

# Research of Photovoltaic Inverter Based on UC3854

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**Abstract**—A research of photovoltaic inverter based on UC3854 is proposed in this paper. UC3854 is a type of dedicated chip applied in control of active power factor correction. This paper uses voltage and current amplifiers of UC3854 to realize the double closed-loop control. Both the main circuit and the drive circuit are designed to be modular. All these improve the stability and anti-jamming ability of the system. Some new devices, such as ICL8038 and 34063 are used in this inverter. Based on them, the sinusoidal signal output, as well as the power design in the system, becomes quite easy and simple. With a simple structure, the inverter is convenient to operate. In addition, the prototype based on UC3854 is developed in this paper. It can supply power for the local load and make economic and social benefits.

**Keywords**—Photovoltaic invert, UC3854, ICL8038, SPWM

## I. INTRODUCTION

As the traditional resources have become rare, renewable resources are developing quickly. Photovoltaic (PV) generation is one of them, and has been developing a lot. In this background, a variety of inverter control technologies have been appeared to reduce the cost of solar power. However, in the market, most inverters are designed with high-end digital chip. Considering some small application field without needing high accuracy, if the conventional method is applied, there will be disadvantages, such as high price and complex design of the system. Therefore, after a comparative study, this system adopts integrated chip UC3854 as the main controller. The chip is mainly used for Power Factor Correction. But it is possible to design the control loop due to its specific voltage and current error amplifier and internal analog multiplier.

By system testing, the design based on UC3854 can completely power the local load. The output PWM waveform is very good, and the inverter output voltage is sinusoidal wave. Therefore, the rationality and feasibility of this design are verified, the use of UC3854 is enriched and its application field is extended. So the system based on UC3854 has certain practical value.

## II. STRUCTURE AND PRINCIPLE OF PV INVERTER BASED ON UC3854

### 1. Introduction of UC3854

IC UC3854 is a type of dedicated chip applied active power factor correction circuit. The internal structure is shown in Fig.1 [1]. The UC3854 mainly consists of four parts: a voltage amplifier, an analog multiplier, a current amplifier, and a fixed-frequency PWM generator which contains oscillator, comparator as well as flip-flop.

The core of UC3854 is the multiplier, whose output is considered as the current detection reference. As shown in Fig.1, the output of voltage amplifier is connected to the A side of multiplier. The B side signal is 6 pin IAC, which has the function of voltage modulation. The VRMS input compensates for line voltage changes and keeps the input power constant with varying input voltage. To do this, the voltage applied to pin 8 is squared in the UC3854, and then used as a divisor by the multiplier block. The multiplier output, at pin 5, is a current that increases with the current at pin 6 and the voltage at pin 7, and decreases with the square of the voltage at pin 8. The output of current amplifier is connected to the pulse width modulation (PWM) comparator, and compared with triangular wave from pin 14. At last, the output SPWM (sinusoidal pulse width modulation) wave is generated. A resistor from RSET to ground will program oscillator charging current and maximum multiplier output [2].

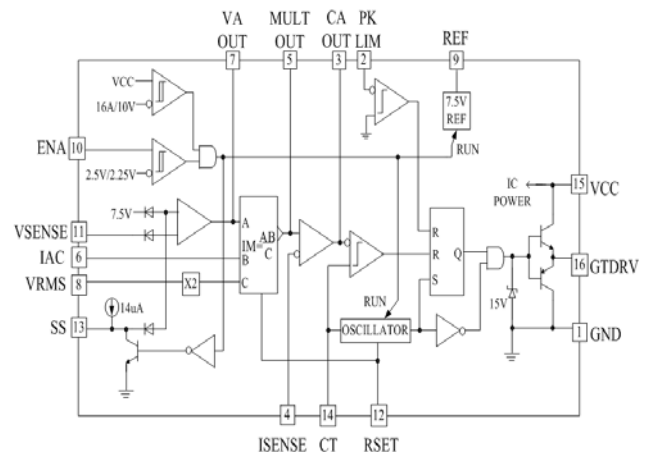


Fig. 1: The internal structure of UC3854

In addition, as the output holding potential is set up at 15V in the internal of UC3854, the signal for power IGBT gate driver will not be too strong.

