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Designing a PWM based Inverter for Low Power Areas using Multisim

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ABSTRACT

Power shortage is one of the common problems faced by those who live in rural and far-flung areas. The impact of electricity on households, especially to low income families is huge. When there is to no electricity, houses cannot even have a lit bulb to help them do their activities, especially during nighttime. Their livelihood is very much affected, as some of the equipment they use are powered by electricity. Due to these circumstances, a simulation has been conducted in order to test the effectiveness of a developed system composed of rectifier, a 12V rechargeable battery, and a PWM inverter. This system is suitable for usage in communities far from the city. This simple design has been proven to work through simulation on NI Multisim. The results show that the rectifier can charge the said battery, which in turn can power up the PWM inverter to an output of 220V AC.

Key words: Rectifier, Pulse width modulation, PWM inverter, power shortage, NI Multisim

1. INTRODUCTION

The energy crisis is a global issue that alarms the world, as the demand for electricity exponentially increases. Several solutions help solve the issue, such as solar energy and renewable energy. However, these solutions introduces additional costs to economically challenged members of the community. Most of the people who live in rural areas cannot afford expensive devices just to provide themselves a reliable and cost-effective power solution. Thus, an inverter can be used to supply sufficient power to those who need it [1].

Inverters are devices that can convert DC (direct current) into AC (alternating current). These inverters can give off high voltage and current even if it came from a low power source like a battery. These electronic devices are helpful when operating electrical appliances that need AC, especially when there are power cuts or power shortages [2]. The market's most available inverters operate the PWM (Pulse Width Modulation). Generally, PWM inverters use MOSFETs in their output switching stage, which are called PWM MOSFET inverters. This inverter works since the PWM keeps the output voltage at its rated voltage depending on the country. This rated voltage can be 110 V AC or 220 V AC. By changing the width of the switching frequency, the PWM inverter can correct its output voltage depending on the load connected at the output. This can be achieved by feedback, a part of the output into the PWM controller, which can be an IC. With this process, the PWM controller will do the corrections of width which will change the output voltage of the PWM, making it a constant regardless of the load variations [3]. This capability makes PWM inverters have edge and advantage over the other inverters. The output waveform of the PWM inverter has 3 types namely: sine wave, quasi sine wave, and square wave [4].

With these in mind, the students' aim is to design a system that can power up areas that have low power supplies. From this, the students first design a rectifier that can charge a 12V rechargeable battery. Additionally, the battery can be connected to the PWM inverter, thus supplying a constant AC sine wave output. As it is based on the Philippines, the output voltage of the inverter will be at 220V AC.

PWM is used in the following applications: servomotors [5], a form of signal modulation in communications systems [6-8], for power delivery [9], voltage regulation [10], and audio effects and amplification [11-12]. PWM inverters are very popular in industrial applications. Three-phase PWM inverters that is voltage-fed are now popularly used for high-power industrial drivers [13]. PWM inverters are proven to be effective in reducing energy consumption and improving control processes [14].

2. SYSTEM MODEL

This section discusses the system model for the PWM based inverter as well as the circuit used to charge a 12 V battery from an unstable AC supply. Figures 1 and 2 show the block diagrams that the circuit follows. For the unstable AC values, the researchers set it between 50V to 100V AC. These values are just arbitrary values wherein they are not the exact values obtained in low power areas. The unstable AC could have a variety of values, but for this study the researchers will only be using 50-100V AC for testing purposes.

