Research of the Wireless Management System for Solar Street Lamp Based on NanoLOC AVR Module

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Abstract – In order to improve the service life of solar street lamp, it is necessary to manage the lamp's battery in the form of on-line detection via wireless communication. A wireless management system for solar street lamp based on nanoLOC AVR module is researched in this paper, the system can real-timely detect the solar street lamp's battery voltage, current, temperature, internal resistance, residual capacity and so on. And the collected data is transmitted to computer's management via wireless communication to achieve recording, storage, analysis and processing for various parameters.

Key words – *solar street lamp*; *nanoLOC AVR module*; *wireless communication*

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1 Introduction

Due to the influence of climatic factors such as temperature, humidity, illumination, etc., or electrical parameters such as depth discharge, overcurrent, undervoltage, overvoltage, etc., solar street lamp's service life will be impacted remarkably, even causing unstable running or damage[1]. Traditional management for the solar street lamp is basically artificial and regular inspection, which is backward. As a result, we cannot find the breakdown for the solar street lamps timely, and thus causing damage to solar cell modules or battery. Aiming at the backward problem of solar street lamp's management technology, this paper puts forward a way to manage system for solar street lamp based on wireless communication. The system can implement regional management for solar street lamp with a way called one to many, which is shown in Fig.1.

This system can realize real-time and on-line detection for the operational state of the solar street lamp, and give an alarm signal and remove operation for the breakdown, to make the solar street lamp safe and reliable and long-term operation.

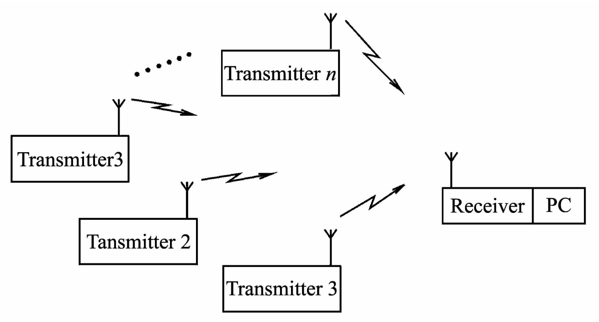

Fig.1 "One to many" wireless monitoring and management

2 Overview for the core module of the system and basic structure and principle

2.1 Overview for the core module of the system

The core of this system utilizes WellNode Electronics' nanoLOC AVR module which integrates all the required components for a complete Radio Frequency (RF) module based on Nanotron's innovative nanoLOC TRX Transceiver. As well as the nanoLOC chip, this module includes the Atmel AVR ATmega 644 V microcontroller, a Band Pass Filter (BPF), a balun, and an integrated 2.4G Hz chip antenna[2].

The nanoLOC AVR module is programmable over Joint Test Action Group (JTAG) or Serial Peripheral Interface (SPI) interfaces. 36 peripheral module pins in total are provided, with 16 programmable digital I/Os and 2 analog inputs. The module also provides a Pulse-Width Modulation (PWM) output, a microcontroller reset input, a Universal Synchronous RX/TX (USART) input/output, and a TX/RX signal that enables an external PA. Power supply voltage is 2.5 V±0.2 V.

Atmel AVR ATmega 644V microcontroller is a low power Complementary Metal Oxide Semiconductor (CMOS) 8-bit microcontroller based on the AVR enhanced Reduced Instruction Set Computer (RISC) archi-

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tecture with 64 Kb Flash, 4 Kb SRAM, and 2 Kb EEPROM. This microcontroller drives the nanoLOC chip via the SPI interface nanoLOC supports a freely adjustable center frequency with 3 non-overlapping frequency channels within the 2.4 GHz ISM band. This provides support for multiple physically independent networks and improved coexistence performance with existing 2.4 GHz wireless technologies. Data rates are selectable from 2 Mbps to 125 Kbps. Programmable output power is from − 33 dBm to 0dBm. Receiver sensitivity is up to −97 dBm. Operating temperature ranges from −40 ℃ to +85 ℃.