### 2. Inverter topology structure

The system topology structure is shown as Fig.2. This inverter comes from the second half part of the PV power generation system. The batteries are charged up from the solar panels. By the PV controller, the power is converted to DC 24V, which can power the load, and at the same time can supply power for this inverter. In structure, full-bridge structure has been applied in the main circuit. By using L-filter, the inverter is connected the load. Moreover, after inverter output voltage and current are sampled by the control circuit, the PWM pulses will be generated to drive full-bridge inverter circuit. In the main circuit, the circuit is designed to be modular, which enhances anti-jamming capability and stable performance

of the system, and improves the circuit integration as well.

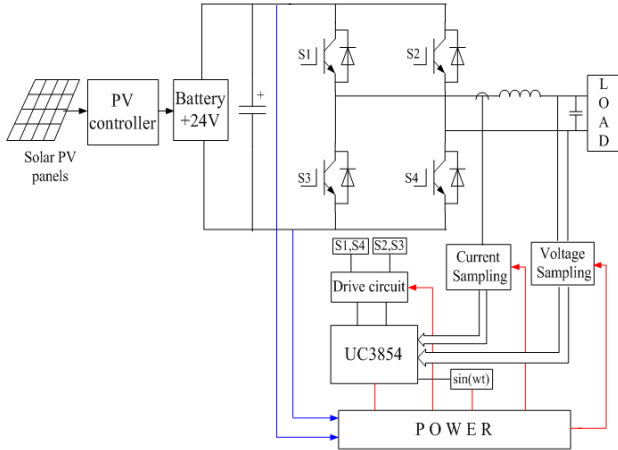


Fig. 2: System topology structure

### 3. Principles of PV inverter based on UC3854

In this paper, double-loop control is formed by using voltage and current error amplifiers. The control block diagram of this inverter is shown as Fig.3.  $U_{ref}$  is considered as the given reference voltages and  $U_0$  is the feedback of the voltage outer loop. Through the sampling circuit, inverter output voltage is connected to the input of the voltage error amplifier. After this output voltage and 7.5V reference voltage are compared in comparator, the resultant error of voltage external loop with PI regulator is directly connected to the A side of multiplier [3].

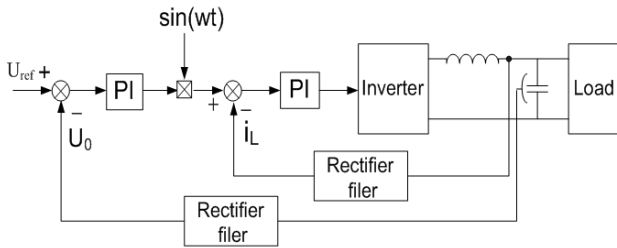


Fig. 3: The control block diagram of inverter based on UC3854

In addition, an analog multiplier in the chip creates the current reference signal by multiplying the line voltage with the outer loop error amplifier, so that the current reference signal has the sinusoidal shape and links with current error amplifier. After PI regulation, the output of current amplifier makes comparison with triangular wave from pin 14, so a sinusoidal pulse width modulation (SPWM) technology is applied in the design.

### III. THE MAIN CIRCUIT DESIGN OF INVERTER BASED ON UC3854

In the paper, full-bridge inverter structure has been applied in the design. The main circuit is designed to be modular. As shown in Fig.4 [4], this module is integrated with isolation drive part, half-bridge of power electronic devices, as well as buffer protection circuit. Compared to the conventional circuit, the modular design has several advantages, such as high integration, strong anti-jamming and more stable performance. Therefore, the various parts are tied very closely and can directly connect to these chips, such as UC3854, DSP, microchip, and other

integrated chips, without using isolation circuit and drive circuit.

