# THE DESIGN OF INVERTER 1 PURE SINUS WAVE PHASE ON ARDUINO MICROCONTROLLER BASED

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**Abstract: The rapid growing technology both in industry and households causes the increasing necesity for electricity resources. If this electric power supply is insufficient, the continuity of electricity services to consumers is not achieved. Therefore, an alternative energy is needed in the provision of electricity that is capable of serving consumers in a sustainable manner. Based on these problems, a tool to provide solar cell electricity supply has been designed. An inverter is a device that consists of a power electronic circuit and serves to convert or convert an electric current in the same direction into an alternating current. The purpose of making this tool is to produce a tool that can back up the electricity source if the electricity goes out so that it helps continue do the work during the electric black out. Moreover, it can be the main or backup electrical energy sourced from 12 VDC battery and with 220VAC output, which can be applied to households as backup electricity at an economical cost.**

***Key word : Inverter pure sine, baterai, solar cell***

## I. INTRODUCTION

At present we know that in Indonesia there are already many uses of solar panels as an alternative power plant, where the output of the solar panels is in the form of DC voltage. Therefore, it is necessary to design the right inverter as a tool to convert DC voltage from the output of the solar panel to become an AC voltage which can then be used for household purposes.

From the description, the author tries to put forth the idea to write a thesis entitled " THE DESIGN OF INVERTER 1 PURE SINUS WAVE PHASE ON ARDUINO MICROCONTROLLR BASED" which can use sources from solar panels which are then converted into AC voltage.

This inverter functions as an alternative backup power provider when the home electricity goes out. In the long run, DC to AC inverters will play an important role in converting DC energy from renewable energy sources to solar cells into AC electricity that we use on the daily basis [1].

## II. BACK GROUND OF STUDY

### A. *Inverter Pure Sine Wave*

An inverter is a device that consists of a power electronic circuit and serves to convert an electric current in the same direction into an alternating current. The inverter is also the opposite of a converter or adapter, which functions to convert alternating voltage (AC) into a direct voltage (DC). As time went on, inverters developed into typologies ranging from an inverter with alternating voltage (AC) only up to an inverter that can produce pure sine voltage without being accompanied by harmonization. Inverter is also divided according to the phase part, including one phase, three phase and multiphase [1].

The main function of the inverter is converting direct voltage (DC) into alternating voltage (AC). Inverters are usually used in the fields of automation and industrial engineering. Inverters are usually applied to linear processes, namely parameters that can be changed. In UPS, the inverter system is also used to convert the energy from the battery to the output current to the user device [1].

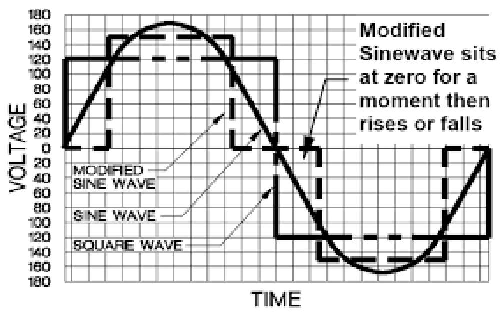



**Figure 2.1** *Square, Modified, and Pure Sine Wave[1]*

A pure sine wave inverter is capable of simulating precisely the AC power delivered by a power outlet. Generally, sine wave inverters are more expensive then modified sine wave generators due to the addition of circuits.

This cost, however, is made due to its ability to provide electricity to all AC electronic devices, allowing inductive loads to run faster and quieter, and reduce audible noise in audio equipment, TV lights and fluorescent lights [1].

*Inverter Classification*

Based on the waves produced, the inverter can be divided into three, namely: Square Wave, Modified Sine Wave, Pure Sine Wave (True Sine Wave). This inverter is differentiated based on its output, including variations in the level of efficiency and distortion that can give effect to electronic equipment in different ways [2].