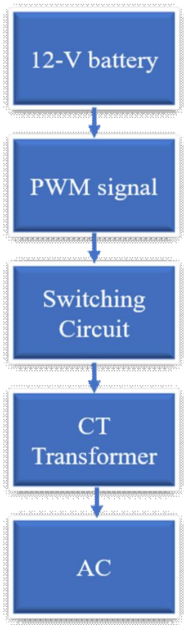

Figure 1. Block diagram of the PWM-based inverter

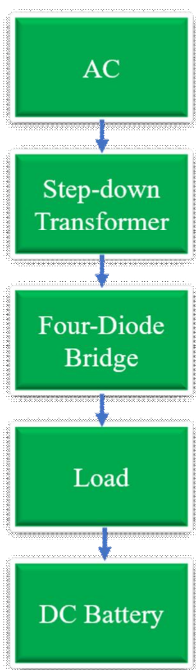

Figure 2. Block diagram of the rectifier

2.1 PWM Based inverter

The system starts with a 12 V battery supply which will then be converted into a PWM signal by using the NE555 timer circuit. The topology used is the monostable multivibrator (See Figure 3). This topology was chosen mainly because the duration of its output pulse is determined by the values of a resistor that is connected to the discharge pin and the capacitor that is connected to the voltage control pin (1) [15]. The output PWM signal is then connected to a switching circuit which is simply composed of MOSFETs. However, it is advised that there should be a MOSFET driver in between the output of the 555 and the MOSFETS, but because of the limitations of the software, it was neglected and the researchers opted with a half-bridge configuration for the MOSFETs. This is because the two switches or the two transistors act as complementary switches. This means that as the first switch is on, the second switch is off and vice versa [16]. This will then create two separate PWM signals which are then connected to a center tapped transformer which then converts the DC pulse into AC. Figure 4 demonstrates how this works. With this, a capacitor is attached to the output to convert the square wave into a sine wave.

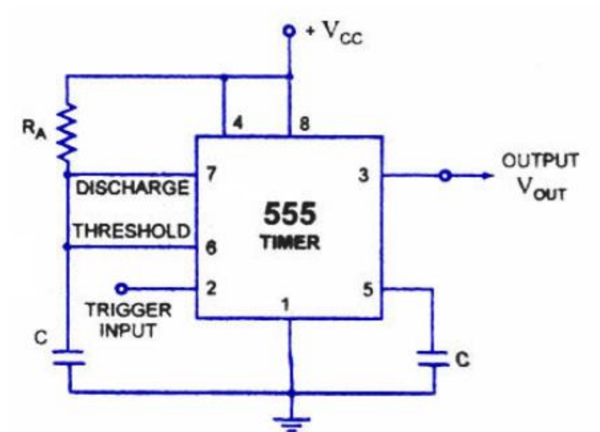

Figure 3. Monostable multivibrator

$$T = 1.1RC \tag{1}$$

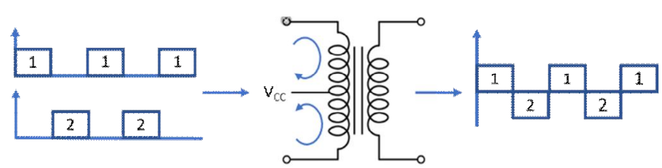

Figure 4. DC to AC with CT Transformer

2.2 Rechargeable Battery Station

For low-power AC sources, the minimum and maximum expected voltage provide the necessary configuration of the full-bridge rectifier. Firstly, given that a 12V battery supply is required for the modified PWM inverter, the isolation transformer is used to distribute sufficient voltage. The diode, MURB1620CTG is a standard rectifier diode. For the voltage regulator, NCP1117ST12T3G is used for a 12V output. This regulator controls voltage input up to 20V. To avoid cross conduction, a potentiometer with an actuator is supposedly connected before the voltage regulator. This allows the faders to reduce the overall current prior to the IC.

3. SIMULATION RESULTS AND DISCUSSION

Figure 5 shows the output of the 555 timer that is taken from an oscilloscope that is set to 10V/div. Figure 6 shows the final design of the PWM based inverter circuit. Then, Figure 7 displays the battery charger schematic design. As can be seen, a potentiometer is utilized with the 555 timer circuit, so that the user can change the duty cycle of the PWM signal. Setting the potentiometer to a 100% of its value will create a 50% duty cycle. The MOSFETs used for the H bridge are IRF540 which is chosen because it is commonly used for different inverter circuits. For the center-tapped transformer, the turns ratio was determined by conducting a trial and error method. They change the value until the output reaches 220Vrms or 311Vp. The value that achieved this is at 12.3.

