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Research Article

Comparative Study of TLP250 and IR2132 Driver-Based Inverter for Induction Motor Driving

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Abstract

As time progresses, electric motors are used for industrial or commercial purposes. The need for a motor that is robust, simple, and easy to maintain has been answered by creating an induction motor that can handle the purpose. At the beginning of its use, induction motors were more often used at constant speeds. Using an inverter becomes one of the solutions at hand to control the induction motor. Nowadays, most inverters are controlled by the SPWM (Sinusoidal Pulse Width Modulation) method. This method can adjust the output voltage and frequency by setting the carrier signal's frequency value and the reference signal's amplitude. A driver circuit is needed to implement an SPWM-based inverter. This driver circuit is needed to isolate the power circuit from the controller. Moreover, this circuit is also used to increase the microcontroller output signal to trigger the IGBT gate switch. The IR2132 and TLP250 drivers are often used in three-phase inverter applications. These drivers have advantages and disadvantages. This paper discusses the capabilities of these two drivers when applied to a three-phase inverter that functions as an induction motor drive. This inverter-controlled induction motor is advantageous because it can be rotated at a nominal speed and frequency.

1. Introduction

As time progresses, the use of electric motors for industrial and commercial needs is increasing. Currently, induction motors are one of the most frequently used motors because they are easy to maintain, relatively simple to use, and reliable as a construction. However, this induction motor also has disadvantages because it is not easy to control. Several ways to control an induction motor include changing the frequency or voltage value entering the motor [1]. Before modern power electronics technology was discovered, induction motors were often used at constant speeds. With advances in power electronics and semiconductor technology that are increasingly rapid nowadays, it becomes possible to regulate induction motors using an inverter [2].

Initially, the simplest inverter topology was a square wave inverter. This inverter uses an IGBT (Insulated Gate Bipolar Transistor) power switch. IGBT is used because it can handle high currents and voltages [3]. In its development, a digital single-chip-based control technology allowed power switch settings to permit pulse width modulation (PWM) [4]. With this method, switching can produce an AC output voltage whose value can be changed according to needs.

Several types of PWM techniques can be used to regulate the power switch on an inverter, including Single-pulse Width Modulation (PWM), Multi-pulse Width Modulation (MPWM), Sinusoidal Pulse Width Modulation (SPWM), and Space Vector Pulse Width Modulation (SVPWM) [5]. The modulation technique used in this discussion is Sinusoidal Pulse Width Modulation (SPWM). This technique compares a sinusoidal reference signal with a triangular carrier signal, resulting in a modulation frequency that can determine output voltage frequency [6]. In implementing a 3-phase inverter, a driver circuit is needed to isolate the power circuit from the control circuit. Apart from that, this driver circuit is also used to forward the control signal produced by the controller to the gate section of the IGBT [7]. This paper compares IR2132 and TLP250 as drivers for the three-phase inverter.

The discussion comparing IR2132 and TLP250 drivers in three-phase inverters uses sinusoidal pulse width modulation as speed control for the three-phase induction motors. With a digital controller type dsPIC30f4012, the method generates a reference signal with a lookup table [8]. These drivers have their respective advantages and disadvantages in their application for three-phase inverters. Each driver's advantages were considered when selecting the driver used in subsequent stages.

2. Research Method

The method used for this research is an experimental one. The experimental method allowed the researcher to descriptively discuss the Three Phase Induction Motor Drive and the three-phase inverters used to control induction motors. In application, research from the Development of Active Gate Drivers to Reduce Switching Loss for Inverter Systems. Informed that the three-phase inverters cannot work alone but require a controller circuit and driver circuit [9].

2.1. Three Phase Induction Motor

Three-phase induction motors are the motors that are currently most often used in industry because they are easy to maintain and relatively cheap. In addition to the construction of these motors, they are relatively simple to use [10]. The three-phase induction motor consists of a stable part called the stator and a rotating part called the rotor. The working principle of this induction motor is based on electromagnetic induction in the stator coil, which affects the rotor coil. The magnetic field generated in the stator coil rotates the rotor based on the principle of Lorentz's law. The rotating magnetic field in the stator has the following Eq. (1).

$$Ns = 120\frac{f}{p}\ (rpm) \tag{1}$$

where Ns is the stator synchronous speed, f is the source frequency value, and p is the number of poles.

