

## Single Phase Full Bridge Inverter Using Arduino Uno R3 Controller

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**Abstract:** Electricity has two types which are DC (Direct Current) electricity and AC (Alternating Current) electricity. Electricity which generally used for household components is utilized AC electricity. AC power can be generated from DC electricity by using an inverter tool. The inverter has various methods of converting DC power to AC power. In this research, inverter built using full bridge configuration. Using the full bridge configuration, it is obtained more efficient results by using other configurations. The inverter design using voltage source 12 volt battery with a capacity of 35 Ah. The maximum power capacity which generated by the inverter is 100 watts. To control this inverter, arduino uno R3 microcontroller is used. The process of switching uses square wave in the PWM frequency 20 kHz. In that frequency, every 400 PWM waves generated forms a sine wave. From the results of experiment testing the inverter has a good waveform and a good frequency, with THDv 5%.

**Keyword:** Inverter, Microcontroller, Full Bridge, Sine Pulse Width Modulation, THDv.

### I. INTRODUCTION

Technology advancement in both industrial and home appliances will not be separated from the use of AC power. AC power is the most important requirement to powerise all household electronic devices. The use of AC power is widely used by people in Indonesia. It happens because Alternating Current electricity is a type which firstly emerged in Indonesia at that time. To meet the needs of the AC electricity, the government made a program of built power plants throughout Indonesia.

AC-type electricity can be generated through DC (Direct Current) power. The stages to obtain AC power from generating using DC electricity which use a reversing system of the pole of the DC electrical output which connected to the load is called as an inverter.

Inverter is a device that can convert alternating voltages into direct voltages with adjustable frequency and level of voltage (Rashid, 1993). The inverter circuit consists of three parts, the first part of a circuit formed from the converter circuit which converts the alternating voltage source of the mesh into a direct voltage and eliminates the ripple at direct voltage output. The second part is a circuit of inverters that convert a direct voltage into a one-phase alternating voltage phase with the various frequencies. These two circuits are called the main circuit. The third part is a control circuit which functioned as the main circuit controller. The overall combination of the circuit is called an inverter unit (FATEC, 2006).

### II. LITERATURE REVIEW

#### A. Inverter:

Power inverter is an electronic device that can convert direct current source into alternating current. Inverters are many applied, for example used in a condition where only low DC available such as battery (Accu) or solar panels and it is required to supply electronic equipments with AC input.

There are three wave differences in AC voltage which generated by the inverter in general, that are the output of square wave, modified sine wave and pure sine wave. The modified sine signal is the output of the inverter which is in the form of square waves or modified square waves whose shapes follow the sine wave pattern. This type of sine modification is easier to make than an inverter with pure sine output. The pure sine inverter produces an output waveform that is identical to the wave which generated by the power supply provider.

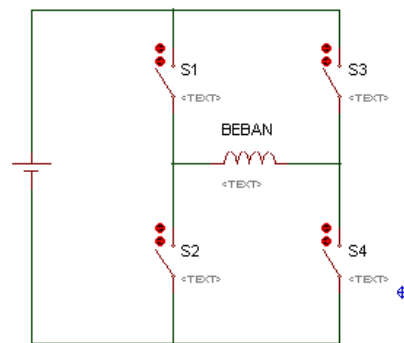


Fig. 1. Full Bridge Converter

#### B. Full-Bridge Converter:

Full bridge converter is a circuit method used to convert DC voltage to AC. This configuration consists of 2 pairs of switches that S1S2 and S3S4 which active alternately. In a full bridge converter configuration, the DC voltage is converted to AC by switching alternately to reverse the polarity which connected to the load quickly. The use of full bridge configuration requires four switches to convert DC voltage into AC voltage. The use of the switch can be in form of transistor, SCR (Silicon Controlled Rectifier) or FET (Field Effect Transistor).

*C. Modified Sinewave Inverter:*

The modified sinewave is the development of modified squarewave. Modified sinewave can be generated by using PWM (Pulse Width Modulation) wave. The use of PWM as generation can be generated from the use of microcontroller. This PWM wave modification has an adjustable voltage value in each PWM wave period. Hence, it can be applied an approach by cutting the sine wave into several parts and taken the average voltage value on each part of the sine wave. From the result of the average voltage, it can be assumed to get the voltage value, it should be modified so that the voltage on each cut section has different voltage value .

