

DC to AC Inverter Prototype for Small Scale Power Supply with SPWM Method

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Abstract— Inverter is a device to convert Dc current voltage into AC current voltage. In this article, the inverter is designed using the H-Bridge configuration. The advantage of this configuration is that there is no need for diodes and capacitors to balance the voltage. The main components in designing this inverter are the Arduino Nano, the IR2103 IC, and also the MOSFET. The switching method used is SPWM with H-Bridge configuration which is controlled by 2 IC IR2103. Based on the test results, the output voltage of this inverter is 7.45 Volts. With a DC voltage of 12 Volts. With the use of an oscilloscope that is used to measure the output waveform from the switching results of the MOSFET, the signal is still in the form of a square wave. To make a sine wave, an inductor filter is needed which functions to produce a signal to become a sine wave, and to keep the frequency at 50Hz. The voltage generated from the step-up transformer can be adjusted by rotating the feedback trimpot. The resulting voltage is 88 Vac to 260 Vac. and can accommodate a maximum load of 250 Watts. This inverter is also equipped with a PZEM-004T sensor which functions to read voltage, current, frequency and power data.

Keywords— Inverter, Arduino Nano, SPWM, H-Bridge, Mosfet

I. INTRODUCTION

At this time electricity is a very basic thing, especially for household use as well as for industrial needs. Many various electronic equipment that uses electricity to help complete human work [1]-[3]. When the electricity from the PLN goes out, the electronic equipment that is sourced from AC power will definitely stop working, so to help turn on the equipment you have to use a generator or inverter device. The inverter itself is divided into several groups, namely pure sine wave inverter, modified sine wave inverter, and square wave inverter. Of the three types of inverters have different waves. The pure sine wave inverter is the best type because it has sine waves like PLN electricity. The advantage of a sine wave inverter is that it can be used for all household appliances and is also safe for induction equipment. Unlike the square wave and sine wave type inverters, although these inverters are the same as producing AC current, they cannot be used for induction equipment. In this research is to make an inverter equipment that is designed to meet electricity needs when in an emergency. The inverter is designed in such a way as to be able to produce electricity and the same frequency as PLN with sine waves which can later be applied to all electronic equipment with a maximum power of 250W [4].

The inverter designed by rizzki kurniawan Penulis makes control of this inverter system using a DC source input with a 12V voltage. The Arduino Uno microcontroller is programmed to control circuits such as processing soil moisture sensor input data, generating 50 Hz and 25 Hz SPWM waves, displaying indicator lights, and Arduino being programmed to control active filters in system circuits according to the frequency of the inverter. This inverter is designed with an H-bridge topology [5]-[8]. This topology is one of the topologies used to manipulate DC (unidirectional) power sources into AC (alternating) electricity. Based on test results, the inverter control system prototype is capable of producing sine waves with a frequency according to the percentage of soil moisture content, in dry soil conditions with a moisture percentage of less than 25%, the inverter produces a frequency of 48.83 Hz, for moist soil conditions with a percentage of 25-40%, the inverter produces a frequency of 24.61Hz and on wet ground with a humidity percentage of more than 40% the inverter is in standby mode. The inverter voltage is capable of producing 200 Volts at the same frequency, after being connected to the water pump motor, the inverter experiences a voltage drop, so that the inverter voltage in dry ground conditions is measured at 163 Volts, while in moist soil conditions the measured voltage is 137 Volts [9].

Research conducted by Yustinu the author used a push-pull inverter with the TL494 IC. This inverter circuit changes the 12 Volt DC voltage from the battery to 220 Volt AC with a frequency of 60 Hz. This inverter uses IC TL494 as a square wave generator. The author has conducted 10 tests of mylar capacitors, trying to get a frequency of 60 Hz. In load testing, the authors tested it 11 times with different wattage lamps from 5 W to 55 W. Based on the test results, the greater the wattage of each lamp, the dimmer the lamp will be. When measured with an oscilloscope, the output of this inverter waveform is a square wave [10].