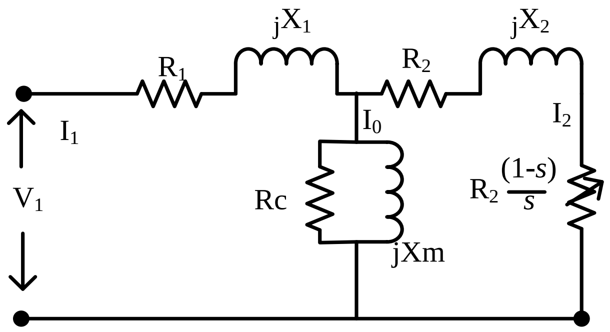

Figure 1. An Equivalent circuit of the three-phase induction motor is preferred to the stator side [11]

The equivalent circuit of the three-phase induction motor is shown in Figure 1. Figure 1 shows the stator side of the induction motor. R1, X1, RC, and Xm are the stator side resistance, reactance, and core loss resistance. Meanwhile, R2 is a magnetizing reactance, R2 and X2 are the rotor resistance, and reactance refers to the stator side. The last one, $R_2\frac{(1-s)}{s}$ represent the mechanical load of the motor as an electrical equivalent. This motor has a slip speed, which is caused by differences in the speed of the rotating magnetic field, with the rotor rotational speed whose value changes according to the load on the motor [12].

2.2. Three-Phase Inverter

An inverter is a converter used to convert DC voltage to AC [13]. The type of three-phase inverter used in induction motor settings is a voltage source inverter (VSI). The voltage produced by the inverter becomes a supply for the three-phase induction motor. The alternating voltage produced by this inverter comes from direct voltage by forming waves. The most basic topology in an inverter is a square wave inverter. The alternating voltage produced in this topology is a square wave [14]. This type of inverter is called a Six-Step Inverter. The topology and switching of this type of inverter can be seen in Figure 2.

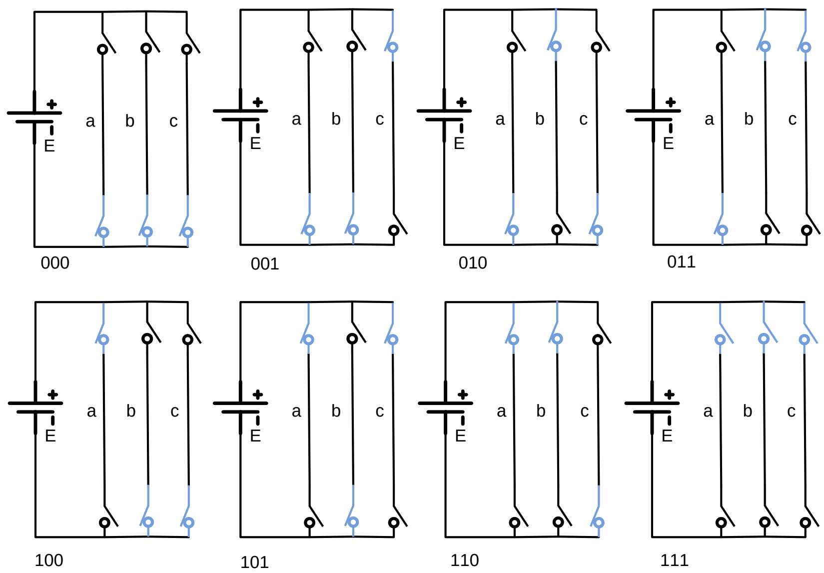

Figure 2. Six-step inverter topology switching configuration

This topology generates an output voltage waveform based on switching possibilities, as shown in Figure 3.