*D. Low Pass Filter:*

The frequency filter is divided into two, namely active filter and passive filter. The active filter is a circuit offilter that uses passive electronic components such as operational amplifiers (OP-AMP), transistors and others. Passive filter is a circuit of filters that use passive electronic components in the form of resistors, capacitors and inductors.

The Low Pass Filter (LPF) is a circuit that forwards signals that have frequencies below their transition frequency and weakens signals that have frequency above their transition frequency.

$$X_c = R$$

$$\frac{1}{2\pi fC} = R$$

$$f_c = \frac{1}{2\pi RC} \tag{1}$$

$X_c$  is the value of capacitive reactance. The amount of reactance value is determined by the magnitude of the frequency and the value of the capacitor.  $f_c$  is the cut-off value of the frequency, the cut-off area of the frequency is determined by the value of the resistor and capacitor.

*E. Transformer:*

A transformer is an electrical device that can move and convert electrical energy from one or more electrical circuits to other electrical circuits, through a magnetic coupling and based on the principle of electromagnets. A transformer does not work if the primary coil is connected to DC voltage source.

The transformer works by inducing the core to deliver high power to lower power. The use of transformers in the design of this inverter is to distribute a power from low voltage to higher voltage. The transformer used is a transformer with an iron core. The selection of this transformer is based on the ability of an inverter that has an output wave resembling a sine wave, therefore the use of a transformer with an iron core can work properly

**III. RESEARCH METHOD**

**A. Inverter Block Diagram**

The design of this inverter has two circuits which are microcontroller power supply circuit and inverter driver circuit. Fig. 2 show block diagram of this system. Before the circuit is created, a simulation is done using proteus software as shown in Fig.3. The inverter circuit scheme in figure 3 consists of a series of microcontrollers, mosfet drivers, full bridge circuits, low pass filters and transformers.

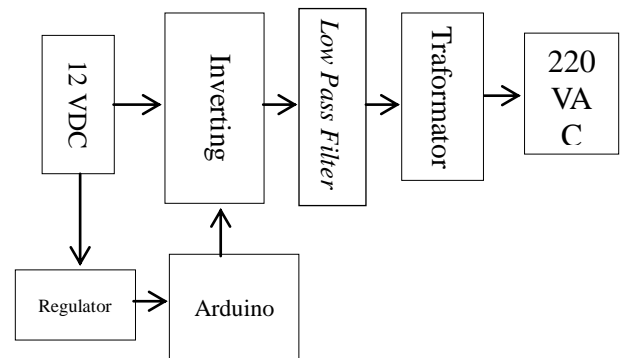


Fig. 2. Block Diagram Inverter

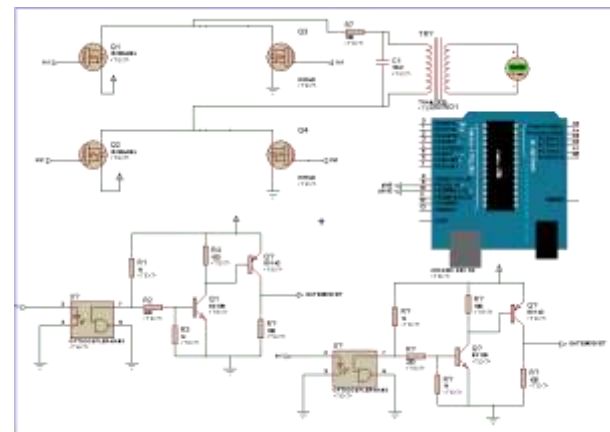


Fig. 3. Inverter Circuit Scheme

*B. MOSFET Driver:*

The MOSFET drivers use to separate between power circuits with control circuits or to separate low-voltage circuits with high-voltage circuits. Mosfet driver functions also to raise the voltage or voltage amplifier so that the magnitude of the trigger voltage on the gate mosfet can have a large open value (full open). The configuration of this mosfet driver uses transistor amplifier, and to separate high voltage with voltage on microcontroller,optocoupler is used.