At the RF interface of the nanoLOC chip, a differential impedance of 150 Ω exists which is matched to the asymmetrical 50 Ω impedance of the antenna port by a 150/50RF balun. Additional external components at the RF interface have a power and noise matching function that allows a sharing of the antenna without an external RX/TX-RF switch.

2.2 Basic structure and principle of the system

The whole system is divided into two parts, that is transmitter and receiver, as shown in Fig.2. The transmitter includes the battery's voltage acquisition module, current acquisition module, temperature acquisition module, control circuit, signal modulation and transmitted module. The receiver contains receiver module, signal demodulation, display, keyboard and alarm.

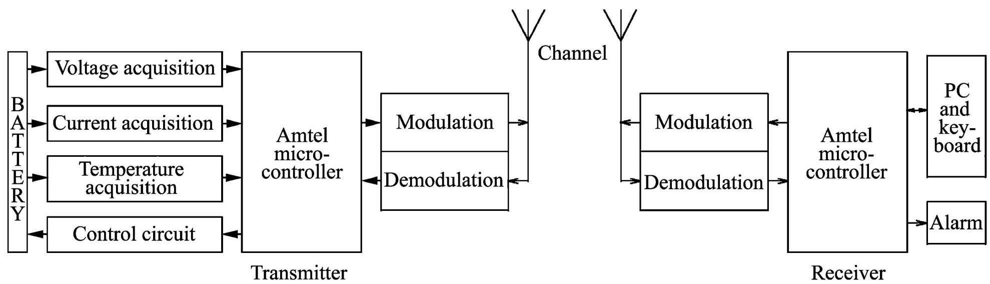

Fig. 2 Block diagram of the system

Acquisition modules real-timely collect voltage, current and temperature signal for the battery of solar street lamp, and through amplification, analog switches etc., and a built-in A/D converter of Atmel 8 bits SCM ATmega 644 V transforms the collected data in the form of analog signal into digital signal, then the SCM analyzes and processes the data collected by the acquisition modules and outputs data into a chip called nanoLOC TRX. Finally, the signal modulated transmits in the form of RF signal.

The receiver demodulates the RF signal, restores the original data information which is sent to SCM and processed. Finally, the collected information is shown in PC, and then we can understand the operation state of solar cell modules and battery. Additionally, the system can give an alarm for some states which will be wrong or damage solar cell modules and battery, and can provide a function with control as well. This control signal is transmitted in the form of wireless communication. Solar street lamp's battery is controlled via control circuit, avoiding some electrical parameters such as overcurrent, undervoltage, overvoltage, etc, to damage solar cell modules or battery.

3 Hardware design for the system

3.1 Voltage acquisition module circuit

This system conduct an experiment with a 12 V (17 Ah～80 Ah) battery, its normal working voltage ranges from 10.5 V to 14.7 V. Fig.3 shows the voltage acquisition circuit for 12 V battery, the voltage signal is collected by a 10-bits precision A/D channel which is built in 8-bits Atmel microcontroller ATmega 644 V on the nanoLOC AVR module. Due to the collected voltage signal is a dynamic value, and this signal collected by ATmega 644 V A/D acquisition interface can not exceed 2.5 V. To make SCM can accept this voltage signal, a voltage circuit is designed, as shown in Fig.3.

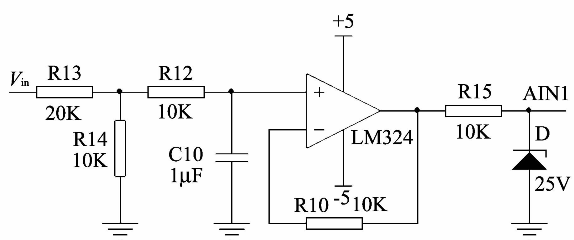

Fig. 3 Voltage acquisition circuit

3.2 Current acquisition module circuit

Current signal can be converted into voltage signal. In the circuit, we place a precise resistance R21, and thus current signal will be converted into voltage signal. The solar street lamp's battery has two kinds of states that is charging and discharging. When state for charging, voltage output of operational amplifier is positive. When the state for discharging, voltage output of operational amplifier is negative. However, SCM can only collect a positive voltage signal. Authors add a reference voltage to push up the voltage, to convert negative voltage into positive voltage, which is shown in Fig. 4. So the output is positive whether positive or negative.