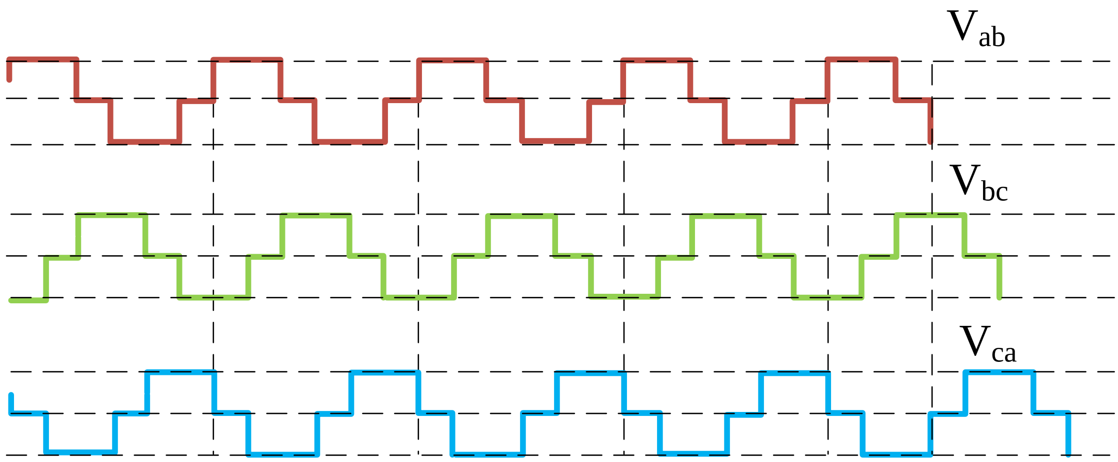

Figure 3. Output voltage of six-step inverter topologies

As seen above, Figure 3 shows the voltage output of a six-step inverter, where the voltage output between the phases for the six-step inverter topologies is the first step to developing an inverter to become another type of advanced topology.

2.3. IR2132 and TLP250 Drivers

The output signal produced by the microcontroller as input to regulate the switch on the IGBT gate is only 5V. Meanwhile, the input signal required for the IGBT gate is 12V to trigger the gate so that it can regulate switching. Therefore, a driver circuit is needed to forward the 5V signal from the microcontroller to the inverter circuit [15]. This driver circuit must become isolated between the power and microcontroller circuits. This is why when the power circuit has a problem, it does not affect the microcontroller circuit, which works at low voltage.

The IR2132 driver works at a voltage of 10-20V. This driver is equipped with three independent output channel reference signals. A safety feature to protect against an excessive current is also available on this driver. When excessive current occurs, the six output signals on the IR2132 automatically turn off. This driver also has an internal deadtime feature of 0.8 µS to provide a delay time for switching pattern control between the high and low side gates.

Figure 4 below shows the pin configuration of the IR2132, the VBx, HOx, and VSx pins connected to the IGBT Gate terminal. These pins become the exit route for the control signal to the IGBT Gate. Each output on the IR2132 has a pair for high and low switching, but the low side has the same ground for each IGBT Gate switch. The FAULT and TRIP pins are connected to the resistor as an overcurrent protection. The value of the installed resistor limits the installed inverter's maximum current capability.

