenient operation instruction, so a full Chinese man-machine interactive graphical interface [8] can be constituted, parallel port mode can be used for transmission of data / instruction data with the microcontroller P1 port.
Design of the LED indicator circuit as shown in Fig.(7).
A red 5mm light emitting diode, a yellow 5mm light-emitting diode and a green 5mm light emitting diode are used for charging state indication circuit in LED, The phenomenon of red LED light and green LED extinguished means no charge or abnormal state of charge ,the phenomenon of green LED light and red LED is extinguished means normal charging.
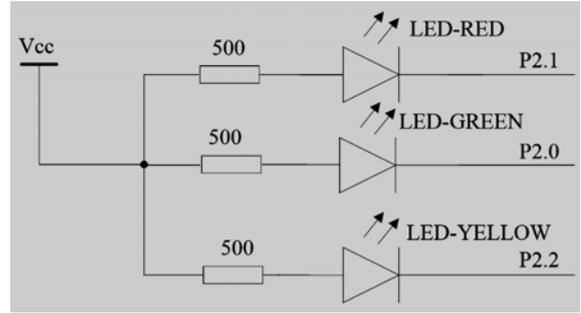

Fig. (7) LED indicator circuit

Because the SCM can withstand the current irrigation co., 500Ω/0.25W current limiting resistor are respectively connected in series to prevent excessive current damage of MCU in circuit design ,the two LED conduction state are controlled by the MCU for detecting the charging current.If there is no current in the circuit is that no charge,or too large current is that abnormal charging (normally the charging current is not more than 2A, if more than 2A may have a short circuit), the red LED is lighted,if there is a current and the current value is less than 1.5A thatis normal charging, green LED is lighted.The green light, red light, yellow light end are respectively connected with the SCM of P2.0, P2.1, P2.2, the others end are connected with power through 500Ω/0.25W current limiting resistor .

IV. DESIGN OF SOFTWARE

The design of the software includes main program and subroutine. The function modules such as LCD liquid crystal display module,ADC0832 module, speech synthesis chip SYN6288-UART serial communication module, LED module, and so on are encapsulated into instructions written subroutine, the main program is designed according to the need to directly call. The main program flow chart as shown in Fig.(8).
The first to initialize each function module, voltage and current loop to read and process data, voice prompt the current state, the liquid crystal display the charging state parameters, the red, green, yellow LED indicator is controlled to light or extinguish.
Design of liquid crystal display subroutine flow chart as shown in Fig. (9).
Liquid crystal display subroutine to definition of data and function interfaces, the D0-D7 data export, RS register selection, R/W selection, EN enabled, PSB serial / parallel selection, and so on are needed to define .The display switch, display mode, the cursor switchand others function are initialized, liquid crystal on the work state of busy are detected, the SCM can read and write operation of liquid crystal in the liquid crystal free.
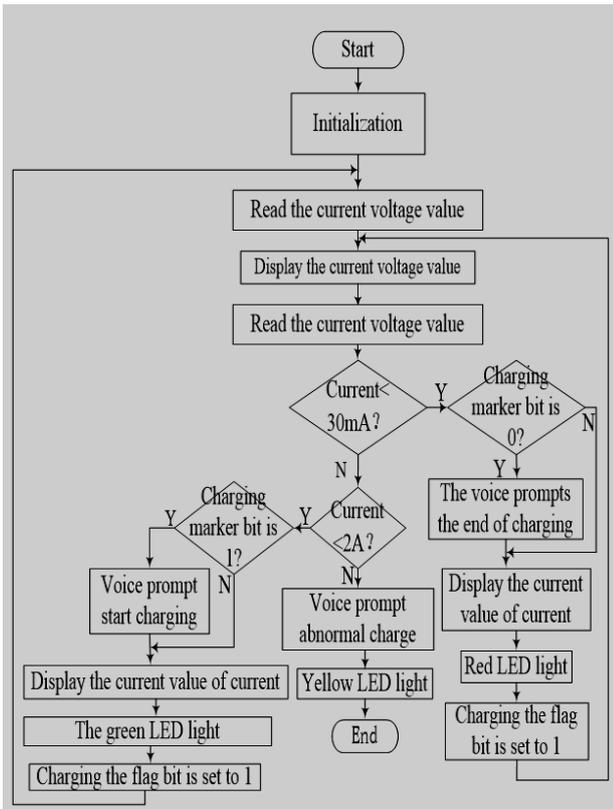
Fig. (8). The main program flow chart

Design the voice of the subprogram flow chart shown in Fig.(10) .

The serial port function is initialized by the speech subroutine, the baud rate and busy state detection are set. The baud rate is the benchmark rate of serial communication, the same baud rate must be have between the equipment in using the serial communication, data can be synchronized, the baud rate is the frequency signal generated by the timing function of timer / counter T/C1. Detection of busy, because of a speech synthesis module if you are playing the voice unable to receive new instructions or data, only when the busy state after the end the new instruction and data can be received and handled [10].

