Single-Phase Sine Wave Frequency Inverter Power Supply

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Abstract. Single-phase sine wave frequency inverter power supply can be used to convert Direct Current (DC) into Alternating Current (AC) in order to power up some ac device when people only have dc power. Our design is to create a device that we can change its frequency and output voltage. So we use inverter circuit to produce ac current and use Microcontroller to change its frequency. Eventually this circuit can generate 40-50Hz sin waves which can be used to replace ac power in some situation.

1. Introduction
As present, the standards of electrical source are not uniform, so inverter power has board ways. Inverter supplies can be used in car electrical device or boat device where it is very hard to find ac power. The uniform frequency of ac power in Chinese is 50Hz, but sometimes people need higher frequency supplies to support the device, use inverter people can get fixed or variable frequency. The input of inverter can be cell or battery. So it is very convenient and portable. The development of sine wave inverter power supply can bring considerable social and economic benefits.

Under the investigation of current study, the uniform design of inverter always have Power MOSFET, control ship and Sinusoidal Pulse Width Modulation (SPWM) generator [1]. There are two ways to generate SPWM. First one is to use single ship and software to generate SPWM wave. Second one is to use hardware circuit to generate it. SPWM scheme functions by comparing a modulating sinusoidal signal at desired output frequency with a high frequency (in KHz range) triangular signal acting as a carrier. This wave is used to control turn-on and turn-off devices like.

This project uses chip EG8010 to generate SPWM waves, because it will be easier than use software and there are many resources on the internet and chip to use. Use hardware can save the space of single ship, Central Processing Unit (CPU) can do other sophisticate work. Then we use IR2110 to drive full bridge circuit and use STM32 to control EG8010 generate the SPWM wave [2] [3]. STM32 is used to send the frequency or voltage information to EG8010’s serial port. Based on the message, EG8010 use voltage feedback system and SPWM modulating process to control switching devices [4] [5]. And in Fast Fourier Transformation (FFT) the SPWM is equal to sin wave [6]. When the inverter is connected to load, the output will be equal to ac power.

Our circuit can invert dc voltage into ac voltage and its frequency can change between 20Hz-100Hz, peak voltage of sine wave is determined by the dc input. The effectiveness of this device is 90% and total harmonic distortion (THD) is smaller than 2%.

2. System Design
As shown in the Figure 1. The entire system is composed of full-bridge, control chip STM32, SPWM generator chip EG8010, LC filter and driver chip IR2110. The output of LC filter is ac voltage.
STM32 can take sample of output and compare sampling voltage with given voltage, if there are differences, STM32 can send control information through serial port to EG8010 and let EG8010 change the duty cycle of SPWM. The small signal sent from EG8010 can be magnitude through IR2110 and enough to drive the full-bridge.

![Cross-section Dimension of RHS/SHS](image1)

**Figure 1** Cross-section Dimension of RHS/SHS

### 3. Hardware Design

#### 3.1. Full-bridge and sinusoidal pulse width modulation

Basic full bridge circuit is showed in Figure 2(a). Q1, Q2, Q3 and Q4 are MOSFETs. It is equal to switch in circuit. When Q1 and Q3 open, $U_{out}$ is equal to $U_{in}$. When Q2 and Q4 open, $U_{out} = -U_{in}$, so there are two basic output of full-bridge, $U_{in}$ and $-U_{in}$. The output wave of full-bridge is showed in Figure 2(b). And the full bridge PCB circuit is shown in Figure 3.

![Full bridge circuit](image2)

**Figure 2** (a) Full bridge circuit, (b) Output of full-bridge

![Full bridge PCB circuit](image3)

**Figure 3** Full bridge PCB circuit
The generation of desired output voltage is achieved by comparing desired reference waveform (modulating signal) with a high-frequency triangular ‘carrier’ wave as Figure 4(a) depict. Depending on whether the signal voltage is larger or smaller than the carrier waveform, either the positive or negative dc bus voltage is applied at the output. When \( U_{ac} > U_{am} \), output is equal to \( U_{in} \). If \( U_{ac} < U_{am} \), \( U_{out} = -U_{in} \), the result is showed in Figure 4(b). Note that over the period of one triangle wave, the average voltage applied to the load is proportional to the amplitude of the signal (assumed constant) during this period. Because inductance can delay the change of current. The resulting chopped square waveform contains a replica of the desired waveform in its low frequency components, with the higher frequency components being at frequencies of an close to the carrier frequency. In FFT analyze the output voltage is equal to sin wave voltage. The only difference is output voltage contain many high frequency harmonic. All the harmonic wave superimposed with base wave and become the result showed in Figure 4(b). When the square voltage go through LC filter, only low frequency can pase the filter and high-frequency part go through the capacity. Inductance have the attribute to keep the constant of current, so the square wave can be converted into constant wave showed in Figure 5. With right inductor and capacity, the output voltage can be very smooth.