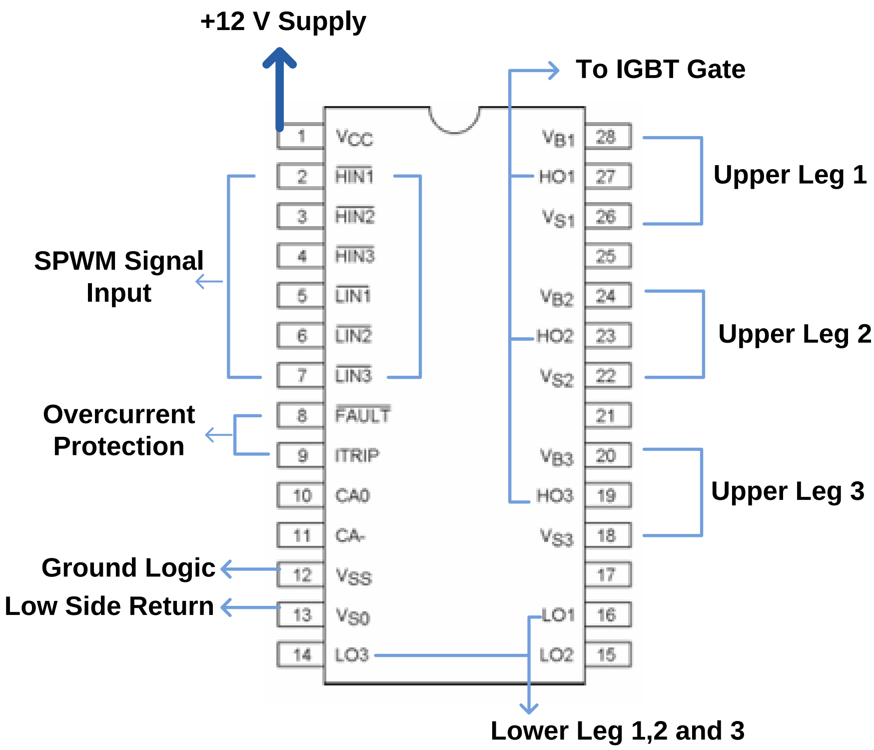

Figure 4. IR2132 pin configuration

As seen in Figure 5, the input signal is for IR2132. This input signal comes from the microcontroller output signal. However, studying Figure 5 taught that the input signal for IR2132 does not need a deadtime to delay the high and low sides because the deadtime is provided by IR2132 hardware. After passing the driver, an output signal is equipped with the deadtime.

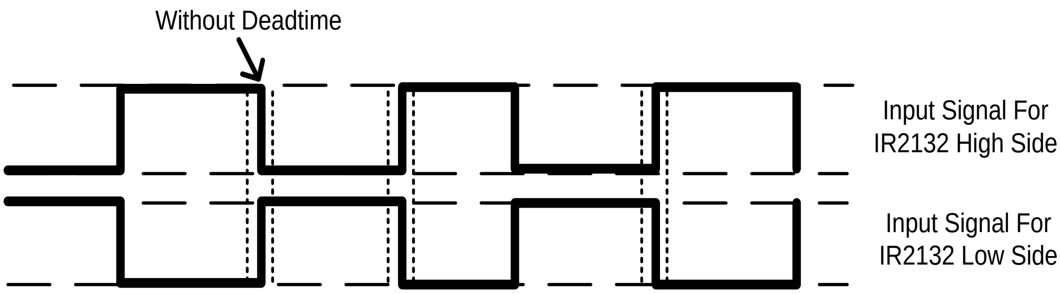

Figure 5. The input signal for the IR2132 driver

Next, the TLP250 driver is compared with the IR2132 driver. It has a working voltage between 10-35 V[16]. Even though it does not have a current protection feature like the IR2132 driver, this driver can work at switching frequencies up to 25kHz. Because one TLP250 driver can only be used to control one IGBT gate, the number required to regulate the six switches on the inverter is also six. Unlike the IR2132, which already has an internal deadtime, the TLP250 still requires a separate deadtime setting. Previously, digital microcontroller technology is developed today by initially setting the deadtime on the TLP250, which still requires an analogue circuit of capacitors and resistors to adjust the delay time.

Nowadays, the analogue circuit is left over. Any researcher uses deadtime setting by software in the microcontroller. Software settings make the hardware implementation simple. Figure 6 shows the input signal for the TLP250 driver. This input signal had deadtime to delay the high and low sides. The micro-controller software setting provides the deadtime setting for TLP250.

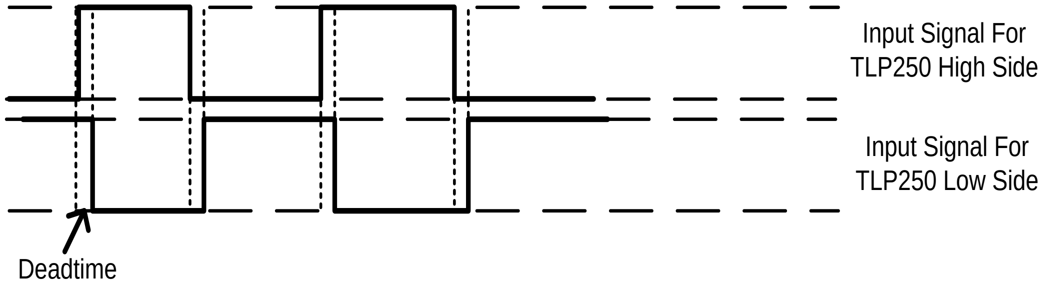

Figure 6. The input signal for the TLP250 driver

Next, Figure 7 shows the IGBT driver circuit without any deadtime analogue circuit. Hardware implementation can be done more efficiently using this series of drivers. The deadtime setting in this circuit should be done by employing a software setting in the microcontroller. Also, DC sources for high-side IGBT must be isolated between the phases.