*1. Square Wave Inverter*

A square wave inverter is an inverter that has a square wave output. In general, this inverter cannot be used on household electronic devices because the output is not a sine wave, while almost all electronic equipment requires modified sine or sine waves. This wave form output is square like the image below [1]:

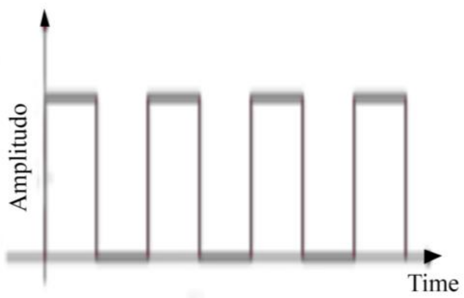



**Figure 2.2** Square Wave

The advantage of this inverter model is [1]:

- Simple circuit
- Do not much need for components
- Cheap and easily available components on the market
- Highly recommended

The drawbacks are as follow [1]:

- The waveform is a box-like output, not suitable for Inductive loads (Water pumps, Refrigerators, etc.)
- The generated power is still limited
- The greater the load, the greater the transformer needed.

*2. Pulse Width Modulation (PWM)*

Pulse Width Modulation (PWM)

In electronic power converters and motors, PWM is widely used as a tool to power an alternating current (AC) device with a direct current (DC) source or for advanced DC / AC conversion. Variation in the duty cycle of a PWM signal to provide a DC voltage to a load on a certain pattern will appear on the load as an AC signal or can control the speed of the motor which otherwise will run at high speed or die. This is explained further in this section. The pattern in which the PWM signal cycle varies can be made through simple analog components, digital microcontrollers, or specific PWM integrated circuits [1].

Modified sine wave inverters are almost the same as square wave inverters but use other stages to look more similar to sinusoidal waveforms. In a modified sine wave inverter, there are three voltage levels in the output waveform: high, low and zero as shown in the figure below with the dead zone between high and low pulses [1]:

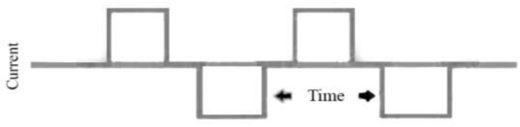



**Figure 2.3** *Modified Sine Wave*

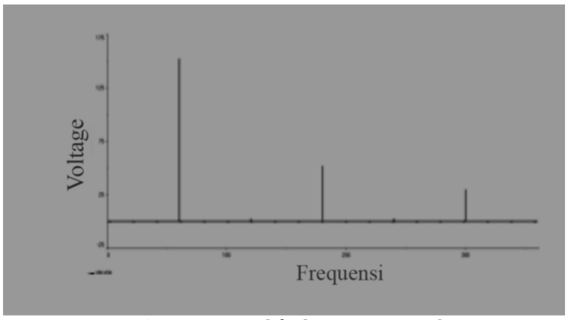



**Figure 2.4** *Modified sine wave Analysis*

Analog PWM controls require the generation of a reference signal and a carrier that feeds to a comparator that produces an output signal based on the difference between signals. The reference signal is sinusoidal and at the frequency of the desired output signal, while the carrier signal is often a serrated saw or triangular wave at a frequency that is significantly larger than the reference [1].

When the carrier signal exceeds the reference, the comparator output signal is in one state, and if the reference is at a higher voltage, the output is in the second state. To produce output with a PWM signal, transistors or other switching technologies are used to connect the source to a load when the signal is high or low. Full configuration or half bridge is a switching scheme that is commonly used in power electronics. Full bridge configuration requires the use of four switching devices and is often referred to as H-Bridges because the orientation is related to load [1].

- Producing low harmonic distortion of the output voltage compared to other types of inverters.
- Being practical and economical to implement (especially power components that have very fast switching times).
- In controlling the AC motor speed, PWM is able to drive an induction motor with smooth rotation and a wide range. In addition, if the PWM signal generation is carried out digitally, a good system performance can be obtained because it is more immune to noise.

The drawbaks are as follows [1]:

- Switching losses increase due to high PWM frequencies.
- The decreasing output voltage.
- The Electromagnetic interference problems (EMI) are caused by high-order harmonics.

### 3. *Pure Sine Wave*

The best resource for most applications is 50Hz pure sine wave, identical to the 120Vrms source available from the state electricity company. All low-power household plug-in devices are designed to work with this source (high-power devices such as cooking ovens using 240V sources) and thus are most likely to work well and most efficiently at that source.

