Design and Implementation of Portable Digital Oscilloscope with Embedded System

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Abstract

This paper takes STC12C5A60S2 single-chip microcomputer as the core. The single-chip microcomputer has its own high-speed A/D converter, which can collect 24kHz signal at the highest frequency. It can realize time-base display and continuous waveform real-time display of function waveforms such as sawtooth wave, triangle wave, square wave and sine wave. The results show that the design scheme initially realized the fundamental function of the oscilloscope. And it helped us to learn more deeply as well as understand the working principle of the oscilloscope and the application of embedded technology.

Keywords

Embedded; Portable; Digital Oscilloscope; Data Acquisition; STC12C5A60S2; LCD12864.

1. Introduction

Embedded technology is a popular electronic technology in the modern era. Digital oscilloscope has become a multi-functional measuring instrument for measurement, monitoring, analysis, recording, etc. And designing a full-featured and portable oscilloscope is a growing trend. Firstly, this paper introduced the production principle of the oscilloscope. Secondly, it introduced the design concept of this oscilloscope, the algorithm and program implementation used. Finally, it demonstrated the results of this oscilloscope. And this paper has guiding significance for learning embedded technology and oscilloscope principle knowledge.

2. The basic Principle of Digital Oscilloscope

The principle of digital oscilloscope is based on the sampling principle, using the A/D converter to sample the analog signal, and then sending the digital signal obtained by sampling to the storage unit. Finally, transmiting the data stored in the storage unit to the LCD display to reconstruct the sampled waveform signal on the LCD diaplay.

3. Hardware Circuit Design

3.1 Power Circuit Design

In view of the fact that many power adapters in our life are 5V DC voltage output and the utility of USB cable, the power circuit design of this work used 5V DC socket, self-locking button switch and one USB cable for DC socket to complete the power supply task of the system. By using one USB cable, the circuit can be powered not only by the power adapter, but also by the mobile power bank to match the portability of this oscilloscope.

3.2 A/D Conversion Circuit Design

STC12C5A60S2 has 8 sets of 10-bit high-speed A/D converter, which are located at P1 port (P1.0~P1.7). They need to be set separately for A/D conversion, and the sampling frequency can reach 250kHz. According to the sampling theorem, there are two sampling points in a period to complete the sampling. In actual work, only 10 or more sampling points in one signal period can display the details of the signal. The STC12C5A60S2 can completely sample the 0-20KHz signal, and finally can recover the sampled information.

Taking advantage of the STC12C5A60S2 internal A/D converter, this project set the P1.7 port as the A/D conversion sampling signal input port. And the reference voltage for A/D conversion was the working voltage of STC12C5A60S2, Vcc (5V).

3.3 Display Circuit Design

The display of this simple oscilloscope used the LCD12864 with a Chinese font library. The parallel data port of the LCD display was connected to the P2 port of the single chip microcomputer, and the parallel command and the parallel read/write data port were respectively controlled by the corresponding bits of the P3 port.

In the construction of LCD display circuit, for the purpose of saving energy and reducing consumption, the project added a circuit with a PNP type triode as a control switch in the backlight interface of the LCD display. And using a button to control the bright and dark of the LCD backlight.

3.4 Button Design

The oscilloscope of this project had been designed with three control buttons to control the display of waveform. K1 is the sampling frequency miuns control button, K2 is the sampling frequency plus control button, and K3 is the LCD display backlight control button.

The whole circuit design is shown as the Fig. 1.