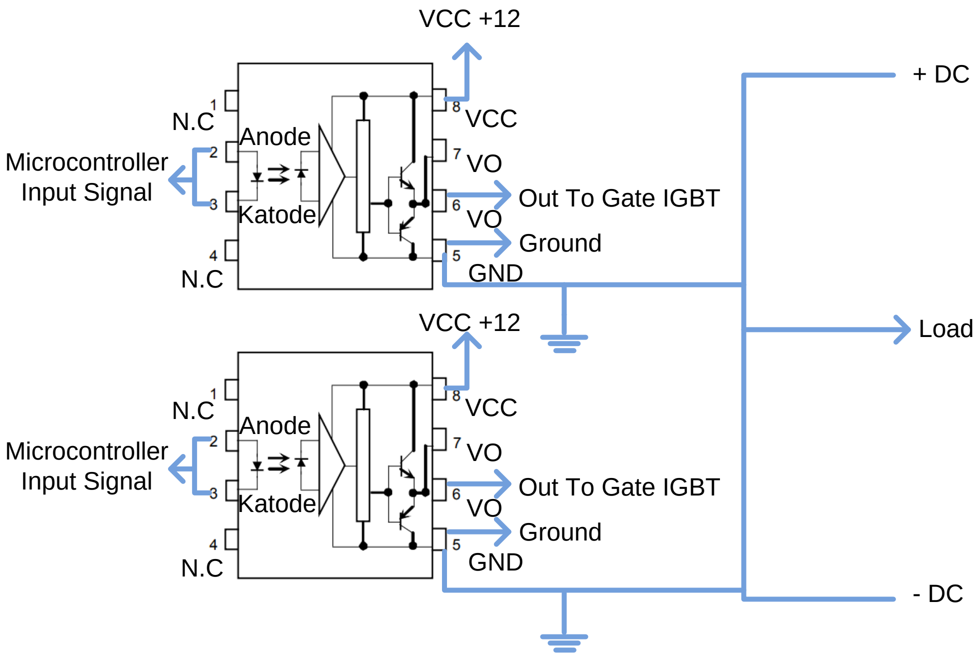

Figure 7. TLP250 IGBT driver circuit

2.4. SPWM Inverter Topologies

Inverters are one of the most popular industrial converters. It only requires a simple operation to make things work more efficiently and economically. The basic inverter topology is called a six-step inverter.

From this topology, we can elevate the method to make the inverter perform better than this method. Sinusoidal Pulse Width Modulation is one of the most popular methods to control the leg of an inverter.

The diagram block of this kind of inverter is shown in Figure 8. This system consists of a 1 phase AC voltage source. This AC voltage source is used for the DC Power Supply, which becomes a source for the inverter and is also used in the controller and driver circuit. The driver circuit is important because it isolates this system's controller and power circuits. Apart from isolating, this driver circuit is also used to increase the output signal voltage from 5V to 12V at the IGBT gate.

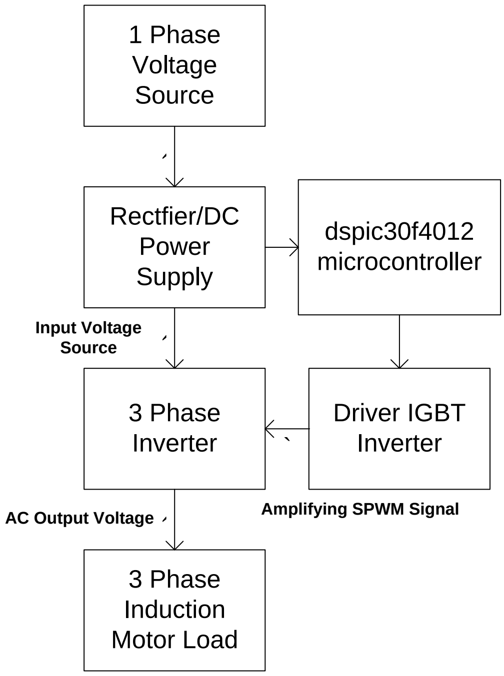

Figure 8. System block diagram

The method used to regulate the six switches on the inverter in this research is the SPWM method. This modulation technique requires a sinusoidal signal as a reference and a triangular signal as a carrier. The resulting modulation becomes a control signal to regulate the IGBT switching on the inverter.

