Design of Single Phase Voltage Inverter Control Circuit Based on Single Chip Microcomputer

Qiaoping Su¹, Yuan Liu ², Shijie Wu¹

¹Institute of Intelligent manufacturing, Anhui Xinhua University, Hefei, China
²Department of medical devices, Anhui Medical College, Hefei, China

*Corresponding author e-mail: suqiaoping@axhu.edu.cn

Abstract: In this paper, a control circuit is designed, which can reverse the direct current into alternating current. This circuit is based on STC12C5A60S2 MCU, using its PCA function to achieve two SPWM signals, then inverts DC 12V to AC 24V. The data test shows that the AC voltage obtained by this device is stable and the frequency error is small, so it can be applied to the demand field of small-scale inverters.

1. Introduction

With the emergence of IGBT, inverter based on IGBT has been widely used in small and medium-sized inverter power supply circuit. Micro control chip is widely used in single-phase voltage source inverter control circuit because of its high speed and high intelligence[1]. This design is based on STC12C5A60S2 microcontroller and IGBT as the switching device, which can achieve DC 12V inverter to AC 24V circuit design.

2. Overall scheme design of the system

The overall block diagram of the system is shown in Figure 1, mainly including controller module, boost module, DC/AC module, Buck module, filter module, etc. The controller module selects STC12C5A60S2 as the control core, and uses its PCA function to realize two SPWM pulse wave outputs to control the DC / AC module. The DC / AC module converts the SPWM pulse signal into sine wave. The boost module boosts DC 12V to DC 34V to provide the conversion power supply for the DC / AC module. The function of the buck module is to convert the DC 12V to the controller work voltage. The filter module converts the sine wave power supply with burr output from DC / AC module into pure sine wave power supply.

3. Hardware design of the system

3.1 Design of minimum system circuit and power supply for single chip microcomputer

The minimum system circuit of STC12C5A60S2 MCU includes power supply circuit, crystal oscillator circuit, key reset circuit and STC12C5A60S2 MCU chip. The power supply circuit converts the input voltage of 12V DC into the power supply voltage that can be accepted by the single chip microcomputer. The current of single chip microcomputer is small, and the current is less than 100mA in normal operation. LM7805 can reduce the voltage and convert 12V power supply voltage to 5V voltage, which can meet the requirements.
3.2 Boost circuit design
The output voltage of the system is designed to be AC 24 V, so the power supply voltage of DC / AC module circuit needs to be 24√2 V, that is 34 V. Therefore, the system adopts LM2577 non isolated DC / DC boost module for boost, and its circuit is shown in Figure 2. There is a switch between the 4th pin and the 3rd pin in lm2577 chip, through which the on and off can be controlled. When the switch is on, the input current charges the inductor through the inductor and switch tube; when the switch is off, the inductor supplies power to the load through the freewheeling diode D4. The inductor and input are added to achieve the boost. The output voltage is fed back to the chip through the partial voltage of the proportional resistor R6 and W1. The chip adjusts the duty cycle of the output square wave through calculation, so that the output voltage is stable at 34V.

3.3 Circuit design of DC / AC module
This system uses full bridge inverter circuit to convert DC to AC. The circuit is shown in Figure 3. Q1 ~ Q4 in the figure are IGBT tubes, and the model used is FGA25N120. FGA25N120 includes two devices: field effect transistor and bipolar triode, which have the comprehensive advantages of the two devices. In the figure, an IR2104 can drive two channels of FGA25N120 at the same time, U1 drives
Q2 and Q4, and U2 drives Q1 and Q3. The second pins of U1 and U2 are connected to the SPWM signal output pins of p1.3 and P1.4 respectively[2-4]. The LC filter module is composed of L1 and C3, which converts the sine wave power supply with burr output from DC / AC module into pure sine wave power supply.

Figure 3. Schematic diagram of DA / AC module circuit.

4. Software design of the system

4.1 General flow chart
The software of the system is mainly to program STC12C5A60S2 MCU. The overall flow chart of the system software is shown in Figure 4. First initialize p1.3 and P1.4, then initialize PCA and timer, and then wait for T0 timer to interrupt. SPWM waveform is generated by timer T0 interrupt service program.