According to the flow chart, it is compiled on the KEIL IDE Vision4 platform with the C programming language [11].
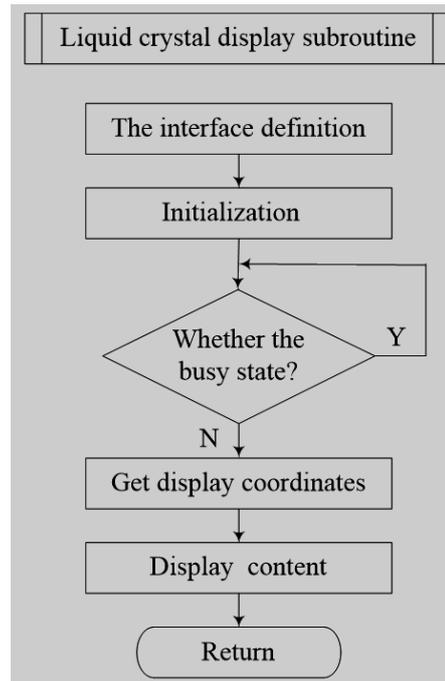

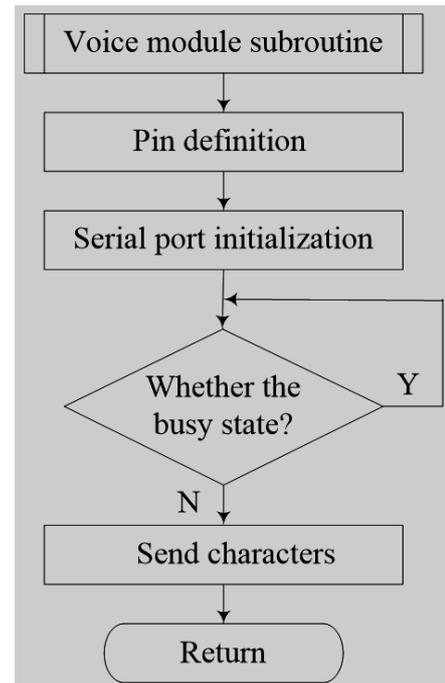Fig.(9) liquid crystal display subroutine flow chart

Fig. (10) The voice of the subprogram flow chart

V. SOFTWARE COMPILATION AND DOWNLOAD

KEIL IDE Vision4 compilation process is:

(1) StartµVision4-IDE, KEIL software integrated development environment is entered, the "Project→ New Project..." Menu is selected, a directory is selected or created for the New Project in the pop-up "Creat New Project" dialog box, and the name of the Project file is input, a Project file (.µv2) is automatically generated. Click the "save" button, select the target chip window as shown in Fig.(11).
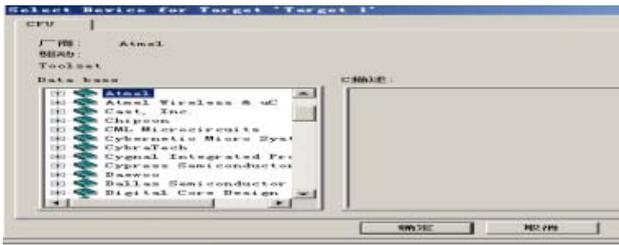

Fig. (11) Select the target chip window

Target CPU is selected in the window, Keil C51 support a lot of CPU, AT89C51 chip of Atmel company is selected, click the "ok" button, a dialog box asked if the standard AT89C51 boot file is chosen and added the project, click "yes" button, it will join the rest of the project file.

Return to the main window, "Target1" is appeared in the project window file page, there is the "+" in front. Click the "+", you can see the next layer of "Source Group1", then click the "+" in the "Source" Group1, you can see a STARTUP. A51 file. This file is just to join, it is suitable for most AT89C51 derived series startup file code. Startup code is executed first starting target chip code in main () function before, it is used to remove data memory, hardware initialization, again into the stack pointer.

"File→ New..." is selected, a new file input window is opened on the right side of the project manager, the source program is input in this window, letter of uppercase and lowercase letter and the semicolon after each row is noticed, don't lose and leakage input wrong.

After the input, "File→ Save" is selected, the File is named and saved. You must add extension, the name of this design using C language, so the extension is ".c", here it is named "mms. c", if the program is written in assembly language, the extension is the ".asm". After the file is saved, the window can be closed.

Then need to manually add source program to the project, click on the "Source Group1", make its reverse display, and then click the right mouse button, a shortcut menu appears, the Add file Group "and" Source Group1 "is selected, a dialog box appears, it is asked to find the source file. Double-click the mms. c file, the file is added to the project. Note that after the file is to join the project,

the dialog does not disappear, waiting for continue to add other documents. At this point, click the "Close" to return to the main window, after the return, click the plus sign in front of "Source Group1", mms. c file is in it, double-click the file name, the source program has been opened.

