Design of High Precision Digital Barometer

Jing Zhang
School of Energy Engineering, Yulin University, Yulin,719000, China
zj_zhangjing@126.com

Keywords: Barometer; Baroceptor; V/F converter; LCD display

Abstract. Barometer is a tool for measuring atmospheric pressure, digital barometer has the advantages of simple operation, high accuracy and so on. In this paper, the real-time pressure display is achieved by SCM(Single Chip Microcomputer) as a core component, combining with baroceptor, V/F converter, LCD display and other peripheral devices. The designed pressure gauge is from 30 hPa to 1050 hPa with a measurement accuracy of 0.1% and a display resolution of 0.01. It has the advantages of easy to carry, simple operation, high accuracy, with some referential significance for the design of similar measuring instruments.

Introduction

Barometers have been widely used in the mine, weather stations, environmental protection, laboratories and other engineering situations. Common mercury barometer and alcohol barometer are bulky with low accuracy, not easy to carry and easy to damage, so the digital barometer becomes the research focus of the current barometers, which uses the baroceptor to be measured pressure signal into a voltage easily detectable Or current signal, and then follow-up circuit processing, so that pressure information can be displayed in real time[1,2]. Baroceptor is the core component of barometers, which played an important role in measuring the physical parameters of pressure, and using SCM to process data has the advantages of easy and simple control.

Analysis of System Structure

The design is composed of baroceptor, AD conversion, SCM main control circuit and display circuit, the baroceptor transforms non-electrical pressure signals into electrical signals, and needs to display and send the digital information after processing by the AD converter. Display circuit displays the pressure value through the LCD display. The specific block diagram shown in Fig. 1.

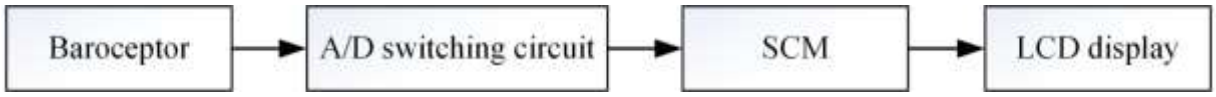

Figure 1. Block diagram of system

Hardware Circuit Design

Baroceptor. According to meteorological research, atmospheric pressure at sea level is 1013 hPa under standard atmospheric conditions. Atmospheric pressure is due to the gravitational effect of the atmosphere, and the vertical pressure decreases with the elevation of altitude. In the near-surface area, the air pressure decreased by 10 hPa for each 100 m ascent, 7 hPa for each 100 m ascended from 5 to 6 km above the ground, and 5 hPa for each 100 m ascended from 9 to 10 km above the ground. The air pressure will increase when the there is a descending airflow, and vice versa will be reduced. This shows that the general pressure gauge range 300hPa ~ 1050hPa can meet the daily measurement needs [3,4].

The baroceptor occupies the core position in the barometer, and the baroceptor can be selected according to several performance indexes such as measurement range, measurement accuracy, temperature compensation, and absolute pressure measurement when designing. At the same time in

order to simplify the circuit, improve the stability and anti-interference ability, requires that the baroceptor should be with temperature compensation.To choose Motorola's MPX4105 barometric baroceptor to measure absolute pressure value. The temperature compensation range of this baroceptor is -40~125℃; pressure range is 0kPa~1050kPa; output voltage signal range is 0.3~4.65V; measurement accuracy is 0.1%VFSS[5]. The relationship between the output voltage and atmospheric pressure is shown in Eq. 1:

$$v_{out} = v_s(0.01059p - 0.1528) \pm error \quad (1)$$

Where Vs is the operating voltage (5V), P is the atmospheric pressure value, Vout is the output voltage.

AD Conversion. What the baroceptor outputs is an analog signal, the signal must be converted to be digital signals suitable for SCM to process by the AD conversion circuit. Here the voltage/frequency converter (V/F converter) is used to convert the output voltage of the baroceptor into a pulse train proportional to its voltage amplitude. The A/D conversion function is completed by the timer/counter control. LM331 chip is selected to complete the V/F conversion. The chip frequency conversion relationship is shown as Eq. 2:

$$f_o = K \times v_i \quad (2)$$

K is calculated as shown in Eq. 3

$$K = R_s / (2.09 \times R_t \times C_t \times R_L) \quad (3)$$

The typical design values of Rt, Ct, and R_L are 6.8kΩ, 0.01pF and 100kΩ, respectively. In the design, the value of K is taken as 2000, and R_S = 28 KΩ (where R_S consists of R_{12} and R_{13}). V/F conversion circuit is shown in Fig. 2, where Vi is derived from the baroceptor information, fo is the frequency of V/F converter converted pulse information, and connected with the P3.5 pin of SCM. R_1 and C_1 constitute a low-pass filter, filter out the input voltage signal interference pulse. Among them, Cin is taken as 0.1μF, Rin is 100kΩ, C_L is the capacitance with capacity of 1μF and small drain current. It should be noted that the working voltage of LM331 is 9V.