*C. Modified Sinewave:*

In the design of a single phase inverter, it uses pin 9 and 10arduino uno microcontroller which will be connected with mosfet driver. An arduino uno microcontroller is used for switching mosfet so it results in sine-like or

modified sine wave. The speed of the arduino switching is changed to 20 kHz. To get a sine wave with a frequency of 50 Hz with a switching frequency of 20kHz, every one sine wave hertz should be 400 PWM waves. Fig. 4 shows modified sinewave.



Fig. 4. Modified Sinewave

#### IV. EXPERIMENTAL RESULT

##### A. Design MOSFET Driver:

The use of MOSFET as a switching requires circuit that can trigger the gate of the mosfet to be active. The transistor circuit cuts the negative voltage. The use of type bd 139 transistor has a transition speed which reaches 100 Mhz. With the transition speed in switching the frequency of 20 KHz, the use of bd 139 has a reliability. Supply voltage mosfet driver uses 12 volt voltage. From the data sheet which contained in bd 139 has a maximum voltage of 80 volts and the passable current is 1.5 amperes. In the use of resistors connected with collector transistor, it utilizes 100 ohms resistor. At a voltage of 12 volts with a large resistor 100 ohm is obtained a passing current of 1.2 amperes. The current value is still within the safe boundary of the transistor. The base of the transistor is connected to a 330 ohm resistor. The maximum voltage of the microcontroller is 5 volts. Hence, in a maximum voltage conditions, it is obtained 15 current, 15 mA.

##### B. Full Bridge Inverter Single Phase:

The making of a full bridge inverter using PWM as a sine waveformer has many advantages. Configuring an inverter circuit using a full bridge can produce the better efficiency with other configurations. Full bridge bridge construction uses IRF 9540 and IRF 540 MOSFET. The use of two types MOSFET aims at obtaining good results when it is used.

The reason for using of IRF 9540 mosfet is because the inverter used has 12 volt input voltage with maximum current of 10 volts. Referring to the values of the voltages and the currents, the use of IRF 9540 has a characteristic for a voltage value that can enter into a drain of 100 volts and for a value current that can be charged at 23 amperes. The chosen of the use of IRF 9540 mosfet is based on current capacity which can be forward by mosfet.

The use of mosfet irf 540 is mosfet with P type. The irf 540 type mosfet chosen has a characteristic which is voltage in a drain has a maximum capacity of 100 volts with voltage capacity of 12 volt inverter mosfet usage with such characteristics have a good reliability. In the characteristics of a current which can be passed irf 540 has a maximum current that can be passed for 28 amperes. From these characteristic data, the use of 12 volt inverters with maximum current passed is 10 amperes irf 9540 and irf 540 is a reliable mosfet.

##### C. The Result of Modified Sinewave:

The modified sinewave waveform is a modification of the PWM wave which regulated its duty cycled values to obtain different voltage values at each point. To get modified sinewave waveform, it is used atmega 328 microcontroller which programming using arduino software. The modified sinewave wave test uses digital pins 9 and 10 of arduino uno with a frequency velocity of PWM of 20 kHz. Fig.5 and 6 show result of modified sinewave on each arm and merge of two waves.

From this result, the number of wave in each periode can count using this equation:

$$N = \frac{f_{PWM}}{f_{sinus}}$$

$$= \frac{20000}{50} = 400 \text{ wave} \quad (2)$$

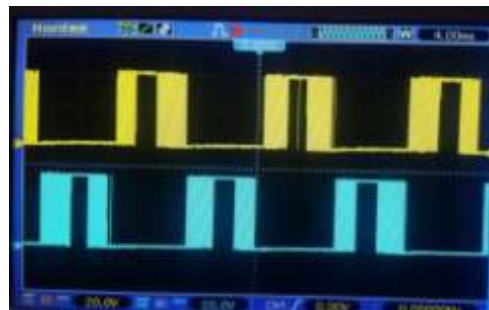


Fig. 5. Result Modified Sinewave

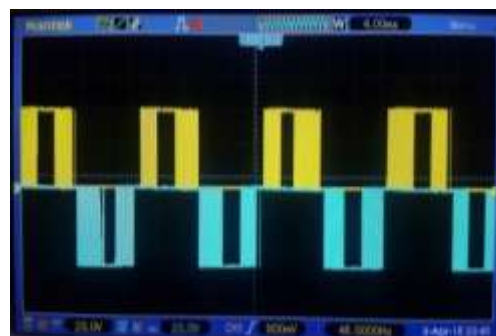


Fig. 6. Merge Of Modified Sinewave

##### D. Result of Low Pass Filter:

The low pass filter circuit uses a passive electronic component which has the advantage which does not require additional resources to work. The use of low pass filter circuit aims to obtain 50 Hz frequency. The