This type of inverter has a pure sine wave output so it is more efficient than other types of inverters. In this study we will try to design this type of inverter [1].

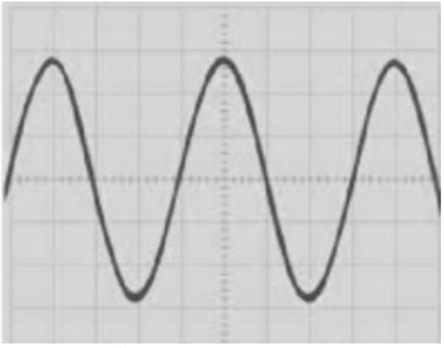


**Figure 2.5** *Pure Sine Wave*

A wave or waveform is a graph that states a signal as a function of time. Or it is also called simple harmonious vibrations which are harmonious motion with a fixed frequency and amplitude. While the sine wave form is a relentless repetition of an oscillation between two –peak-values, namely the negative peak and positive peak. The best resource for most applications is a pure 60Hz sine wave, identical to the source of 120Vrms available from any US electricity company [1].

All low-power household plug-in devices are designed to work with these sources and, as such, are likely to work well and most efficiently at such sources. The correct sine wave sources are produced most easily for high-power applications through rotating electric engines such as naval gas turbine generators, home-resistant diesel generators or gasoline backup generators, or various generators used by power companies that use shaft torque to create AC Sources provides relatively pure sine waves (less harmonics and high frequency noise) due to the analog rotation arrangement [1].

Such rotation machines may not be suitable for the use of low power reserves because of the high cost, large size and required maintenance. Thus, a smaller digital pure sine wave inverter can be very useful. Waveforms are grouped into:

1) Basic waveforms including stair, sine and exponential waveforms.
2) Composite waveforms are waveforms composed of several basic waveforms.

Vibration period or time (T) is the time interval needed to do one complete vibration (seconds). Frequency (f) is the number of vibrations performed in one second (Hertz). Relationship between frequency and period: $f = 1 / T$

The favourable points of *Pure Sine Wave [1]:*

- The inductive loads such as microwave ovens and motors run faster, lighter, smoother, more efficient, and cooler.
- It does not damage induction electronic devices such as fan motors, fluorescent lights, audio amplifiers, tv, fax etc.
- Preventing crashes on the computer, weird printouts, and interference on television monitors and computers.

The drawbacks [1]:

- Modified sine waves will not function properly on photocopier laser printers, hard drives, coffee makers, electronic sewing machines, and transformers.
- Modified sine waves can increase radio interference, the effect of higher heating on a motor or microwave.

## B. *Mikrocontroler*

Arduino is designed to facilitate electronic use in various fields. Arduino devices are able to take input from various sensors or switches, and control various lights, motors, and other physical outputs. Arduino devices can be given a set of instructions so they can do something using language Arduino programming and Arduino software.

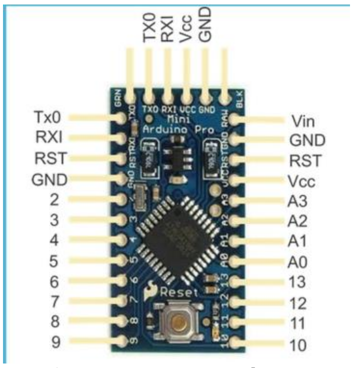



**Figure 2.6** Micro controler

## C. *Transformator*

Transformer (transformer) is a device used to increase or decrease alternating voltage (AC). The transformer consists of 3 main components, namely: the first coil (primary) which acts as an input, the second coil (secondary) which acts as an output, and the iron core which serves to strengthen the magnetic field produced [1].