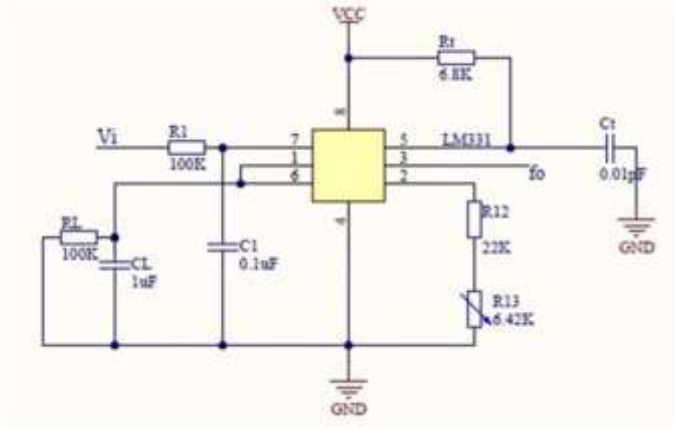

Figure 2. V/F conversion circuit

SCM. The implementation of the barometer needs to use the SCM to read the frequency information from the V/F conversion circuit, and requires a timer, a counter and a timer interrupt source, the design selected AT89C51 ATMEL SCM, the device has four A 8-bit parallel I/O ports, two 16-bit timer/counter, five interrupt sources, can be directly connected with the LCD display to meet the design requirements[6].

LCD Display. In the display, the LCD1602 is used to display the barometric pressure value. The LCD1602 display is a character display that can display two lines of 16 characters each, equivalent to 32 LED digital tubes. With single 5V power supply, the external circuit configuration is simple and has a high cost performance.

Three-Terminal Regulator. The design of the LM331 power supply using +9 V, but the SCM, MPX4105, LCD displays require +5 V power supply, so a special power supply circuit needs to be designed to meet the power requirements of the entire system. In this design, Motorola's three-terminal low-current linear regulator chip MC78L05 is selected as a power circuit. Its input voltage range: 2.6 ~ 24V, output +5 V fixed voltage; with internal short circuit limit and thermal overload protection, no external components. The entire system can provide 9V operating voltage, after using three-terminal regulator, the output 5V voltage can provide power for the SCM and other peripheral chips[7].

Software Design

In terms of the SCM, the input signal is actually a set of pulses with a certain frequency sequence, the frequency value needs to be obtained through the SCM's internal counter and timer together. In the Design of software, the C language is used to complete the overall programming [8].

Calculation Method of Pressure Value. The measured air pressure is converted into voltage output by sensor MPX4105, according to the MPX4105 chip information, the relationship between the output voltage V_{OUT} and atmospheric pressure P is shown as Eq. 4

$$Vout = V_{cc}(0.01p - 0.09) \tag{4}$$

The output voltage Vout of the MPX4105 is taken as the input voltage Vin of the V/F device and converted to a pulse sequence fo of the corresponding frequency by the V/F conversion circuit. The relationship between Vin and fo is shown in Eq. 3. Combining with Eq. 3 and Eq. 4. Where Vcc is taken as 5V in Eq. 4. Eq. 5 is obtained:

$$p = \frac{f0/5k + 0.09}{0.01} = \frac{20f0}{k} + 9 \tag{5}$$

Program Flow Chart . T0 timer mode of the SCM is used as a basic timing base. T1 is the counter used to obtain the external pulse signal that is output by the V/F device pulse frequency signal, in order to improve the calculation accuracy, T0 timing control after 500ms to read the counter value to calculate the pressure value, this time T0, T1 work in the way 1. T0 as the maximum timing is less than 500ms. In the actual situation, 50ms is used as T0 time-base signal, the flow chart is shown in Fig. 3:

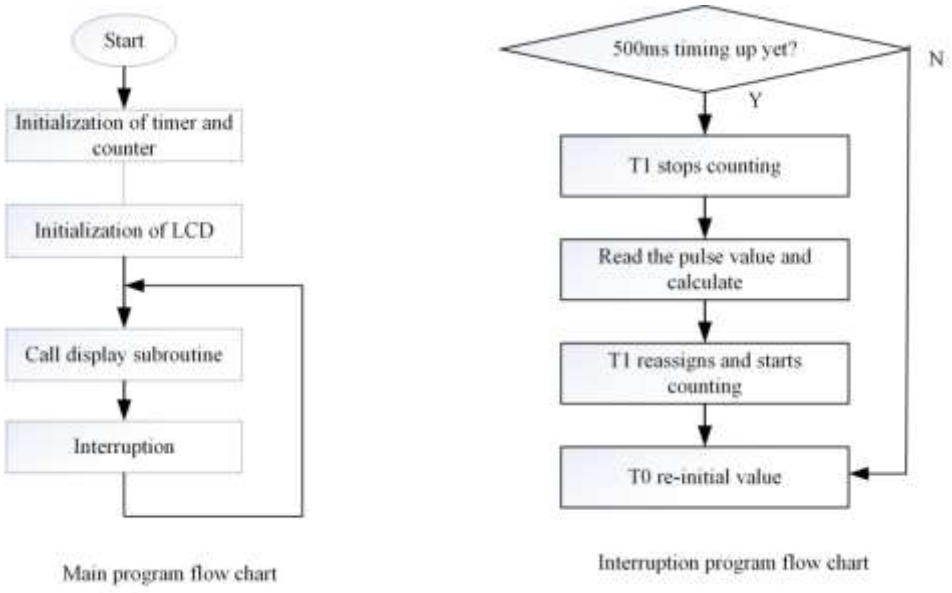

Figure 3.

System Debugging and Simulation

In order to ensure the correctness of the digital barometer design, Proteus software is used to simulate the whole system [9,10]. Simulation process is divided into schematic drawing, program debugging, system operation simulation, after the above series of work is completed, enter a series of pressure value on the MPX4115 barometric pressure, check the display value on the LCD monitor to authenticate the function of digital barometer. The input values and display values are as shown in Table 1:

Table 1 comparison of input value and display value of barometer

input value[hpa]	display value[hpa]
850	849.94
900	899.92
950	949.95
1000	999.96
1050	1049.96

The above data shows that the input value is the absolute barometric pressure value and the output is the value processed by the V/F conversion and SCM. Due to the calculation process in the process of conversion, the display precision takes only 2 digits after the decimal point. There is a certain error in the data, but the total error rate is within 0.1% to meet the design requirements.

Conclusion

In this design, SCM is used as the main control unit, baroceptors, V/F devices and other components are used for information processing, and ultimately the pressure information displayed on the LCD, which has the advantages of easy to use, high precision, simple display compared with the traditional baroceptor. There is a certain increase in interference ability and stability than pure hardware circuit barometer. This design method can provide a new idea for instrument design.

References

[1] Tian Haiyan,Design of digital barometer system based on MS5534C,Ordnance Industry Automation. 31(2012)86-88.
[2] Chen Qing, Disturbing factors of digital measuring instruments and countermeasures ,Telecom World.3(2014)61-62.
[3] Fang Liuhai,Design of precise digital barometer based on BMP085,Electronic Design Engineering. 24 (2014) 69-71.
[4] Zhu Ye,Design of digital barometer controlled by single chip microcomputer, Modern Electronic Technology.16(2015) 100-105.
[5] Lei Furong, 51 SCM common module design query manual, second ed., Tsinghua University Press, Beijing,2016.
[6] Li Zhaoqing. Microcontroller theory and interface technology fourth ed., Beijing Aerospace University Press, Beijing, 2013.
[7] Gu Shuzhong. Altium designer tutorial - schematics, PCB design and simulation second ed., Publishing House of Electronics Industry. Beijing, 2014.
[8] Cao Wandan,AVR-based intelligent digital barometer optimization, Master, Wuhan University of Science and Technology, Wuhan,China,2009.
[9] Liu Shubo, et al. Design of the barometer alarm system based on Proteus,Electronic Design Engineering. 8(2015)100-102.
[10] Deng Hubin, et al. Principle and application technology of SCM - based on Keil C and Proteus simulation, People's Posts and Telecommunications Press, Beijing, 2014.