Research conducted by Jeremiah designed an inverter consisting of a DC-DC step-down converter circuit. For push-pull mode, the dc-dc buck converter requires only one transistor and two inverting transistors. Compared with full bridge inverter inverter, this inverter has the advantages of fewer switches and easier control. The main single-phase inverter circuit consists of a buck converter circuit and a push-pull inverter. A buck converter is used to produce the output in the form of a half sine wave DC waveform. The

function of the push-pull inverter is to convert a half sine wave DC wave into an AC sine wave [11]. The single phase inverter control circuit consists of a function generator and an arithmetic unit which are used to form a reference sine wave with a fundamental frequency of 50 Hz and a triangular wave with a switching frequency of 2.5 kHz and a duty cycle of 50%. An amplifier (op-amp) is used to form a pulse width modulated (PWM) wave [12]-[14]. In this study, unipolar mode is used as a PWM switching mode, where the PWM switching frequency that works on the MOSFET buck converter is doubled. The developed single-phase inverter is capable of producing a sine wave with an alternating voltage of 211 volts at idle. When the inverter is loaded with 5 watts, the voltage drop becomes 133 volts, with a load of 60 watts the voltage drop becomes 90.8 volts and with a load of 100 watts the voltage drop becomes 58.4 volts [15].

II. METHOD

The SPWM inverter digital bridge is known as a microcontroller-based inverter because it uses Arduino Uno as a digital SPWM signal generator. The SPWM signal generated from the digital bridge will be the same as the SPWM analog signal and the resulting amplitude will be the same as the operating voltage of the microcontroller [16].

This inverter uses the Hy5208 mosfet as a switching device, IR2103 and bootstrap components so that the drive circuit can work according to the Half Bridge circuit topology. Next, do the arrangement of the circuit with the help of software and make the hardware then do the testing. This inverter uses Arduino Nano as a SPWM signal generator. to smooth the output waveform used LC filter circuit. The inductor functions to filter the frequency issued by the inverter and the capacitor is used to smooth the sine wave so that it approaches the PLN wave [17].

A. System Design

To make this inverter circuit, you need the right electronic components because to support a device to work optimally. With the main components of the mosfet, PWM ic, and also the micro controller as the PWM controller. In this inverter design is equipped with a feedback circuit. The function of this circuit is to regulate the voltage that you want to output from the step up transformer. We can adjust the output voltage even above 220VAC [18]. For more details see Fig. 1.



Fig. 1. Inverter 3D design

B. Inverter Block Diagram

The inverter design in this study has an inverter control system, namely Arduino Nano. The Arduino Nano function in the inverter functions as a PWM generator. The design of this inverter consists of a PWM generator, battery, driver mosfet, H-Bridge mosfet, and step up transformer. The block diagram above explains that a 12VDC battery is used as the main source and also as a power supply for Arduino Nano. The function of the Arduino Nano is for PWM generation and also as a feedback voltage control, so that the output from the inverter can be adjusted. The PWM generated by Arduino is then sent to the MOSFET driver IC as control for the H-Bridge MOSFET. The H-Bridge mosfet functions to switch the incoming voltage. If Q1 and Q4 are closed then the current will pass through the mosfet. And if Q1 and Q4 are open, current will flow through Q2 and Q3, so that the output of this mosfet produces an alternating AC current. Because the output of the MOSFET is still small, it is necessary to use a step-up transformer which functions to increase the AC voltage to 220V. The inductor is needed as a frequency filter, so that it is stable at a frequency of 50Hz. Only then can the electricity generated by the inverter be used in household electronic equipment [19]. The block diagram can be seen in Fig. 2.

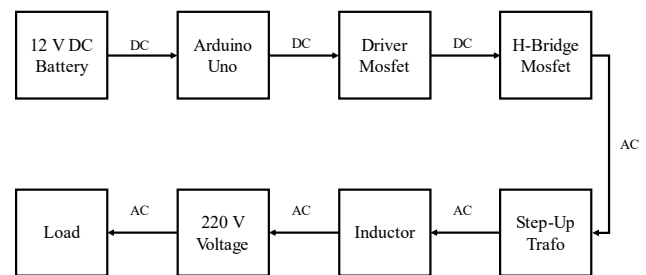


Fig. 2. Inverter block diagram

C. Sensor Block Diagram

This inverter is also equipped with sensors so that it can read power, current, voltage, and frequency when the tool is in use. The design of this sensor requires an Arduino Uno, PZEM-004T sensor, and an LCD to display reading results. The working voltage of this sensor requires a DC voltage of 5V or a power bank can also be used. The way this sensor works is when the PZEM-004T sensor reads data from the inverter load, the data will be sent to Arduino Uno. After the data is successfully processed then it will be displayed on the 16X2 LCD [20]. This sensor block diagram can be seen in Fig. 3.