(2) The project Settings

After building project, further engineering is set to meet the requirements. Double-click the Project window "Target1" first, and then click the right mouse button, the "Project→ Option for target" and "Target1"are selected from the shortcut menu, Project Settings dialog box appears. This dialog has 10 pages, including the driver pages, target pages, output pages, a list of pages, C51 pages, A51 pages, BL51Locate pages, BL51Misc, debugging and utility pages, most of items is set by default.

(3) Compile and link

After project settings, it can be compiled and links. Menu "Project → Build target" are selected, the current engineering is connected, if the current file has been modified, it will be to compile the file first, and then be connected to generate the target code; If the "Rebuild All target files" is selected, it will recompile all the files in the current project, and then be connected, the goal of eventually produce code is to ensure that the latest; The "Translate..." item is compiled only the current file, don't connect. The above operations can also be directly via the toolbar button, from left to right are: compiling, compile link, all the reconstruction, stop compiling, download to Flash Memory and to set up the project.

Compile information will appear in the output window in the process of the Build page, compile results display window as shown in Fig.(12).
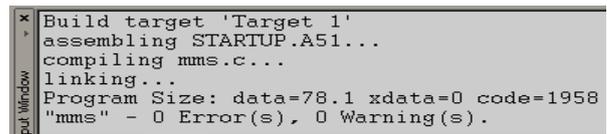

Fig. (12) Compile results display window

If the source has grammatical errors in the program, there will be a bug report, double-click on the bank, the location of the error can be positioning, compile again after the source program to modify, until the error is 0. At the same time, the amount of code of the program, internal RAM usage, external RAM usage information and so on can be seen in the window. In addition, compile and link also have some other relevant documents, including the relocatable object files (.obj), relocatable file list. (.lst), an absolute address the target file (no suffix), an absolute address list file (. m51), connecting the input file (.inp), these can be used for simulation and debugging of Keil C51 to start debugging after this step.

Press Ctrl+F5 key combination or use the menu "Debug→ Start/Stop the Debug Session" can be entered into a state of debugging. Most of the command on the

Debug menu can be found corresponding shortcut button in the run and Debug toolbar. Generally from left to right in turn is reset, running, pause, single step, process step, the execution of the current subroutine, run to the current line, the next state, to open the tracking, observation, the disassembly window, observation window, code analysis, 1# serial window, memory window, performance analysis, tool button command window. After debugging success under the interface block diagram shows "0 Error (s)".

(4) Software download

Download software used on STC official download software, the target file is directly open after the port is selected, and then click download, and the MCU with electricity, software download can be completed. Program download interface as shown in Fig.(13). If the download is successful, the "operation is successful!" will be displayed in the lower right corner block diagram.

Fig.(13) Program download interface

VI. THE EXPERIMENTAL RESULTS

All unit circuit are simulated on the Proteus platform, the PCB board is designed and produced after simulation, the MCU of download the program and other components are welded on the PCB board [12], physical diagram is shown in Fig.(14). power on, the function is test.

LCD display voltage and weak current at no charge. Insert the USB load or connect the battery, the LCD screen display voltage and large current after charging starts, After start charging LCD display is shown in Fig.(15), and the voice prompt "start charging". The LCD screen display voltage and small current end of charging or pull out the USB load, and the voice prompt "end of charge". Testing the 10V solar panels solar panels, terminal voltage 9.76V is displayed without charging, the charging current is 0.02A, the yellow indicator light. When entering the state of charge USB load insertion or connect the battery, solar battery board terminal voltage is displayed 8.94V, the charging current is 0.45A, the green indicator light is on, the voice prompt "start charging", the system enters the state of charge. When charging is

completed or USB load after pulling out, the display content return when charging state, the red indicator light is on, the voice prompts "the end of charging", not into the state of charge.
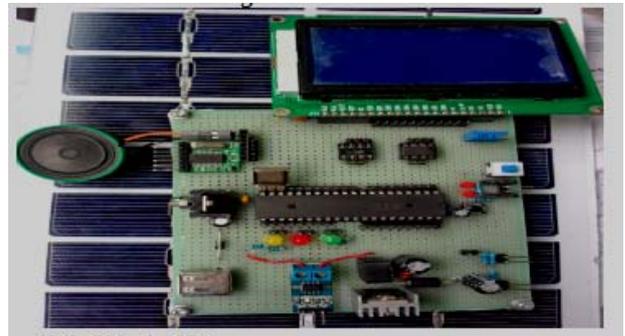

Fig. (14) Physical diagram

Fig. (15) After start charging LCD display

VII. CONCLUSIONS

Solar energy is a very abundant renewable resource, it has a very broad practical prospect. Solar charger design not only can be used for agricultural monitoring devices, but also with appropriate transformation can be applied to many electric chargers used in daily life, such as mobile phone, digital camera, MP3 player, a tablet computer, etc.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

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