result of a wave using a low pass filter has a sine shape with a frequency of 50 Hz. The use of a low pass filter circuit has a change of pure sine wave with a THDv wave value of 5.27%.

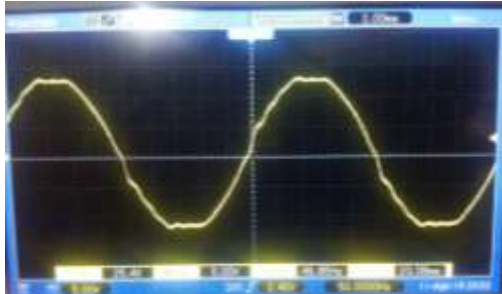


Fig. 7. Low Pass Filter Waves



Fig. 8. Spectrum of Sinewave

Table 1. The Result Efficiency Inverter with Resistive Load

Load	Power Input (Watt)	Power Output (Watt)	Efficiency (%)
0	10.44	6.75	64.65
10	25.44	18.99	74.64
20	33.235	24.7	74.31
30	47.41	35.34	74.54
40	61.985	44.39	71.61
50	72.912	53.2	72.96
60	75.35	59.4	78.83
70	87.78	61.88	70.49
80	95.92	67.64	70.51
90	108.24	66.3	61.25
100	114.29	69.3	60.63

*E. Inverter Efficiency by Resistive Load:*

Testing inverter is using different resistive load on the inverter. The goal of this testing is to know how the influence of varies loading. Table 1 show the result of testing. From tis table we can conclude that inverter efficiency is more than 60% and vary by the value of resistance load.

*F. Inverter Efficiency by Inductive Load:*

Thesecond inverter testing is inverter give two inductive loads, and this testing will be showthe effect inductive load on efficiency. Putting on an inductive load uses induction motor with 25 watt power for induction motor 1 which has two speeds. In addition, the second electric motor has a power of 30 watts with the speed of the induction motor constant. Tab:e 2 show the testing, and from this table we gwt efficiency of inverter using inductive load is more than 80%.

Table 2. Inverter EfficiencywithInductive Load

Inductive Load (W)		Pin (W)	Pout (W)	Efficiency (%)
1	2			
25 (Speed 1)	30	67.2	56.55	84.15
25 (Speed 2)	30	70.92	58.9	83.05

*G. The Effect of Total Harmonic Distortion on Load:*

Harmonic is a component of a periodic system or magnitude of a sinusoidal whose frequency is an integer multiple of the fundamental frequency. If the component of its frequency has a twice value of its fundamental frequency, it is called the second harmonic. Table 3 show, harmonic distortion changes caused by the load. From this table we get that THD is below 15%, and get best value in the 10 W load within THD value below 5%.

Table 3. The Effect of Resistive Load on THD

Load (W)	THDv (%)	Efficiency (%)
10	4.91	74.64
20	6.34	74.31
30	6.40	74.54
40	6.50	71.61
50	10.57	72.96
60	11.13	78.83
70	9.02	70.49
80	12.53	70.51
90	13.42	61.25
100	11.77	60.63

The effect of resistive loading has an impact on the value of THDv generated. The greater of the load value which provided, the result of the inverter efficiency is decreasing and the value of THDv is greater.



Table 4. The Effect of Inductive Load on THD

Load (W)		THDv (%)	Efficiency (%)
1	2		
30	25 (Speed 1)	9.1287	72.60
30	25 (Speed 2)	9.3169	67.63

From table 4, it can be seen that the inductive load does not influence on THDv, because the THD is like a constant on a value, that is 9%. But small differences on THD will produce different results on efficiency. From fig. 9 and 10, showing the relation between THDv and the efficiency in the resistive load and inductive load.