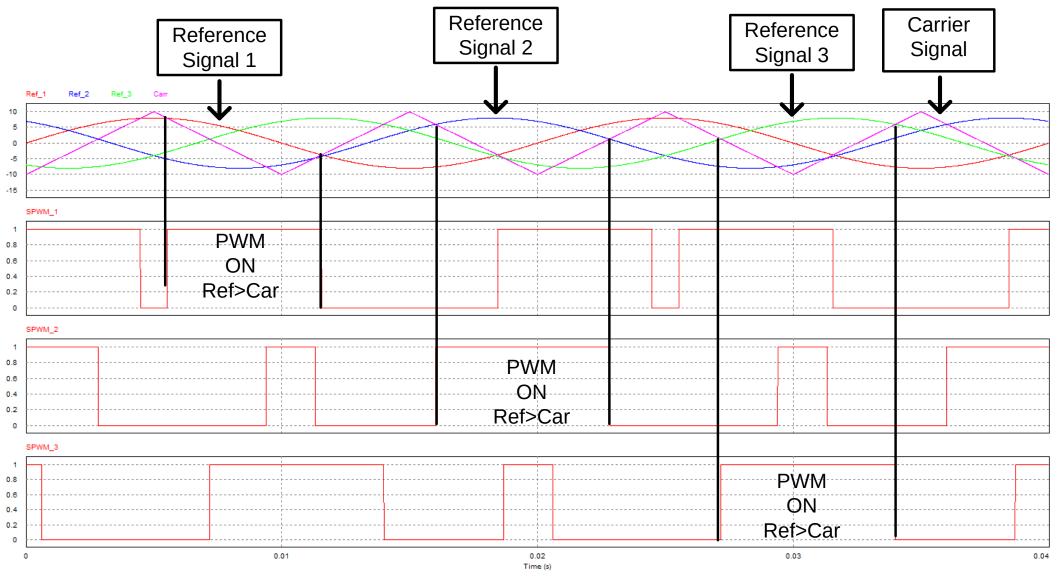

Figure 9. Generating three three-phase SPWM waveforms

The fundamental frequency value of the SPWM wave is the same as the reference wave frequency. Meanwhile, the output amplitude value compares the relative amplitude between the carrier and reference waves. The amplitude value can be calculated with the modulation index value, calculated with the Eq. (2) below.

$$Modulation\ Index = \frac{information\ amplitude}{carrier\ amplitude} \tag{2}$$

Figure 9 shows the stages forming SPWM waves by comparing the reference and carrier signals. A PSIM software creates the modeling of the SPWM switching technique in Figure 9. The reference signal is a 50Hz sinusoidal wave with an offset angle between phases of 120o. The method to generate SPWM waveforms in the hardware implementation is carried out in a step different from the simulation. The simulation of the SPWM waveform is carried out using an analogue circuit, as seen in Figure 10 below.