Figure 4. Overall flow chart of the system.
4.2 SPWM waveform generation

4.2.1 SPWM waveform design initialization
STC12C5A60S2 MCU has PWM module circuit, including PCA counter, PCA capture mode, 16 bit software timer mode, high-speed output mode, pulse width regulation mode and other functions. Pulse width regulation mode is a technology that uses program to control the duty cycle, period and phase of waveform. It only needs to set its PWM register to generate two PWM signals. SPWM is also a kind of PWM, but their output form is different. SPWM is more complex, PWM signal after different time and duty cycle to get sine wave SPWM signal. In the program, the data of different duty ratio are put in an array, and the MCU can call the data in the array at different times by using the timer. In this design, there are 54 PWM array data, and the array is PWM [54] = {255, 240, 226, 211, 196, 182, 168, 154, 141, 128, 115, 103, 91, 80, 69, 59, 50, 42, 34, 27, 20, 15, 10, 6, 3, 1, 0, 0, 1, 3, 6, 10, 15, 20, 27, 34, 42, 50, 59, 69, 80, 91, 103, 115, 128, 141, 154, 168, 182, 196, 211, 226, 240, 255}[5-7].

In order to realize the output of SPWM signal, the timer and PCA should be used together. Timer initialization and PCA initialization are the key points.

The timer initialization procedure is as follows:
- TMOD = 0x21; // counter 0 works in mode 1
- TH0 = 0xf7; // the count value of T1 is 2048
- TL0 = 0xff; // low count value of T1
- AUXR = 0xc0; // all counters work in 1T mode.
- ET0 = 1; // counter 0 interrupt
- TR0 = 1; // turn on counter 0
- SC0N = 0x50;
- TH1 = 0xff;
- TL1 = TH1;
- PCON = 0x00;
- EA = 1; // start total interrupt
- TR1 = 1; // start timer

The main function of this initialization is to set the working mode of the timer T0 to mode 2, which can automatically reset the count value when the timer T0 overflows.

PCA initialization procedure is as follows:
- CMOD = 0x02; // the overflow of counter 0 is the clock source of PCA counter, allowing PCA interrupt enable
- CCON=0x00;
- CCAPM0 = 0x42; // 8-bit PWM output, no interrupt
- CCAPM1 = 0x42; // 8-bit PWM output, no interrupt
- CL = 0x00; // clear PCA counter
- CH=0x00;
- CCAP0L = PWM [0]; // initialize the duty cycle of SPWM output
- CCAP0H=PWM[0];
- CCAP1L = PWM [0]; // initialize the duty cycle of SPWM output
- CCAP1H=PWM[0];
- CR = 1; // run PCA counter

The main function of this initialization is to set the clock source of PCA counter, the number of PWM output bits and the initial duty cycle of SPWM output.

4.2.2 T0 interrupt service procedure
According to the principle of area equivalence, this waveform can be equivalent to the effect of sine wave. In the design, four SPWM signals are needed to control Q2, Q3, Q1 and Q4 respectively, and the control signals are provided by p1.3 and P1.4. The HO pin of IR2104 controlled by P1.3 drives Q2, the LO pin drives Q4, the HO pin of IR2104 controlled by P1.4 drives Q1, and the LO PIN drives Q3.
If Q2 and Q3 work in the first half cycle and Q1 and Q4 work in the second half cycle, the output signals of P1.3 and P1.4 are required to be complementary. The half cycle flag indicates that the current work is the first half cycle or the second half cycle. If the first half cycle is 0, the half cycle flag will reverse after entering the second half cycle.

The generation of SPWM waveform is mainly realized by T0 interrupt service program. First, reload the count value, and then look up the table according to the index value. Because the assignment of half cycle is 54, when the assignment is equal to 54, it means that the SPWM waveform of half cycle has been completed.\[8-9\] Turn off the PCA count, clear the index value, and reverse the half cycle flag. If the half cycle flag is 1, P1.3 outputs low level, otherwise P1.4 outputs low level, and turn off the corresponding PWM module, and set another PWM module work mode, and then turn on PCA count. Determine the half cycle flag bit again, and assign the corresponding value of duty cycle in the array indicated by the index value to CCAnH. If the index value is not equal to 54 after entering the interrupt service program, it means that the output of SPWM waveform in half a cycle has not been completed, then the corresponding value of duty cycle in the array indicated by the index value can be directly assigned to CCAnH.

5. Conclusion
This design uses the PWM function of PCA in STC12C5A60S2 single chip microcomputer. It only needs to set its PWM register to generate two PWM signals. The control is accurate. After testing, the AC frequency error and amplitude error obtained by inverter are low. A 12V battery is used as the input, and the output waveform is observed by the oscilloscope. The sine wave is very standard. The incandescent lamp, small motor and other electrical appliances are tested, and they work properly, which can meet the expected function.

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