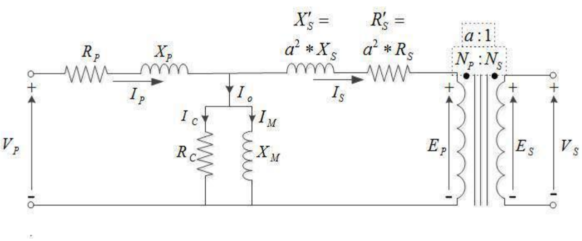



**Figure 2.7** Equivalent transformer Frame [1]

In the picture above, it can be seen the position of the components that makes up the transformer. The further description of the image is as follows:

- Ip is the primary current
- Vp is the primary voltage
- Rp is the primary obstacle
- Is is a secondary current
- Vs is secondary voltage
- Rs are secondary barriers

The working principle of a transformer is when the primary coil is connected to an alternating voltage source, the change in electric current in the primary coil creates a changing magnetic field. The changing magnetic field is strengthened by the presence of an iron core and an iron core is delivered to the secondary coil, so that at the ends of the secondary coil an induced emf will emerge. This effect is called mutual inductance [1].

Based on the comparison between the number of primary turns and the number of secondary turns of transformers there are two types, namely [1]:

- The step up transformer is a transformer that converts the low alternating voltage to high, this transformer has a higher number of secondary coil turns than the number of primary turns (Ns> Np).
- The step down transformer, which is a transformer that converts high alternating voltage to low, this transformer has a greater number of turns of primary coil than the number of secondary turns (Np> Ns).
- In the transformer (transformer) the amount of voltage released by the secondary coil is [1]:
- Comparable to the number of secondary turns (vs. ~ Ns).
- Comparable to the magnitude of the primary voltage (VS ~ VP).
- It is inversely proportional to the number of primary turns.

## D. *Osilator*

An oscillator is a circuit that provides a filtered sine wave of the frequency desired by the user based on the configuration of resistors and capacitors on the circuit. This circuit completes this task with four operational amplifiers that support or amplify the signal. This oscillator is a phase shift oscillator, however unlike other phase shifts that require a phase shift of 90 degrees or more, the bubba oscillator only requires a 45 degree shift to function. This is because of the four op amps, when it is placed in series, it produces a total 180 ° shift. This oscillator offers several features that cannot be done by other oscillators, the biggest factor is that frequency stability remains valid while still providing low distortion output. The reason for this involves four filters that pass through the signal, giving a clear and stable signal at point P5, as shown in Figure below [1]:

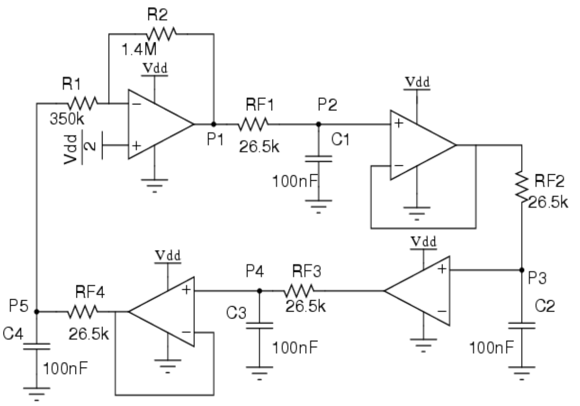



**Figure 2.8** Osilator Circuit [1]

## III. DESIGN AND CONSTRUCTION

### A. *GENERAL DESIGN SPECIFICATION*

The design of this final project was carried out to provide solutions to problems in the field. The problem in this case is the use of solar cells in providing alternative solutions to electrical energy in addition to using electrical energy from PLN. The following steps are carried out in the design to produce a solution to the problem that exists. Before designing a blog diagram, the initial specifications of the circuit must be made to make it easier to design the circuit. The initial specifications of the whole set of systems are:

- 100 watt solar cell as a basic input
- Solar charger controller to adjust the current for charging to the battery, avoid over charging, and over voltage.
- Battery functions to store electrical energy
- Inverter pure sine functions as converting direct current into alternating current

Here the author will explain each step of making this system hardware. Step by step needs to be pondered considering the success of the system depends on how to make the system part by part based on the specified stages.