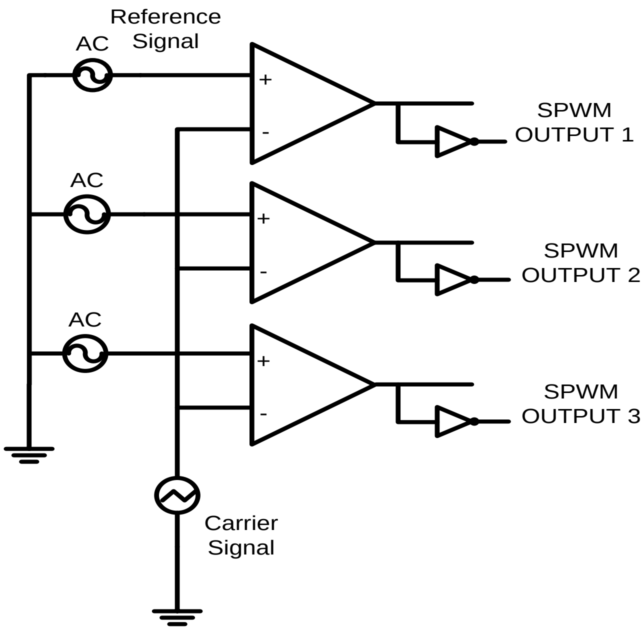

Figure 10. SPWM waveform generated by an analog circuit

The type of inverter used in this research is a Voltage Source Inverter. This converter can be called a voltage source converter because when the two conditions are fulfilled, one of the switches on one leg would need to conduct simultaneously with the currents of the AC so short circuits do not occur. The switch used for this research is an IGBT switch, where each leg consists of two switches with complementary operating modes.

The formation of SPWM waves during the hardware implementation with a digital microcontroller is based on dsPIC30f4012. The formation of the sinusoidal reference signal is obtained from the lookup table method, while the triangular carrier signal is produced by setting the timer and interrupt functions on the microcontroller. The PWM Control and Deadtime functions are used when the driver is the TLP250. Meanwhile, when the driver is IR2132, the PWM control and deadtime functions do not need to be used. The programming algorithm with the IR2132 driver is shown in Figure 11 in more detail.

Figure 11 is a flowchart for SPWM programming using the TLP250 driver. When using the IR2132 driver, the sinusoidal signal value is compared with the carrier to determine the output value on the specified port. A 3-phase sinusoidal wave is formed by arranging the data sampling in the lookup table to produce a phase difference of 120^o.