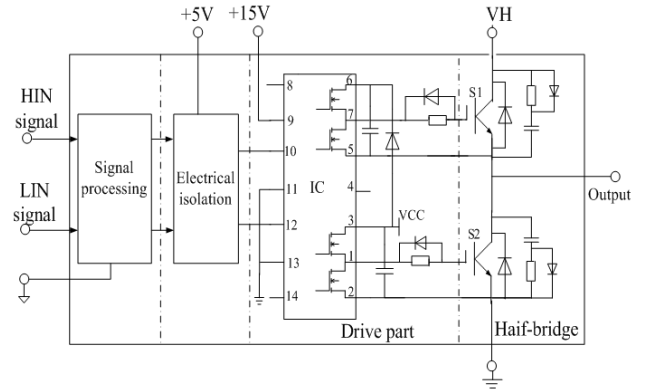


Fig. 4: Half-bridge module diagram

In this design, one module consists of two up-down bridge arms in series, and each of bridge arms consists of a controlled device and an anti-parallel diode in parallel. Therefore, single-phase inverter will only need two modules. At first, the control signals of up-down bridge arms are generated by UC3854, and then go to the signal processing part. According to the requirement of up-down bridge arms, dead time can be chosen to join between the control signals. After that, the signals are made inverse and enter the next stage. Electrical isolation part can realize isolation between control circuit and main circuit, and provides logic input for the driver part. Through the shifting of level and output protection in the driver part, signals can be converted into PWM pulses which have enough power.

### IV. THE CONTROL CIRCUIT DESIGN OF INVERTER BASED ON UC3854

#### 1. General design of control circuit

The general design of control circuit based on UC3854 is shown as Fig.5. In the paper, IC UC3854 is the core of control circuit. Peripheral circuits consist of detection circuits, protection circuits as well as auxiliary powers. Sinusoidal modulation signal can be produced by new device ICL8038. After a double loop, the last current loop output and triangular wave in the internal are compared to generate SPWM wave.

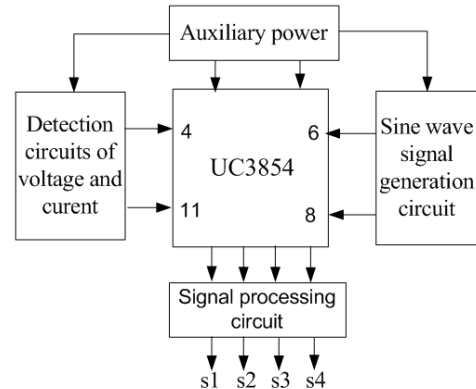


Fig. 5: The general design block diagram of control board

#### 2. Sine wave signal generation circuit

Modulation signal at pin 6 of UC3854 comes from sine wave signal generator based on ICL8038. The package of

this chip is DIP14. It can produce high-precision sine with a minimum of external components. As shown in Fig.6, when this signal generator is designed, pin 7 and 8 should be connected directly. The principle of the circuit is shown as follow: an external capacitor C11 is charged and discharged repeatedly by two current sources to generate triangular wave. Current source 2 is switched on and off by a flip-flop, while current source 1 is on continuously. Through the nonlinear conversion circuit in the chip, triangular wave can be converted to sine wave signal conveniently [5].

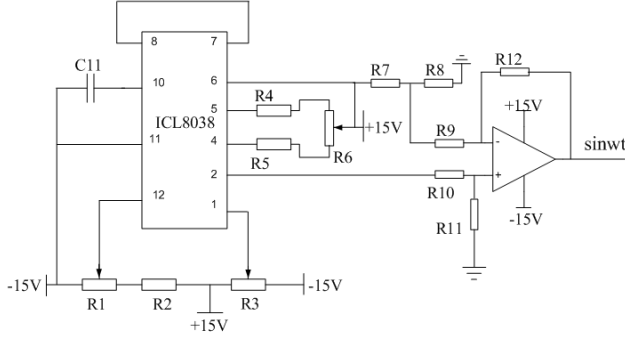


Fig. 6: Sine wave signal generation circuit

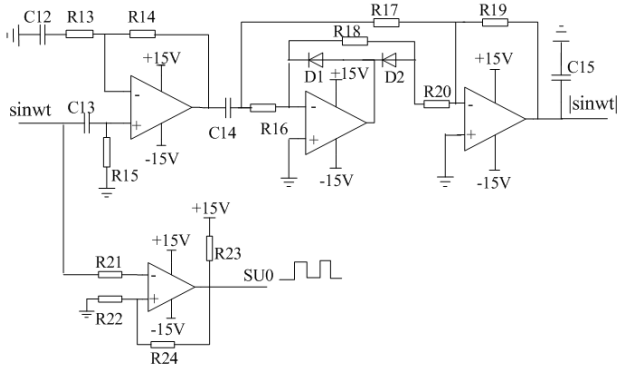


Fig. 7: Rectifier and zero-cross detecting of sine wave signal

In Fig.6, Sine wave signal generation circuit based on ICL8038 is shown. The operational amplifier plays a proportional regulation role in the circuit. As shown in Fig.7, the upper part of the circuit is a precision rectifier part of sine wave signal, which can turn the negative half-cycle waveform. The lower half is the zero-cross detecting circuit. By this circuit, the sine wave signal can be converted to a square-wave signal.