### B. *Block Diagram System*

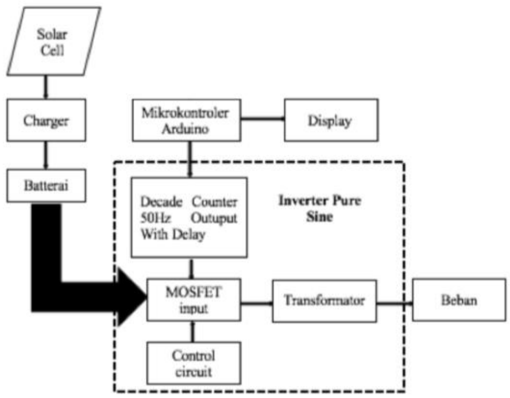



**Figure 3.9** Block diagram system

### C. *Standard operation system*

- The Solar Cell block functions for main power input.
- Block Charger Control functions to regulate the current released / taken from the battery so that the battery is not 'full discharge'.
- The Battery Block functions as storing electrical energy in the form of chemical energy, which will be used to supply (provide) direct electricity (DC).
- The Microcontroller block functions as a controller / controller of all the workings of the circuit so that this system can work according to their respective functions.
- Block pure sine functions to convert or convert unidirectional voltage (DC) to alternating voltage (AC).

### D. *The Hardware Design*

#### 1. *Pure Sinus Inverter*

This circuit is a circuit that functions to alternate or convert direct voltage (DC) to alternating voltage (AC). The preferred component in this tool is a pure sine inverter circuit, because this inverter is very good to use. Techniques are needed especially for loads that are still using the motor to work easier, smoother and not hot. Therefore, in terms of price, this inverter is the most expensive among the others because it is the one closest to the shape original wave from the PLN electricity network. Following are the features of the inverter:

- Micro CPU processor control
- Pure sine wave with alternating current output
- Works with AC equipment widely, such as air conditioners, refrigerators, pumps, tv, lights, fans and so on, depending on the size of the inverter
- Full of intelligent protection, overload, overcurrent, over voltage, heat, short circuit, low voltage and so on.
- The Voltage and frequency are: 220V / 50hz
- The input voltage is 24V DC.

To minimize power loss and utilize higher switching speeds, the N-Channel MOSFET is chosen as a switch on the bridge. The level of translation between the signal and the voltage needed to continue the high-side bias of the N-Channel MOSFET. Bridge circuit diagram with MOSFETs and drivers shown in figure below:

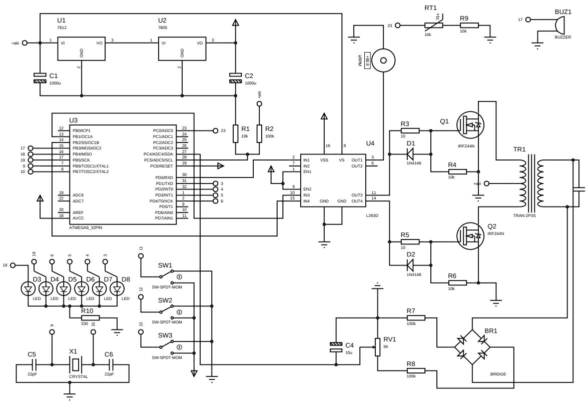


**Figure 3.10** *Bridge mosfet* [7]

The operation of the IRFP250N device will be controlled through the signal generated. The signal will be fed to pins 9 and 10 simultaneously. An additional pin that requires an external connection is a VSS pin that will be tied to the ground, the Vcc pin that will be connected to 24V.

a) Transformer

Transformer or transformer is an electrical device that transfers electrical energy from a series electricity to another electrical circuit through a magnetic coupling based on the principle of electromagnetic induction.

In designing this inverter, a step up transformer is used to increase the voltage to 220 VAC where in the transformer (transformer) there are two coils or windings namely the primary coil and the secondary coil.

This ratio or difference in the number of turns in the Primary and Secondary Coils determines whether a Transformer is a Step Up Transformer or a Step Down Transformer and also as a determinant of the voltage level it produces.

A Transformer is said to be Step Up if Np <Ns so that Vp <Vs, while the Step Down Transformer is if Np> Ns so that Vp> Vs. Where Np and Ns are the number of turns each in the Primary Coils and Transformer Secondary Coils, while Vp and Vs are the Voltage on the Primary Coils and Secondary Coils.