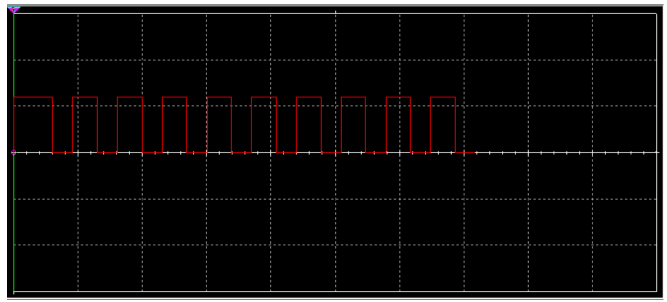

Figure 5. PWM signal from 555 Timer

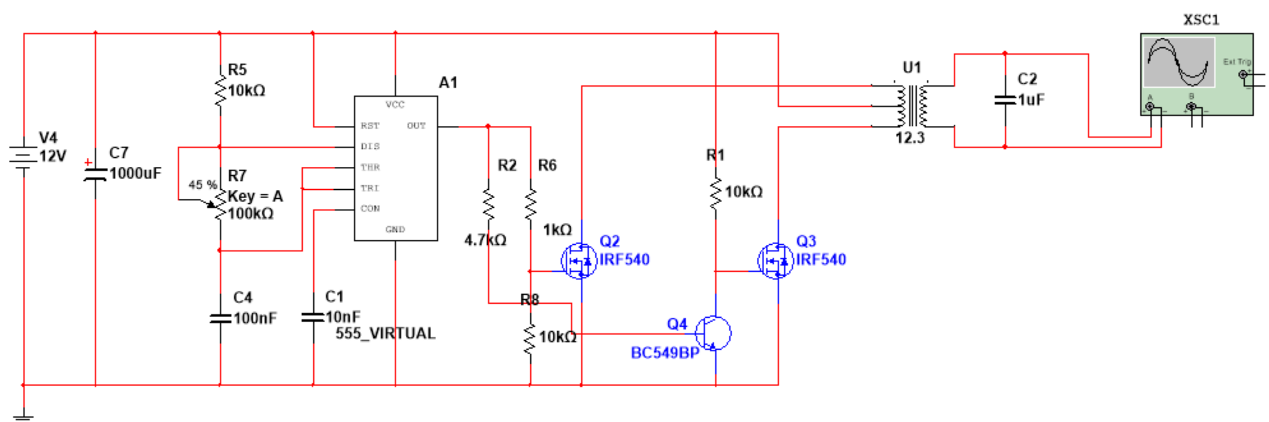

Figure 6. PWM Based Inverter

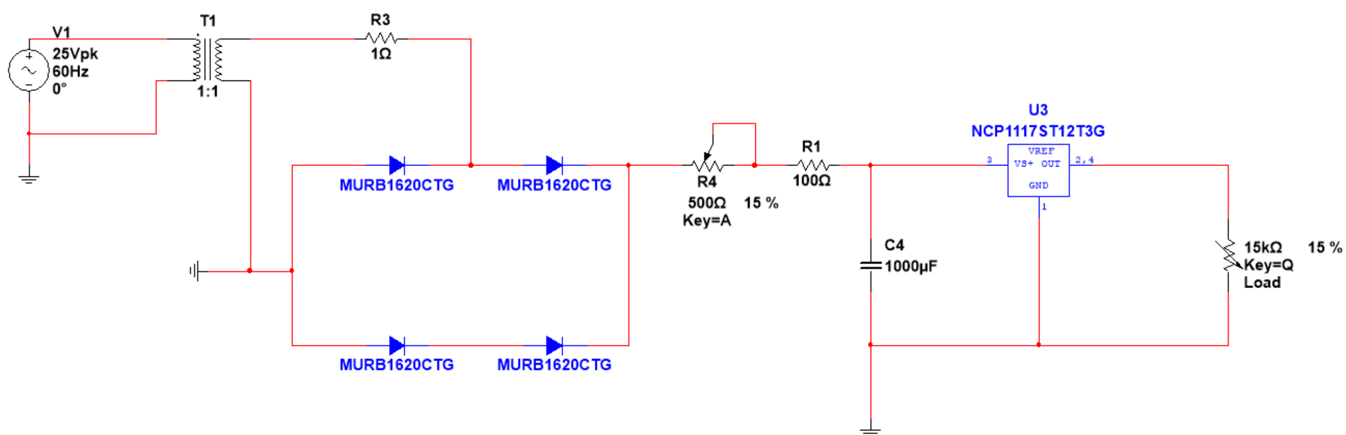

Figure 7. 12-V Battery Charger Schematic Diagram

3.1 Output waveform of inverter

Figure 8 shows the result of the inverter. The oscilloscope was set to 200V/div. This means that the output waveform is approximately 311 Vp or 220 Vrms. The AC signal generated is not a perfect sine wave but it could still be used as a source of electricity. This means that the circuit created can be used to power the necessities such as the lights and devices. It is more stable as compared to the AC voltages obtained from their supply.

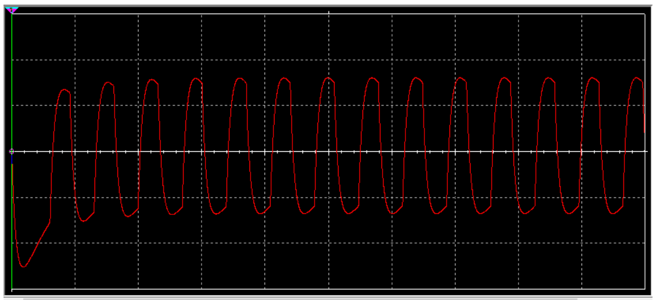

Figure 8: Output of the PWM inverter.

3.2 Output Waveform of Rechargeable Battery

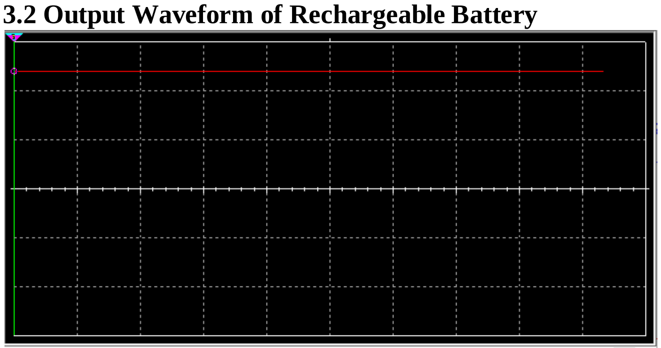

Figure 9. Rectifier Voltage at Load (50V AC)

Table 1. DC Voltages

AC Source	Resistance	DC Load
50 Vp-p	50 Ω	12.028 V
75 Vp-p	250 Ω	12.033 V
100 Vp-p	500 Ω	12.040 V

Given the range of 50 to 100 Vp-p AC source, the rectifier design is capable of attaining the sufficient 12 V necessary for the PWM inverter.

4. CONCLUSION

The researchers were able to create a PWM based inverter using the NE555 timer. The results give a good 220V AC waveform by utilizing a half bridge configuration for MOSFETs. They were able to introduce a simpler design of a PWM inverter. Although it is not a pure sine wave, it is sufficient to power the needs of people living in provincial areas. They were able to create a rectifier circuit that is connected to the unstable AC voltages that charges a 12V battery and is used to run the inverter circuit. Further research is required in applying the circuits created in a real-world application, so that the circuit can be adjusted for other parameters that are not considered by the software simulation.

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