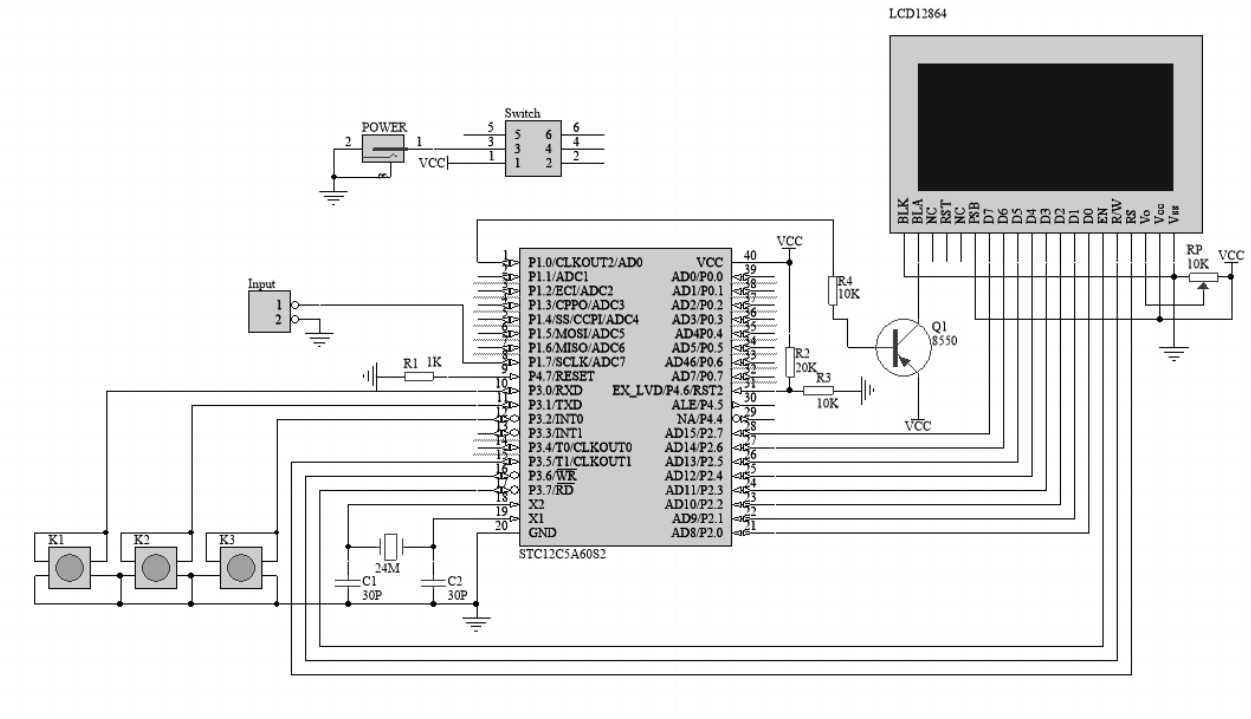

Fig. 1 Schematic diagram of the oscilloscope

4. Software Programming

The flow chart of software program design shows the design idea of this oscilloscope. As the Fig.2 shown.

In order to realize the display of the waveform, the LCD needs to be reset after the work is powered on, and then the LCD needs to be initialized; the A/D converter also needs to be initialized before the A/D conversion of the acquired signal. When reading data from the LCD and writing data to the LCD, it is necessary to perform "busy" detection, that is, to read the status flag of the LCD cyclically, and to judge whether the LCD is idle, and to read and write only when the LCD is idle.

In order to realise real-time display of waveform, the A/D conversion used interrupt to control. According to the MCU Device Manual, the value of ADRJ in AUXR1 register is 0, so the 8-bit A/D conversion results stored in the ADC_RES register are calculated by the following formula:

$$(ADC\_RES[7:0]) = 256 \times (Vin/Vcc) \quad (1)$$

In the formula, Vin is the input voltage of the analog input channel, and Vcc is the working voltage of STC12C5A60S2.

After consulting the manual, the commands of A/D initialization and A/D conversion are listed below:

ADC initialization

```
void InitADC()
{
P1ASF=0X80;
ADC_RES=0;
ADC_CONTR=0xef;
EADC=1;
}
```

A/D conversion

```
void adc_isr() interrupt 5 using 1
{
ADC_CONTR=0xef;
if(over==0)
{
        temp=delnop;
        while(temp)
        {
        temp--;
        }
        dat[dati]=ADC_RES;
        dati++;
        if(dati>100)
        {
        dati=0;
        over=1;
        }
}
}
```