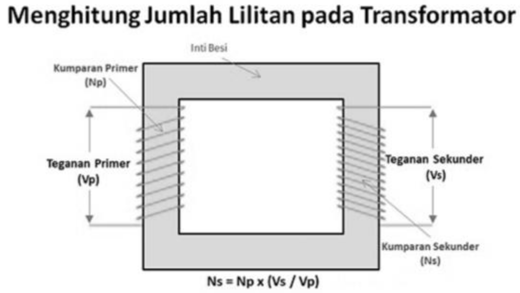



**Figure 3.11** Transformator [8]

The formula to count the coil in the Step Up and Step down of transformer is as follows:

**Np/Ns = Vp/Vs**
Or
**Ns = Np x (Vs / Vp)**

That is :
Np : The number of prime coil
Ns : The number of secondary coil
Vp : The prime voltage Tegangan Primer
Vs : The Secondary VoltageTegangan Sekunder

2. *Solar Cell*

This solar cell has good efficiency. This solar cell is made by using cells with SiN layers. This solar cell is suitable for meeting rural electricity needs for homes in remote areas that do not have access to the PLN network and are suitable for remote industrial applications such as telemetry and instrumentation systems. This product offers increased efficiency through the use of Pollycristal cells and nominal 12V power output, making it ideal for battery charging applications. This solar cell has been proven to work at high temperatures and is designed so that it makes the product durable in the field and easy to use

**Figure 3.12** Solar Cell Panel

The followings are the specification of the solar cell panel:

- Maximum power is 100W
- Polycrystalline cell types
- Voltage at Pmax (Vmp) 17.53V
- Current at Pmax (Imp) 5.71 A
- Short circuit current (Isc) 6.03 A
- Open circuit voltage (Voc) 22.2V
- Maximum system voltage of 1000 VDC

## 3. *Battery*

The battery used is a rechargeable battery designed to provide exceptional performance in conditions of overcharge, overdischarge, and vibration and shock. With a small form this battery can save available space. The use of special epoxy for seals, and electrical lines and cover construction, ensures that these batteries will ensure no leakage and allow them to be used in any position.


**Figure 3.13** Battery

Following are the specifications of the battery [1]:

- 12V nominal voltage
- Rated capacity is 100Ah
- Dimensions (H x W x L) 210 x 173 407 mm (total weight: 236mm)
- Weight 29 kgs

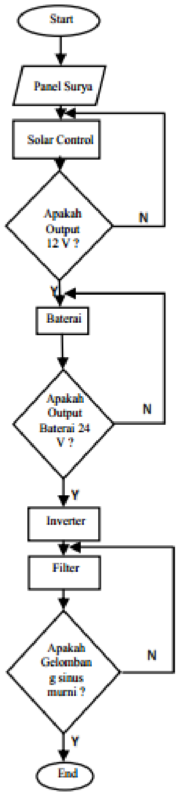
## 4. *Solar charge controller Circuit*

The charge controller is an automatic battery charger that has adopted advanced digital techniques and operates automatically. This controller uses PWM (Pulse Width Modulation) when in the battery charging period. This of course can increase battery life. The charging process has been optimized for long-lasting batteries and improved system performance [1].

Comprehensive self diagnostic and electronic protection functions can prevent damage from installation errors or system errors. This controller can also recognize the system voltage at start up. If the battery voltage is less than 18V, this controller will automatically recognize the 12V battery ab and if the battery voltage is greater than 18V, this controller will recognize the 24V battery system [1].

## E. *The software Design*

The signal is generated using the phase and signal correct frequency by using the 8 bit timer on Arduino. Modulation is solved by updating the value of OCR1A from the sine wave table with different time comparisons. the whole process can be seen in the flowchart below [1]:




In this pure sine process, 256 values will be sent to the microcontroller, so a sine wave will be formed as the output of the Arduino microcontroller. Because programming is done on the Arduino microcontroller, the table value in the sine will be changed first to a heximal decimal value to be included in the program.

Because the required frequency is 50 Hz, then the period for that wave can be written as follows:

T=1/f = 1/50hz = 20 ms

So, the time needed to form a sine wave is 20 ms. So that the time Delay in sending the value in the sinus table is:

D = T / 256 = (20ms) / 256 = 0.79 ms

The above decimal hex value will be sent every 0.79 ms

If the frequency is to be varied, what needs to be done is to change the value of the delay period and time of sending the driving signal, which in this case is the value of the sinus table.