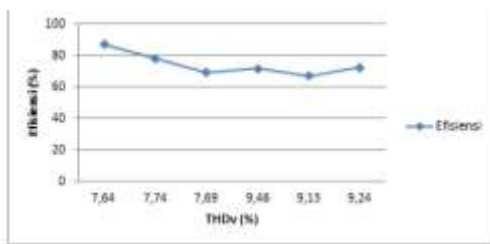


Fig. 9. The Relation of THDv with Inverter Efficiency on Resistive Load

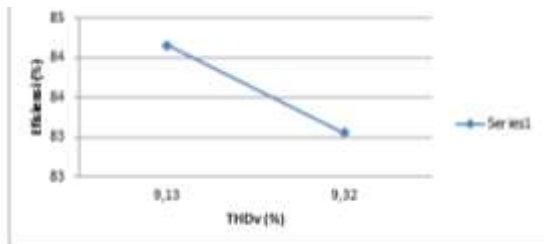


Fig. 10. The Relation of THDv with Inverter Efficiency on Inductive Load

### V. CONCLUSION

The use of a low pass filter can maintain the frequency results passed with a variable load. The greater of the load given, the average frequency is 50.26 Hz. Inverter testing with different loads can reach a stable efficiency results with an average efficiency of 70%. The efficiency results with the same THDv value at the resistive and inductive loads have different values.

#### Suggestions:

The use of iron core makes a loss in a high frequency, it is better for using ferrite transformer to get the better efficiency. In the making of full bridge inverter with a modified sine wave, it will be better using input voltage source 380 VDC. Thus, the result from the inverter has smaller THDv value.

### VI. REFERENCES

[1] Adam, Ahmad Antares, Single Phase Inverter

Circuit Based on Frequency Variation For Controlling The Speed of a Capacitor Motor. Palu: Universitas Tadulaku, 2015.

[2] Ajitha S.N K.alaiarasi: "Implementation of Full-Bridge Current-Fed Resonant Boost Converter using PIC microcontroller"; 2010 International Journal of Computer Applications (0975 – 8887) Volume 1 – No.

[3] Ariwibowo, C., Warsiti, A., dan Kartono. 2010. Perancangan Inverter Dual Conversion Push Pull-Full Bridge Pada Aplikasi Fotovoltaik, Universitas Diponegoro, Semarang.

[4] Chen, Wai Kai. 2000. The VLSI Handbook. Florida: CRC Press.

[5] Effendi, Moh. Zaenal, "Design of inductor", power point materi kuliah, Surabaya: PENSITS, 2007.

[6] Fairchild Semikonduktor. ID Series Datasheet. [www.alldatasheet.com](http://www.alldatasheet.com), diakses tanggal 26 Februari 2012.

[7] FATEC, 2006, "Inverter School Text, Inverter Practical Course", Mitsubishi Electric Corporation, Tokyo, Japan, p.211.

[8] Grotzbach M, Ried Ch, Investigation of AC/DC Converter Harmonics by an Analytical Based Time-Discrete Approach, IEEE Transactions on Power Delivery, vol. 12, No.2, April 1997.

[9] Majhi, Bijoyprakash. 2012. Analysis of Single-Phase SPWM Inverter.

[10] MR, Fadhli, Rancang Bnagun Inverter 12V DC Ke 220V AC Dengan Frekwensi 50Hz dan Gelombang Keluaran Sinusoidal. Depok: Universitas Indonesia, 2010.

[11] Mustafa, Muhammad Faid, Design The Low Passive Filter For Grid Connected Single Phase Voltage Source Inverter System. Malaysia: Universiti Teknikal Malaysia Melaka, 2014.

[12] N. Mohan, T. Undeland, and W. Robbins, "Power Electronics: Converters", Applications, and Design, 2nd ed., New York: John Wiley & Sons, 1995.

[13] Nasution, Muhamad Fadli. 2010. Pulse Width Modulation. <http://inirobot.blogspot.com>. Diakses tanggal 8 Januari 2018.

[14] Rashid M.H., "Power Electronics: Circuits, Devices and Applications", Prentice Hall, 1988. Fernuniversität-Gesamthochschule Hagen; in Germany.