![Figure 4 (a) Pulse width modulation (b) Output voltage](image)

![Figure 5 Output voltage of LC filter](image)

### 3.2. SPWM generator EG8010

EG8010 is a digital sin wave inverter generator chip with dead band control. It can be used in DC-DC-AC two stage power converting or DC-AC one phase step-up transformer. It has to be connected with 12MHz crystal and can accomplish high accuracy and low distortion with minimum harmonics. EG8010 belongs to CMOS chip and it is composed of SPWM generator circuit, dead time control circuit, protection circuit, RS232 serial port and 12832 serial port drive module. EG8010 has two working module, unipolar modulation and bipolar modulation. In unipolar modulation only one bridge arm (EG8010 port SPWMOUT3, SPWMOUT4) works as SPWM modulation output. The other bridge arm works as basic wave output. In real situation filter inductance should be connected with modulation bridge arm. The voltage feedback also should be connected with SPWM modulation bridge arm as showed in Figure 6(a). In bipolar modulation two bridge arm both work as SPWM output and the output can be better if using two symmetry filter inductance in high and low bridge arm as showed in Figure 6(b).
In unipolar modulation, EG8010 can collect output of inverter’s AC voltage signals through port13(VFB). The peak of feedback voltage is compared with reference voltage. When the output is higher than reference voltage, through a operational amplifier the duty cycle of SPWM will decrease and output voltage will decrease too. Vice versa. The port IFB can collect the load current of inverter, so it can be used in overcurrent protection. The reference voltage of this port is 0.5V. Sometimes when the load current is too large. EG8010 can shut down all the MOSFET and set bridge arm output to 0. This situation will be kept until port IFB voltage is lower than 0.5V. The DT0 and DT1 port is used to set dead time, which is the most important parameter of MOSFET because without dead time, the MOSFET in the high bridge and low bridge maybe open in the same time, that means the input voltage is directly connected with ground. So the current pass through MOSFET will be very large and eventually burn the MOSFET. So EG8010 has dead time control. The input of ‘DT1DT0’ decide dead time (Figure 7(a)). ‘00’ means 300nS, ‘01’ means 500nS, ‘10’means 1uS, ‘11’means 1.5uS. Control single chip STM32 can communicate with EG8010 through serial port RS232 (Figure 7(b)). STM32 can set the output voltage, frequency and deadtime. In order to avoid the interference, this design use optocoupler to communicate.

3.3. Driver ship IR2110

The driver circuit is composed of IR2110 (Figure 8(a)) which is full-bridge drive chip (Figure 8(b)). It has two input ports HIN and LIN, two output ports HO and LO correspondent with input ports. So one IR2110 can control high and low bridge arms in the same time. The complementary two SPWM
signals are entered in low and high ports LIN and HIN. Through IR2110 input signals are amplified into higher voltage and are able to open and turn off the MOSFET. So with two IR2110 the circuit can control four MOSFETs. The two MOSFETs in the diagonal position Q2 and Q3 use the same drive signals. The other two MOSFETs use the complementary signal. Because two bridge which are in the diagonal position open in the same time during a cycle and compose a current loop.

Figure 8 (a) IR2110 circuit, (b) Full-bridge circuit

The IR2110/IR2113 are high voltage, high speed power MOSFET and IGBT drivers with independent high and low side referenced output channels. Proprietary HVIC and latch immune CMOS technologies enable ruggedized monolithic construction. Logic inputs are compatible with standard CMOS or LSTTL output, down to 3.3V logic. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. Propagation delays are matched to simplify use in high frequency applications. The floating channel can be used to drive an N-channel power MOSFET or IGBT in the high side configuration which operates up to 500 or 600 volts. IR2110 use bootstrap capacitor to be the ground of high input. And the value of the bootstrap capacitor is calculate in the following formula:

\[ C_1 > \frac{2 \times Q_c}{(V_{cc} - 10 - 1.5)} \]  

For example, FUJI50A/600VIGBT need 250nC gate charge \( Q_c \) to be fully conductive. If the \( V_{cc} \) is 15V:

\[ C_1 = \frac{2 \times 250 \times 10^{-9}}{(15 - 10 - 1.5)} = 1.4 \times 10^{-7} \, F \] 

3.4. Auxiliary power supply

All the chips in circuit need power supply, so in this design the auxiliary power LM2596 can provide the needed power resource, LM2596 can turn 24V into 12V and 5V. Most of the chips power supply are 12V and IR2110 need 5V to offer a reference voltage in digital circuit, as shown in Figure 9(a) and Figure 9(b).
4. Test of sin inverter
The output sin wave is shown in Table I. Using THD measurement equipment, the THD of the output
sin wave is 1.5%. When load resistant change the output voltage is shown in Table II. The load
regulation is
\[ V_r = \frac{U_0-U}{U_0} = \frac{36.1-35.5}{36.1} = 1.6\% \]

When output voltage is 36V and output current 2A, the efficiency is 90%. This design is composed
of three main part: SPWM generator, single chip control STM32 and full-bridge circuit. This design
has fulfill the desire in most situation. The output voltage can change from 0-36V and frequency can
change vary 20-100Hz. THD of the output sin wave is less than 2%, so it can meet the basic need of
most AC device. And the efficiency of the circuit is 90%.

| Table 1 Output sin wave | Table 2 Output voltage |
|-------------------------|------------------------|
| F(Hz)   | U_out(V) | THD   | F(Hz) | U_out(V) | I_out(A) |
| 20      | 20       | No distortion | 50    | 35.5     | 2        |
| 40      | 36.3     | No distortion | 50    | 35.7     | 1.5      |
| 60      | 36.2     | No distortion | 50    | 35.9     | 0.9      |
| 80      | 35.9     | No distortion | 50    | 36.1     | 0        |
| 100     | 36       | No distortion |

5. Conclusion
In this paper, we design a device that we can change its frequency and output voltage. So we use
inverter circuit to produce ac current and use Microcontroller to change its frequency. Eventually this
circuit can generate 40-50Hz sin waves which can be used to replace ac power in some situation. In
the future study, the design need more improve on increase the voltage level and frequency, now its
maximum frequency is 100Hz.

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