Three-phase Inverter Based on STC8A8K Controller

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Abstract. The fundamental principle of the three-phase inverter is introduced in this paper. The method of how to generate sine table is detailed analyses in this paper. The detailed set of the register in the controller and the interrupt code are given. Detailed analyzed and calculated about the device choice were discussed. Experimental results are given, which improve the correctness of the method.

1. Introduction

Three phase inverter is widely used in the AC driver, active power filter and reactive power compensation, renewable energy generation fields etc. The main power interface unit is three-phase three-leg structure; it can be used for three-phase balance load for example electrical machinery [1,2]. The circuit structure is shown in Figure.1.

![Figure 1. Schematic diagram of three-phase inverter](image)

2. Fundamental principle

The three-phase sinusoidal reference signal that is to say modulation signal is:

\[
\begin{align*}
V_A &= V_0 \cos \omega_0 t = M V_{DC} \cos \omega_0 t \\
V_B &= V_0 (\cos \omega_0 t - 2\pi / 3) = M V_{DC} \cos(\omega_0 t - 2\pi / 3) \\
V_C &= V_0 (\cos \omega_0 t + 2\pi / 3) = M V_{DC} \cos(\omega_0 t + 2\pi / 3)
\end{align*}
\]

In the formula, \( V_{DC} \) is half of the DC bus voltage, \( V_0 \) is the amplitude of the out voltage, \( M = V_0 / V_{DC} \) is modulation index, and it is in the range of 0 and 1. If \( M > 1 \), it is named over-modulation, and the output harmonic will be increased.

The difference of the phase-voltage is the line-voltage.
The PWM (Pulse Width Modulation) technology is widely used in AC-DC, DC-DC and DC-AC converter which are controlled by open-loop or close-loop. The amplitude, frequency and phase of the output of the three-phase inverter can be adjustable by use sinusoidal pulse width modulation (SPWM) control method. It has three PWM methods. They are natural sampling PWM, uniformly sampling PWM and direct PWM. Every PWM method has its characteristic and advantage and shortcoming including the difficulty of realize the harmonic content and the maxim of the modulation. The uniformly sampling PWM is a linear sampling process in fact, the mathematical derivation is simple, and it can be easily realized through software by micro-controller or DSP.

Three-phase inverter power was researched in this paper. The STC8A8K micro-controller was used as controller. Using uniformly sampling method, a symmetrical three-phase inverter power was realized in this paper. Experimental results are given, which improve the correctness of the method.

3. Design of software

STC8A8K controller is a strong 8051 MCU. This series MCU of STC8A8K has four group programmed counter array (PCA/CCP/PWM) modules. Soft timing, out pulse capture, high speed pulse output and PWM output can be realized through these modules. SPWM signal can also be realized by software.

Look-up table method is the simplest method that can create sinusoidal wave. Of course real-time calculation method can also be used, but this method will spend more running time. So we create a sinusoidal table, this table has N sinusoidal data; these data include whole 360 degree. The type of the data is 8 bit unsigned char. Every period, a sinusoidal data will be read from the table, and then it will be written to the duty ratio register.

The clock source of the PCA module has nine types that can be selected. In this design, we select the overflow of the timer 0 as the clock source of the PCA module. The main clock of the system was set as 24MHz in the ISP (In System Programmable) software. Every five clock the timer 0 will be overflow that was set in the software. So the clock of the PCA module is 24MHz/5=4.8MHz, the PCA module is eight bits, so the SPWM carrier is 4.8MHz/2^8=18.75kHz, if we want to get 50Hz power supply, the number of the sinusoidal table is 18.75kHz/50Hz=375, the distance of the data and data is 360°/375=0.96°, the period of the PWM interrupt is 20ms/375=53.3us.

The data table’s current location is index by a 16 bit pointer variable; this pointer can index whole 360 degree. When the pointer is zero, it means 0 degree, and when the pointer is 374, it means 359.04 degree. The pointer is adjusted in the interrupt function which is triggered by the falling edge of the PWM signal. The fixed shift is added to the pointer in the function to realize phase shift. In this design, 125 can provide 120 degree phase shift, and 250 can provide 240 degree phase shift. In every PWM interrupt, these two shift values were added to the current pointer, so we can get the other two phase’s sinusoidal pointer. When the pointer is reach to 375, it must be return to zero. The formula of how to create the sinusoidal is shown in the following

\[
\text{Sin table } [i] = \text{INT}[127*(1+\sin(i*2\pi/375))+1]
\]

This formula means the maxim amplitude, if the 127 is reduced, the amplitude of the signal will be reduced. If the pointer is same, the phase is changeless. Muliplegroups sinusoidal table maybe used in the PID control program which can adjust the signal amplitude.

The initializes flowchart of the PWM module is shown in the Figure.2.
The interrupt function of the PWM module is shown in the following code.

```c
void PWMint(void) interrupt 7
{
    CCAP1H=sin_table[AmFactor][order];
    CCAP0H=sin_table[AmFactor][(order+125)%375];
    CCAP2H=sin_table[AmFactor][(order+250)%375];
    order++;
    if (order==375) order=0;
    CCON&=0x78;
}
```

We use PID algorithm in the feedback control, the algorithm structure is shown in Figure 3 [3, 4, and 5].

![Figure 3. Schematic diagram of the PID algorithm](image)

4. Design of hardware

The MOSFET model is STP80NF70, TO220 footprint. The maxim On-Resistance of this MOS is 9.8mΩ, and the maxim drain current is 98A.

The driver chip we selected is EG3013. Dead-time circuit and auto lock logic circuit were integrated in the chip which is for cross-conduction prevention. The big driving current can be used to drive N-channel power MOSFET or IGBT. The chip need few peripheral devices and has SOP-8 footprint. The power dissipation of this chip is ultra-low.

The filter circuit we select is LC low pass filter [6]. The cut-off frequency of the filter is

$$f_0 = \frac{1}{2\pi\sqrt{L_0C_0}}$$

(3)

The frequency of the inverter output is 50Hz; the frequency of the carrier is 18.75 kHz. Three frequencies must be satisfied to the following formula

$$f << f_0 << f_k$$

(4)
The characteristic impedance of the LC filter circuit is

\[ Z_0 = \sqrt{L_0/C_0} \]  \hspace{1cm} (5)

The relation of the load \( R_0 \) and \( Z_0 \) is shown in the following formula

\[ Z_0 = (0.5 \sim 0.8)R_0 \]  \hspace{1cm} (6)

In this system, the load \( R_0 \) is 10Ω, so we decide use the inductance of 1mH and it is made of sendust magnetic rings by bifilar winding to further reduce the distribution parameters and the CBB capacitor we selected is 20μF.

5. Test results
Waveform of three phase voltage is shown in Figure 4, in this waveform, the load \( R_0 \) is 10Ω, star-connected; the current is 1.2A.

![Figure 4. Waveform of Three Phase Voltage](image1)

The grid driver waveform of A and B phase is shown in Figure 5.

![Figure 5. Grid driver waveform of A and B](image2)

6. Conclusions
A three-phase inverter is designed with STC8A8K series of microprocessor. The main parameter of the design is detailed discussed in this paper. The prototype is made and the experiment data shows: this prototype has fast dynamic response, high intellectualized, reliable protective, high efficiency.
7. References

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