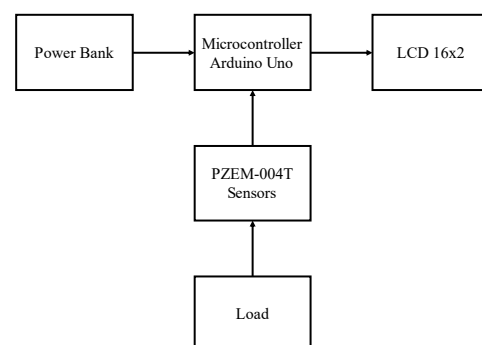


Fig. 3. Sensor block diagram

D. Flowchart Inverter

This inverter is designed with a main source of 12V DC voltage. This voltage is useful for supplying the Arduino Nano as well as being converted to 220V AC voltage. The role of the Arduino Nano microcontroller in this research is really needed. The function of the Arduino Nano is as a system controller and also for generating PWM signals. The PWM pins on Arduino are located on pins 27 and 28. To activate PWM, you need to press the push button. This push button is connected to pin 30 arduino nano and ground. In the mosfet driver, the PWM signal sent from the arduino uno goes to each IC pin Hin and Lin. Furthermore, the output of this IC will control the performance of the H-Bridge MOSFET. This mosfet driver is equipped with a bootstrap circuit that functions as a minimum driver system so that it can work properly. This mosfet driver uses IC IR2103 [21].

The H-Bridge MOSFET uses 4 HY5208 MOSFETs with the help of 2.7Ω resistors and FR107 fast diodes. The function of the resistor and diode is useful for smoothing the SPWM signal going to the circuit. The output voltage generated by this mosfet if the input voltage is 12VDC then ideally it is 7VAC. After the H-Bridge circuit switches, if the transformer is not installed, the Arduino is not active even though pressing the push button many times, but if the transformer is already on, the circuit will be active after pressing the push button. To convert the 7VAC voltage to 220VAC, a step-up transformer is used with inputs of 0 and 7 VAC as well and the output voltage of the 220VAC transformer [22]. Because the frequency generated from the transformer is still unstable, an inductor is needed that is installed in series at one of the mosfet outputs to make the frequency stable at 50Hz. In addition to the frequency filter, the inductor is also useful for reducing current when the inverter is in standby so that the mosfet temperature will be relatively cooler. The Flowchart can be seen in Fig. 4.

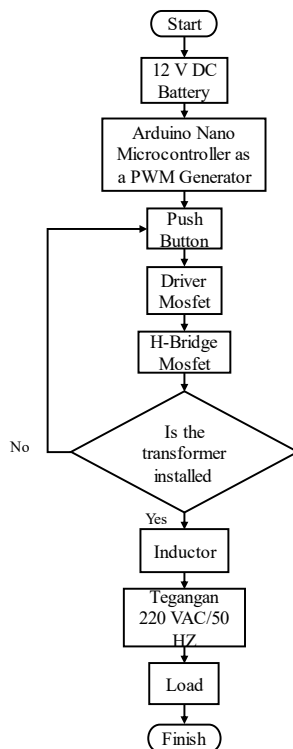


Fig. 4. Inverter system flowchart

E. Flowchart sensor PZEM-004T

This sensor uses the PZEM-004T type. By using 1 sensor it can read some data on electric voltage such as voltage, current, power, power factor, frequency, and energy used. The sensor will read data when the inverter is active. Then the sensor will detect the voltage, current, power, power factor, frequency, and energy used. The detected data will then be processed by Arduino Uno. In the Arduino sensor reading system, it functions as a processor of the data read by the sensor. After the data has been successfully processed by Arduino, the data will be displayed on the LCD [23]. The PZEM-004T sensor flowchart can be seen in Fig. 5.