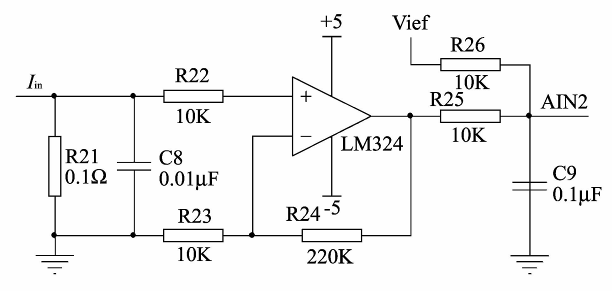

Fig. 4 Current acquisition circuit

3.3 Temperature acquisition module circuit

This system utilizes a 1-wire bus digital temperature sensor DS18B20 which is produced by Dallas Semiconductor Company. The DS18B20 Digital Thermometer can collect temperature data in the practical field and output digital temperature data directly in the form of "1-wire bus", improving the system's anti-interference greatly, so it is fit for temperature measurement in the harsh environment. In addition, 1-wire bus is unique and economical, users can form a sensor network easily and build a measuring system expediently.

The DS18B20 Digital Thermometer has an operating temperature range of −55 ℃ to +125 ℃ and is accurate to ±0.5 ℃ over the range of −10 ℃ to +85 ℃. DS18B20 provides upper and lower alarm trigger registers (TH and TL) that use to set the upper and lower limits of alarm temperature value. These limit values are nonvolatile (EEPROM), so they are retained when the device is powered down. The temperature values collected by DS18B20 compare with TL and TH, if less than TH, or more than TL, the alarm bits set, and will be responded to SCM's search command.

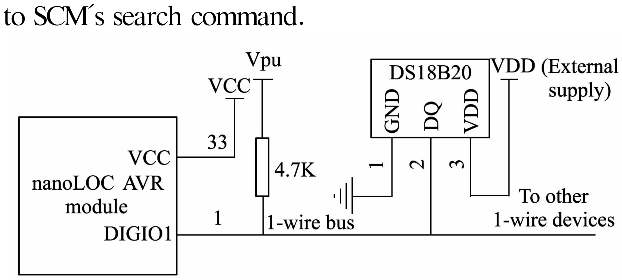

Fig. 5 Temperature acquisition circuit

Fig. 5 shows the temperature acquisition circuit. The nanoLOC AVR module's pin1 is pushed up and connects to the DS18B20's pin2, and the DS18B20 is powered by an external power supply, pin1 of the DS18B20 connects to ground. The DS18B20's pin1 is the main channel for heat, in order to measure temperature of the solar street lamp's battery accurately, pin1 must have a good thermal contact with battery measured.

3.4 Wireless communication module

This design uses nanoLOC AVR module which is a small package high integration module and integrates all the required components for a complete RF module based on Nanotron's innovative nanoLOC TRX Transceiver. Only a few external components are required to build a complete bi-directional wireless communication module, and its size is very small.

The collected data of solar street lamp's battery is transmitted into 8-bits SCM ATmega 644 V which is responsible for processing data. The processed data is transferred into a nanoLOC TRX transceiver. After modulating, the data passes through Band Pass Filter (BPF) and transmits via antenna. The receiver demodulates a RF signal, and then SCM processes the signal demodulated and is returned to original signal. Finally it is displayed on PC, implementing management with wireless communication.

The nanoNET TRX transceiver utilizes a new modulation technique Chirp Spread Spectrum (CSS) developed by Nanotron to modulate data collected via acquisition circuits, CSS uses UpChirp and DownChirp signal to signify transmission bits "1" and "0". Chirp signal is a broadband signal, and it has strong anti-interference, easy to produce, etc[3].