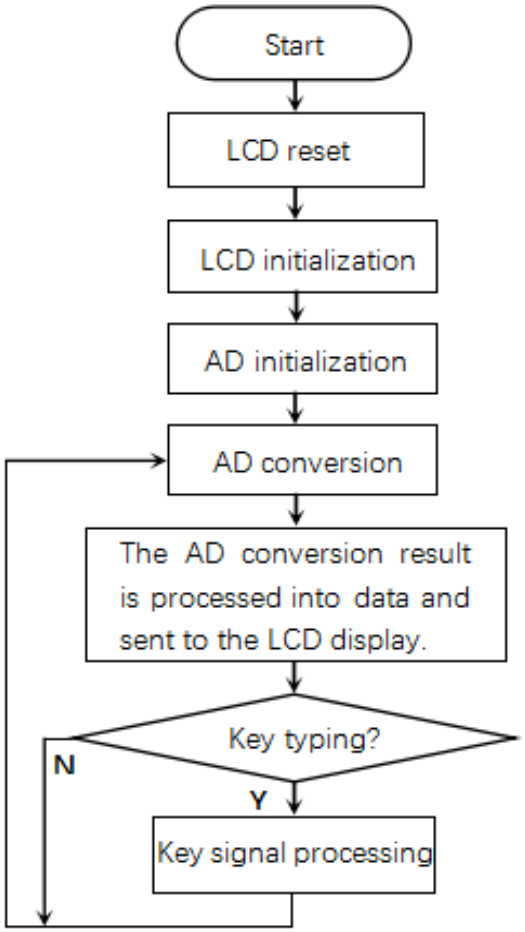

Fig. 2 The flow chart of software program design

5. Conclusion

By studying the signal acquisition, conversion, and the reconstruction of waveform, this project completed the development of a portable digital oscilloscope with the STC12C5A60S2 as the core processor and the LCD12864 as the display component.

In summary, the research of this thesis had mainly completed the following works:

(1) Completed the planning and designing of the portable digital oscilloscope.

(2) Completed the construction of hardware.

(3) Successfully completed the software program designing.

(4) Through debugging and analysing of the designed portable digital oscilloscope system, the system basically completed the display and measurement of the waveform. The test results see Fig.3.

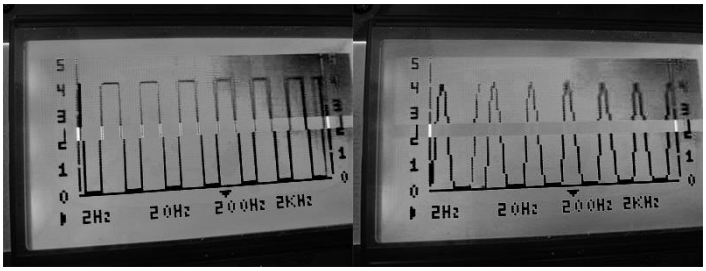

Fig. 3 The test results of the portable digital oscilloscope

Through this research, although the portable digital oscilloscope designed by us still has some inadequacies need to be improved, it basically realized the function of waveform acquisition, display and analysis.

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References

[1] Wenzhe Li. Study of Digital Storage Oscilloscope Based on Embedded System[M].Shandong: Shandong University of Technology. 2014(In Chinese).
[2] Zhengkai Ye, Jianhong Zhu, Lin Li, Hao Wu. Design and Implementation of Digital Storage Oscilloscope Based on SCM[J]. Computer and Modernization, 2014(03): 11-14. (In Chinese)
[3] Zhuchao Shao, Qiang Wu, Mei Ma, Bin Wang. Design of a Digital Portable Oscilloscope[J]. Instrumentation Technology, 2012(12): 51-54. (In Chinese).
[4] Fangwei Yu. Design of Digital Oscilloscope based on Single Chip Processor[J].Communications Technology, 2009, 42(05):269-271. (In Chinese).
[5] Ju Wu. Research and design of portable digital storage oscilloscope[D]. Dalian University of Technology, 2005. (In Chinese).
[6] Kai Gao. Design and Implementation of Digital Oscilloscope Based on STC12C 5A60 S2[J].Electromechanical Information,2010,(12):96,109. (In Chinese)
[7] Kaikun Tian. Design of Digital Oscilloscope Based on LCD12864 Display[J]. Electronic Production, 2011(05):30-37.
[8] MCU Device Manual on http://www.stcisp.com.