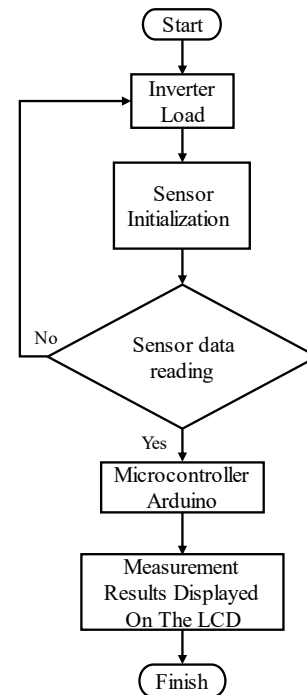


Fig. 5. Sensor block diagram

F. Circuit Schematic

Schematic design of the H-Bridge circuit can be seen in Fig. 6. The circuit consists of 4 MOSFETs, each of which is connected to Ho and Lo. Hin and Lin IR2103 respectively, connected to arduino nano. The Arduino Nano consists of 2 pins connected to the Ir2103 IC. Namely pin number 28 on the Arduino is connected to pins 2 and 3 of the IR2103 IC as PWM A. Pin number 27 on the Arduino is connected to pins 2 and 3 of the IR2103 IC as PWM B. Pin 15 of Arduino Nano as a 12v voltage is connected to each pin number 1 on second ic ir2103. Pin number 7 on both ICs is serialized with R3 so that it represents the switch (Q1, Q4). Pin 5 on both ICs is connected to R4 so that it represents the switch (Q2, Q3). When the MOSFET (Q1, Q4) is closed, current flows through the switch. In this section the MOSFETs (Q2, Q3) are open. Conversely, when (Q2, Q3) is closed and (Q1, Q4) is open, current flows to the MOSFET (Q2, Q3). The flowing current will go back and forth so that the output voltage changes to AC [24]. To create a feedback inverter pin 4 is connected to the feedback circuit trimpot. Feedback function to adjust the inverter output voltage. To make safety on the Arduino a 5 Volt voltage regulator is needed with the aim that when the inverter is loaded with large power the Arduino is not

damaged due to excess current and voltage. The inverter schematic can be seen in Fig. 6.

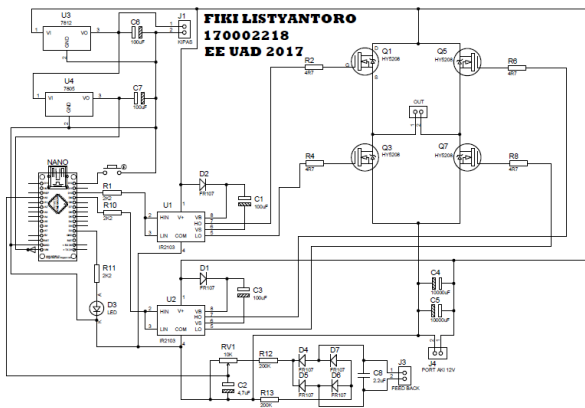


Fig. 6. Network schematic

G. Mosfet Drive Circuit

The MOSFET drive circuit consists of IC circuits, bootstrap diodes, and bootstrap capacitors. The MOSFET drive circuit can work in 2 positions, namely high and low. At low condition, the bottom side switch is activated and simultaneously the bootstrap capacitor is charged via the bootstrap diode from the source (Vcc). When in the high position the bootstrap capacitor will be released to provide voltage to VBS. And the bootstrap diode will ensure that there is no current and voltage flowing to Vcc which can cause a short circuit [25]. The voltage at VBS activates the high side switch. For detailed images can be seen in Fig. 7.

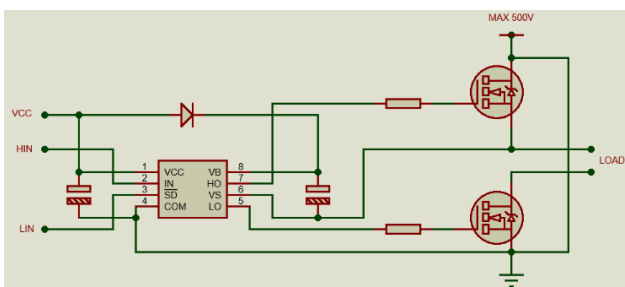


Fig. 7. MOSFET drive circuit

III. RESULT AND DISCUSSION

A. Hardware Design

After doing the hardware design on the next component is PCB printing and component installation. It can be seen in Fig. 8. It is necessary to use a heatsink and also a dc fan to reduce heat when the MOSFET is loaded with a large load.