The transmitter uses a sawtooth wave signal to control Data Control Oscillator (DCO) that generates UpChirp and DownChirp signal, which accomplishes modulation for acquisition signal input with CSS. And then the internal integrated circuit modulates Chirp signals to RF signal which passes through additional external components at the RF interface. These components have a power and noise matching function. Then transmitting signal via an antenna. In the receiver, the Chirp signal is compressed by matched filter which is integrated in the nanoLOC TRX transceiver. Chirp signal's energy is concentrated in a very short period of time and outputted, so as to improve the Signal Noise Ratio (SNR) and be processed[4]. A matched filter is composed of Digital Dispersive Delay Line (DDDL) which is responsible for distinguishing between two possible incoming signals that are generated by another nanoLOC chip. This received signal is either an Upchirp, a Downchirp, or a folded pulse (an Upchirp and a Downchirp at the same time). All of these signals have the same center frequency and the same bandwidth. The DDDL's mechanism is different delay time for different frequency, long time for high frequency, short time for low frequency. So, a carrier signal, frequency from high to low, passes through matched filter, after that, all frequency components almost output simultaneously, Chirp pulse obtains compression of its time. Therefore, each pulse signal is compressed to narrow pulse with large amplitude, high instantaneous power, concentrating energy, which enhances Signal Interference Ratio (SIR). But some signals do not match the filter and do not be compressed of its time, and is filtered to improve the SNR output. Thus, demodulation is finished, which is shown in Fig. 6.

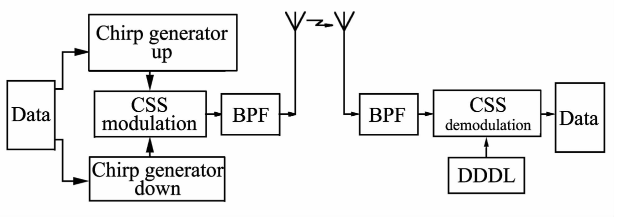

Fig. 6 Modulation and demodulation of the data

4 Software design for the system

4.1 Programming process design of the system

The program of this system mainly includes main program, data acquisition processing program, wireless commuoication program, etc. The program of system is shown in Fig. 7.

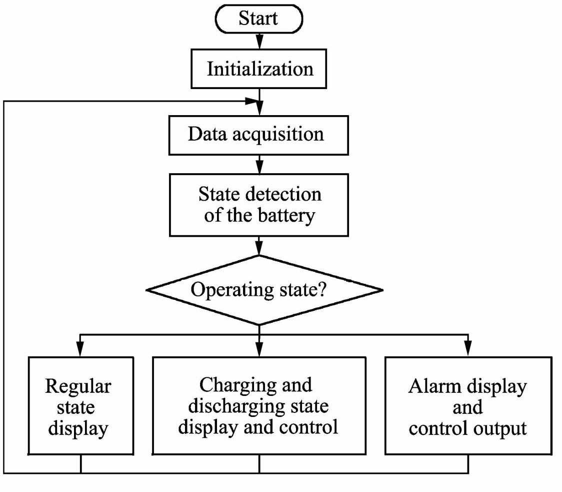

Fig. 7 Flow chart of system's program

After the system starts, it initializes immediately. Current, voltage and temperature acquisition circuits real-timely collect data for the battery of solar street lamp. First of all, digital temperature signal which is detected by a digital sensor DS18B20 is read, and then chooses corresponding channel through the analog switch and calls a corresponding A/D acquisition subprogram to read the voltage signal and current signal. These signals are processed by SCM ATmega 644V, after that, we can know the operation state of the battery, at the same time, SCM calculates the battery's internal resistance and residual capacity. The processed data signals are sent to the nanoLOC TRX transceiver to be modulated and call the wireless communication program. The receiver demodulates these signals, restoring original data which are transmitted into the receiver's SCM. Eventually, operation state of the solar street lamp is displayed on PC. The system will automatically give an alarm and display for some more than allowable value, such as temperature out of limit, overcurrent, undervoltage, overvoltage, etc. The manager can analyze the causes according to the data and make a corresponding measure. For example, when overcurrent, you can click a button of stop charging on the screen to protect the solar cell module and the battery, thereby realizing wireless communication management for solar street lamp.