### 3. Detection circuit of inverter current and voltage

In this paper, Hall sensor produced by LEM Company is adopted to carry on data sample, including voltage and

current. Through precision rectifier circuit, the sampling signal is converted to positive signal, and then sent to UC3854. Hall sensor has great advantages, such as good electrical isolation performance, high measurement accuracy, good linearity, high anti-interference ability, fast response and easy installation. The detection circuit of inverter voltage is shown as Fig.8 [6].

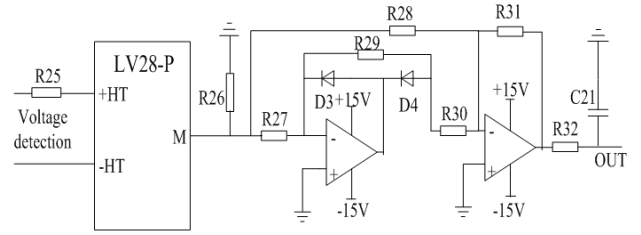


Fig. 8: The detection circuit of inverter voltage

In the detection circuit of inverter current, LA55-P Hall sensor is adopted. Its basic circuit is similar to the voltage detection circuit.

### 4. Generation of PWM modulation wave

In the control circuit, pin 3 and 4 pin of UC3854 constitute the inner current loop, at the same time pin 7 and pin 11 constitute the outer voltage loop. IC ICL8038 connected pin 6 is employed in modulated signal design. The output (pin 3) of current amplifier is connected to the pulse width modulation (PWM) comparator. At last, the output SPWM wave is generated.

The frequency of triangular wave is controlled by pin 12 and pin 14, calculation formula is as below:

$$f = \frac{1.25}{R_{set} C_t} \quad (1)$$

By logic synthesis circuit, the output of UC3854 is changed to two-channel complementary PWM control signals [7]. In this circuit, IC 74LS05 and 74LS09 are applied. The middle part is level-shifting circuit from 15V to 5V.

The detailed circuit design is shown as Fig.9. Where,  $SU_0$  is the output of zero-cross detecting circuit. It might also be noted that IC 74LS05 requires external pull-up resistors for proper logical operation due to its open-collector outputs. In particular, the pull-up resistors of S23 and S14 are set to 390 ohm after repeated.

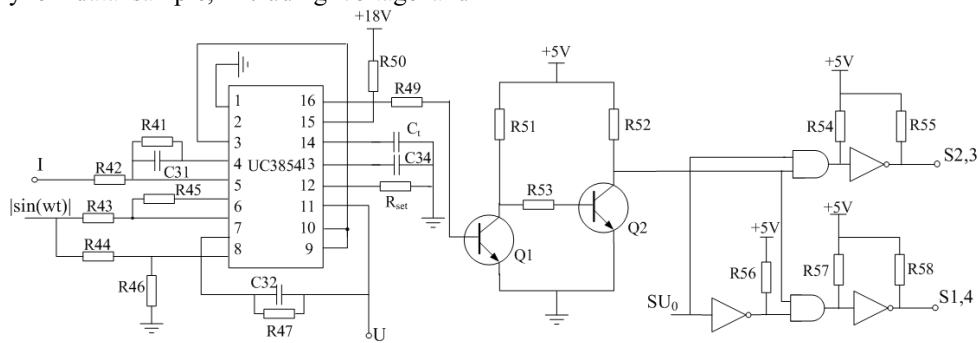


Fig. 9: Generation of PWM modulation wave

## V. THE RESULTS OF EXPERIMENT

In this paper, the prototype of inverter based on UC3854 is tested. The system circuit is shown as Fig.2. A monitor produced by YAAN Company of Tianjin is used as the load, whose power is AC24V/50Hz. At the end of the system, there is a LC filter. The value of the inductance and the capacitance is 1mH/10A and 200uF/50V respectively. The test waveforms of circuit are as follows:

Sine wave signal based on ICL8038 is shown ( $f=50\text{Hz}$ , 10V/grid):