Fig. 8. Inverter circuit

This image includes all the hardware that was created. Seen in the form of the PZEM-004T sensor and its microcontroller, inverter board, AC MCB, inductor, and Step-UP transformer. The function of the Pzem 004T sensor is as a current, voltage, power, power factor, frequency and KWH sensor. This sensor data will be displayed on the 16x2 LCD. MCB AC serves to limit the current flowing or will trip when a short circuit occurs at 220V AC voltage. Because the VCC inverter uses 12Vdc, the step uP transformer uses an input of 0-7V and an output of 220Vac. The overall picture can be seen in Fig. 9.



Fig. 9. The whole system circuit

B. Arduino Nano PWM Wave Test

Testing the output of the PWM wave is carried out when the inverter is on. The PWM pins used are pin 9 and pin 10. To be able to see the waves that come out, an oscilloscope is needed to see the PWM waves generated by this Arduino Nano. Tests were carried out using a DSO-138 oscilloscope and a multimeter to measure the output voltage. Measurement with an oscilloscope by setting time/div 5ms, and Vp 5V. The results of the PWM frequency are between 50Hz – 78Hz. As for the duty, it is in the range of 46% - 49%. Vpp voltage of 12.68V. When measuring voltage using a multimeter, the PWM output produces an AC voltage of 2.39V when measured with a multimeter. The pwm test image can be seen in Fig. 10.



Fig. 10. PWM wave testing

C. Standby Current Testing

The first test is the standby current test. The sensor used for testing this time is the PZEM-015. The standby current is the current that works before the inverter is loaded. In the picture the voltage reads 13.0 V, and the standby current is 734 mA. The power required when the standby current is 9.60 W. Watt. The smaller the power when the inverter is in a no-load condition, the better. Because it will affect battery consumption when the inverter is in use. The following pictures of the test results can be seen in Fig. 11 and Table 1.



Fig. 11. Battery voltage measurement on pzem-015

Table 1. Standby Condition Inverter Testing

No	Inverter Voltage	AC	Battery Voltage	DC
1	231.6 VAC	0.4 mA	13.0 VDC	734mA

D. Testing the IR2103 IC Output Waveform

The second experiment is to test the waveform with the DSO 138 oscilloscope on the LO and HO sections that come out on IC 1. On the V/Div oscilloscope it is set at 5V while the T/Div is set at 10 mS. The read frequency is still high at 147.058 Hz, Vpp is 46.12V and Vrms is 15.91 V. The resulting wave is still a half square wave going downwards. Can be seen in Fig. 12.



Fig. 12. Testing the output waveform of ic2

The next experiment tested the output waveform on the LO and HO pins on ic 2. With the V/div and T/Div settings the same as before. Obtained reading data for a frequency of 134.865 Hz, Vpp of 45.72 V, and Vrms of 15.91 V. The resulting wave is still a half square wave going upwards. Can be seen in Fig. 13.

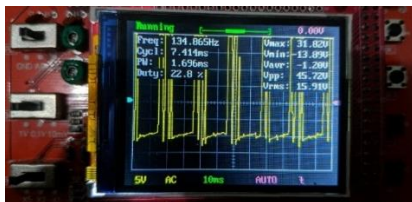


Fig. 13. Testing the output waveform from ic1

The next data collection is to measure LO on IC 1 and measure HO on IC 2, the read frequency is 143.849Hz, Vpp is read as 58.41 V, and Vrms is read as 17.72. The resulting waveform is a full square wave or it can be called a modified sine wave. This wave is formed from the merging of waves on IC 1 and IC . Test data can be seen in Fig. 14.

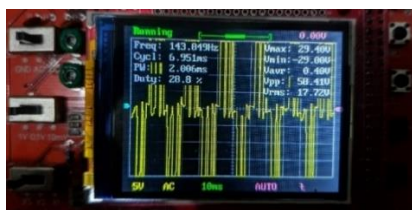


Fig. 14. Testing the combination of output signals on lo IC1 and ho IC2

E. Testing the Output Waveform on a Step Up Transformer

At this stage it is testing the output signal that will enter the step up transformer. It can be seen that the output wave from the inverter before entering the step-up transformer is still a more regular sine wave modification wave. Where the frequency reads 109.890Hz, Vpp reads 31.42V, Vrms reads 9.06V. We cannot expect the shape of the signal and frequency at this stage. We need to add an inductor as a filter the expected frequency is 50Hz. Test data can be seen in Fig. 15.