4.2 Adjustment of the LO's TX and RX frequencies

The TX and RX frequencies of the Local Oscillator (LO) of the nanoLOC TRX need to be adjusted during initialization, during operation, or both in wireless communication system.

The transmitter and receiver frequencies for the nanoLOC TRX transceiver are tuned using switched capacitors[5]. The required TX frequency is 2.44175 GHz, which is the mid-frequency of the 2.44 GHz ISM band. The target frequency value for the transmitter is 0x090B. In the RX part of the transceiver, a frequency down conversion is performed to the ZF-frequency of 250 MHz. Therefore, the target frequency to which the receiver block is tuned is 2.441 74 + 0.250 GHz. The target frequency value for the receiver is 0x0F4B.

To adjust the Local Oscillator's TX and RX Frequencies, do the following: Ensure that the 16 MHz oscillator and clock distribution are on. Manually enable the LO, the 1∶10 divider, and the LO's adjustment clock. Select the LO's frequency mode: either for transmitting or for receiving. Set the target frequency corresponding to the LO frequency mode chosen in step 3. wait 772 μs. If required, read out the values of the switched capacitors and store them, that is, if no frequencyre-adjustment is needed as after transceiver's wake-up. Disable the LO's adjustment clock, the 1∶10 divider, and the LO.

```
#include "OffstMapInit.h" /* TRX register description file */
#include "nnspi.h" /* declaration of routines using SPI-bus */
#include "delay.h" /* declaration of delay routines */
const unsigned char tx_inc_val[ ] = {0x0B, 0x09};
        /* increment value for TX freq adj. */
const unsigned char rx_inc_val[ ] = {0x4B, 0x0F};
        /* increment value for RX freq adj. */
unsigned char datum = 0;
unsigned char tx_lo_caps[2];
unsigned char rx_lo_caps[2];
/* the following code sequence needs the 16 MHz clock distribution on */
datum |= (1<< Silbadero_RfLoEn_B)
      |(1<<Silbadero_RfLoDiv10En_B)
      |(1<<Silbadero_RfLoAdjClkEn_B)
/* enables LO manually, enables the LO's divider, enables LO's adjust clock
*/
datum |=(1<<Silbadero_RfLoRxMode_B);
        /* needed if RX freq must be adjusted */
transSPI(WRIT_CMD,Silbadero_RfLoEn_O,&datum,1);
        /* enables the LO freq adjustment */
us_delay(24); /* waits 24 μs,if RX freq must be adjusted */
transSPI(WRIT_CMD,Silbadero_RfLoAdjIncValue_O, rx_inc_val, 2);
/* starts LO RX freq adjustment. Use tx_lo_caps in case of the LO RX
freq */
```

```
us_delay(772);        /* wait al least 772 us */
transSPI(READ_CMD,Silbadero_RfLoRxCaps_O,
    rx_lo_caps, 2);
/* stores current values of switched capacitors for RX freq */
datum = 0;
transSPI(WRIT_CMD,Silbadero_RfLoEn_O,&datum,1)
            /* disables the LO freq adjustment */
```

5 Conclusion

This system utilizes a nanoLOC AVR module as the core. This module integrates all the required components which contain microcontroller, wireless transceiver chip, etc, for a complete RF module. And this module is easy to operate with numerous interfaces, small size, low cost and strong function in practical application. The innovative points: Fist of all, a set of wireless communication management system for solar street lamp, this system can realize regionalization monitoring and management control in the form of "one to many". Secondly, the system utilizes the high integration nanoLOC AVR module which is a little encapsulation and small size, only a few external components required can realize signal processing, transmitting and receiving.

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