For a frequency of 60 Hz, the period is as follows:

T= 1/f=1/60hz= 16 ms, Sehingga mempunyai waktu delay sebesar :

D= T/256= (16ms)/256= 0,62

D = T / 256 = (20ms) / 256 = 0.79 ms

The above decimal hex value will be sent every 0.79 ms. If the frequency is to be varied, what needs to be done is to change the value of the delay period and time of sending the driving signal, which in this case is the value of the sinus table.

For a frequency of 60 Hz, the period is as follows:

T = 1 / f = 1 / 60hz = 16 ms, so that it has a delay time of:

D = T / 256 = (16ms) / 256 = 0.62

The design of this inverter uses a duty cycle of 50%, which means that Ton and Toff have the same value, so the output voltage of the microcontroller is as the following:

Vout = 1⁄2 x Vin

= 1⁄2 x 5 V

= 2.5 V

# IV. THE TESTING AND EXPLANATION OF THE SYSTEM

Testing on this final project is done to find out whether the system is made in accordance with the tools that are made or not. In testing this tool is also done to obtain data, which then results from processing the tool compared to quantitative and theory related to the working principle of the tool.

Tests carried out include circuit testing and functional testing. The measuring instrument used in testing this tool is the AVO meter and Oscilloscope.

The inverter output test is done so that the writer can find out the output voltage and input voltage in the inverter circuit.In this study the voltage source needed is 24V, which is using 2 12V batteries connected in series with a current of 10 amperes.Below is a picture of a series of systems that have been created.

**Figure 4.14** Inverter Circuit

**Figure 4.15** The entire system

## A. *The testing of output Inverter voltage and non-load-transformer*

The testing of output inverter voltage is done without any load.

**Table 4.2. The testing of outpit inverter and non-load-inverter:**

| NO | $V_{out}$ Inverter | $V_{out}$ Trafo |
|---|---|---|
| 1 | 19 V AC | 221 V AC |

**Figure 4.16** The non loaded Output voltage

## B. *The test of loaded inverter*

This test uses a multimeter to determine the inverter's output voltage. The results obtained after carrying out these tests are obtained as follows:

**Table 4.3** The test of loaded inverter

| No | Benda yang diuji | Tegangan tanpa beban | Tegangan dengan beban | Frekuensi | Arus |
|---|---|---|---|---|---|
| 1 | Lampu (20 watt) | 220V AC | 220V AC | 50 Hz | 0.1 A |
| 2 | TV LED (50 Watt) | 220V AC | 219V AC | 50 Hz | 0.2 A |
| 3 | Bor Listrik (300 Watt) | 220V AC | 217V AC | 50 Hz | 1.3 A |

In the table above we know that a voltage drop occurs when there is a load. From the test it can be said that the inverter circuit works. However, when testing is carried out with the load there has been a decrease in voltage. It can be analyzed that there is a voltage drop due to a large load.

**Figure 4.17** Loaded inverter testing

## C. *Output wave Test*

After controlling and filtering, the output waves are as follows :

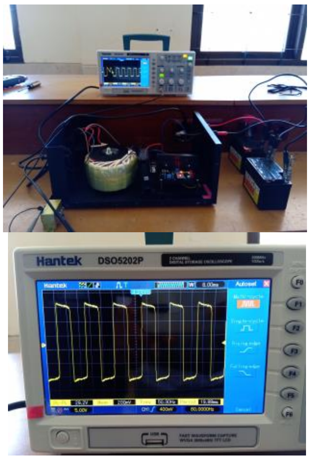



**Figure 4.15** Output wave in osiloscope

The output waveform of the inverter produced in the picture above shows that the wave output is a pure sine type but there is a defect that may be caused by the heat of the mosfet.

## V. CONCLUSION AND SUGGESTION

### *A. Conclusion*

After the process of planning, making and testing the tool and comparing with supporting theories, and from the data that has been obtained, it can be concluded that:

1. The result of the output on the inverter has been successful, that is, it can change the DC voltage to AC voltage
2. The inverter output is 220V AC
3. Wave of Pure Sinus Inverter Output
4. You can turn on the Lights, LED TVs and Electric Drill

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