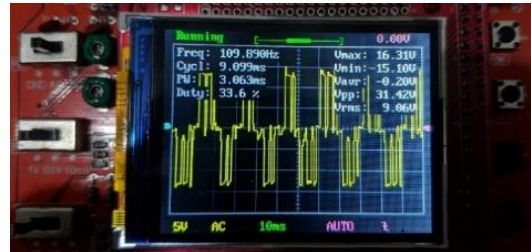


Fig. 15. Testing the output waveform before installing the inductor

In order for the signal to form a sine wave, a step-up transformer is needed and one of the inputs is serialized with an inductor as a frequency filter. The selection of the step up transformer itself must be right. In this study a 0-7Vac to 220Vac step up transformer was used. This transformer serves to increase the voltage from the original 7Vac to 220Vac.

It can be seen in the data image obtained that the read frequency is 50.251Hz, Vrms is read 7.45V, and Vpp is read 23.16V and the output wave is already a pure sine wave. Test data can be seen in Fig. 16.

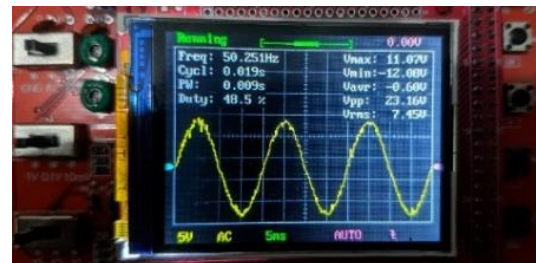


Fig. 16. Wave testing after inductor installation

F. Test Table With Load

In Table 2 is an inverter test and also data reading by the sensor. In the first test using a fan test kit with written specifications of 60 W. When the inverter is loaded before the fan produces a voltage of 230.6 Vac and when given the fan the inverter experiences a voltage drop of 0.2V. In the power readings made by the sensor, the fan has a power of 54.7 watts with a working current of 0.2 A can be seen in Table 3. Meanwhile, the battery voltage is still stable at 8 VDC. The current issued by the battery is 5.16 A.

Table 2. Hardware testing with load

No	Load Type	DC Voltage (V)	DC Voltage (A)
1	Fan	12.8	5.16
2	Drilling machine	12.3	29.3
3	2 Solder	12.7	6.45
4	Iron	12.2	30.7

Table 3. Data reading by sensor

No	Load Power (W)	Sensor reading power (W)	AC Voltage (V)	AC (A)	Voltage Drops AC (V)
1	60	54.7	230.4	0.2	0.2
2	550	271.3	195.0	1.4	35.6
3	70	69.0	231.1	0.3	0.4
4	350	283.8	196.7	1.5	34.7

The second experiment was carried out using a drilling machine with written specifications of 550W. When before the drill is used the inverter voltage is 230.6 Vac and when the drilling machine is turned on the inverter experiences a voltage drop of 35.6 V. For the results of the sensor readings the drill machine has a power of 271.3 Watt with a working current of around 1.4 A. When the drill machine is on the battery is experiencing voltage drop from 12.8 Vdc to 12.3 Vdc. The current released from the battery is 29.3 A.

The next experiment used 2 pieces of solder with a total written power of 70 W. When the solder was not turned on the inverter voltage was 231.5 Vac then after being loaded the inverter solder experienced a voltage drop of 0.4 V. For power readings carried out by the sensor it read 69W and consumed a current of 0.3 A. P issued by the battery is 6.45 A.

The final experiment was to use an iron with written specifications of 350 W. The initial voltage when the inverter was not used was 231.4 Vac, then after being loaded the iron experienced a voltage drop of 34.7 V. The power read by the sensor was 283.8 W with a working current of 1.5 A. the iron is turned on the battery voltage becomes 12.2 Vdc with an output current of 30.7 A.

IV. CONCLUSION

Hardware that is made to run well. The signal generated from this circuit is a pure sine wave signal measured on the Dso138 oscilloscope. In testing the oscilloscope signal, in order to form a sine signal, that is, it combines the signals from the two mosfet channels. The inductor in this circuit is very influential, namely to smooth the output signal of the inverter and also to stabilize the 50 Hz frequency as well as to reduce the standby power of the inverter.

The addition of a voltage regulator works very well on this inverter. The function of the 5 vol voltage regulator is to supply voltage to Arduino Nano. If the voltage regulator is not installed, it will damage the Arduino Nano when exposed to a large shock load. When the inverter is given a load of more than 250w it will experience a significant drop in AC voltage.

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