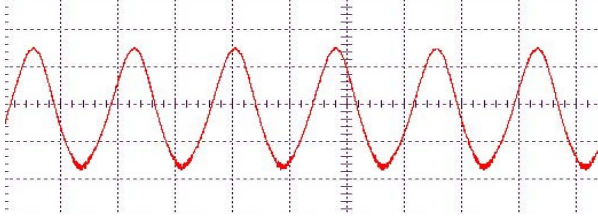


Fig. 10: Sine wave signal based on ICL8038

The output waveform of zero-cross detecting circuit is shown (the blue part, 10V/grid):

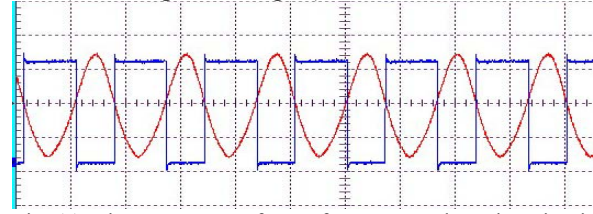


Fig. 11: The output waveform of zero-cross detecting circuit

Rectifier output waveform is shown (the red part,  $f=50\text{Hz}$ , 5V/grid):

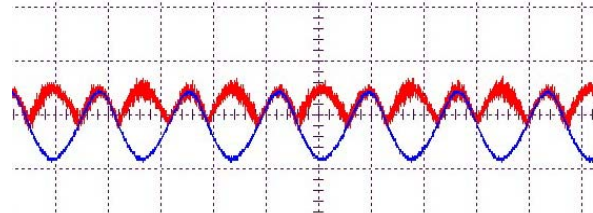


Fig. 12: Rectifier output waveform

By logic synthesis circuit, the output of UC3854 is changed to two-channel complementary PWM control signals, shown as Fig.13. These pulses are used as the gate drive signals of power switching devices. Fig.14 shows the inverter voltage waveform (the monitor power). In this figure, there is some gentle slope between the positive and negative section because of dead zone between the control signals. The dead zone is caused by the minimum value of triangular wave. As shown in Fig.15, the triangular wave is generated by the UC3854 internal oscillator.

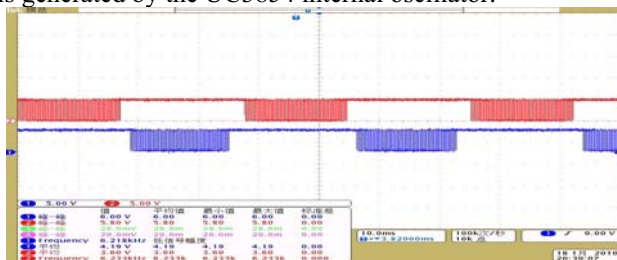


Fig. 13: PWM control signals after logic synthesis circuit

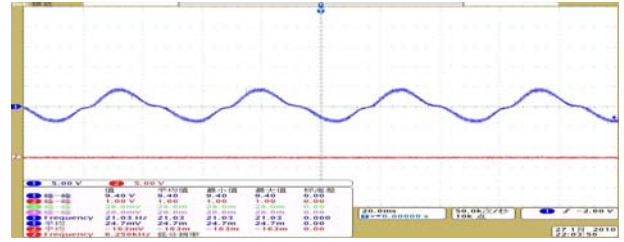


Fig. 14: The inverter voltage waveform

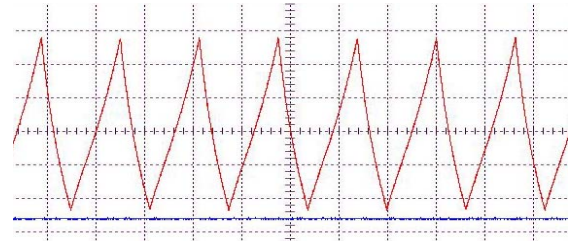


Fig. 15: The triangular wave generated by the UC3854 internal oscillator

## VI. CONCLUSION

In this paper, the inverter based on power factor correction IC UC3854 is researched. A double closed-loop control scheme due to its specific voltage and current error amplifier of PI regulator is adopted. The prototype based on UC3854 is developed in this paper. It can supply power for the local load. The experiment results indicate that the system can satisfy the design requirement. Therefore, the application field of UC3854 is extended, and the system based on UC3854 has certain practical value.

## ACKNOWLEDGMENT

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