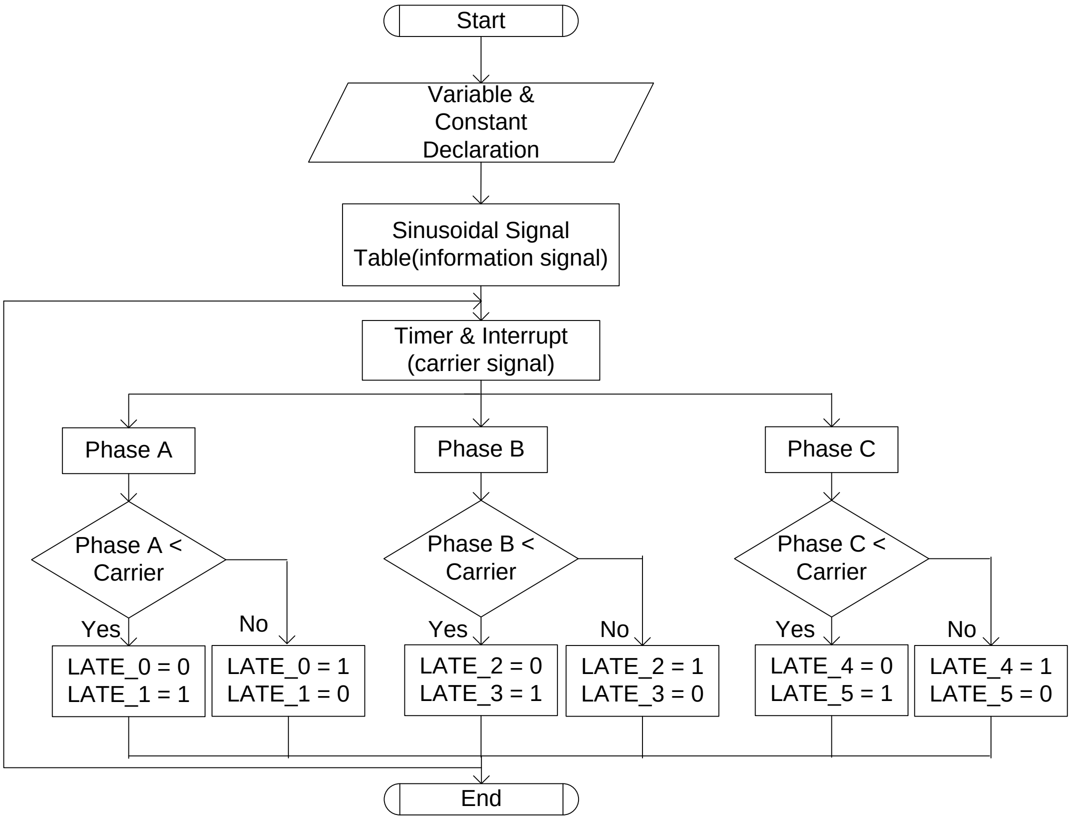

Figure 11. SPWM flowchart with IR2132 driver

Then, Figure 12 shows an SPWM program flowchart using the TLP250 driver. By using the TLP250 driver, there is a need to add a deadtime setting to the program. To set the output on the port, comparing the information signal with the carrier is not used because it is directly regulated by the functions available on the microcontroller.

3. Results and Discussions

In the research, the prototype is implemented to see directly the differences that exist when using the IR2132 and TLP250 drivers. Figure 13 shows the result of implementing the hardware. It is the main part of the device. Other devices, such as a DC-link, can be used as a supply for the inverter. Then, tachometers, multimeters, oscilloscopes, DC power supplies, and current clamps support the testing. The B1212S circuit is used to implement this prototype to supply the DC voltage requirements for the driver circuit.

Using the TLP250 driver requires more attention because adding a deadtime setting to the program is necessary to provide a delay time between the upper and lower legs of the IGBT switch. Apart from that, in the TLP250 driver, more DC voltage sources are needed. The DC voltage sources given to each TLP250 must be isolated from each other so that the TLP250 can work properly. However, when using the IR2132 driver, only one DC voltage source is needed to turn on the driver.

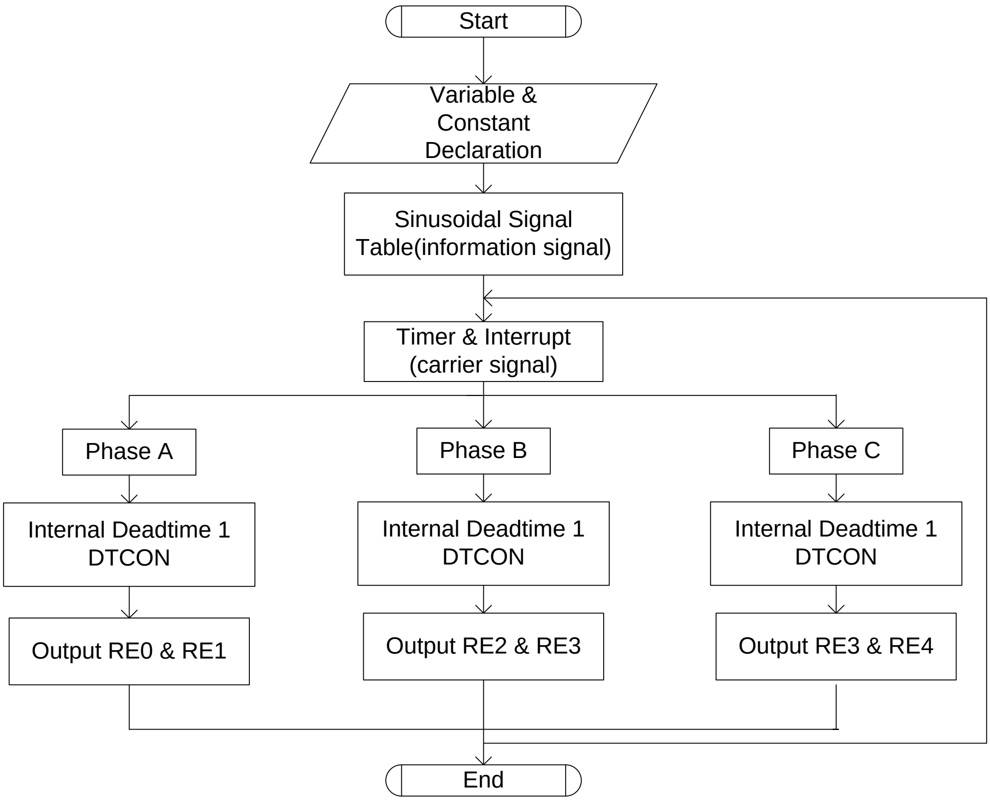

Figure 12. SPWM flowchart with TLP250 driver

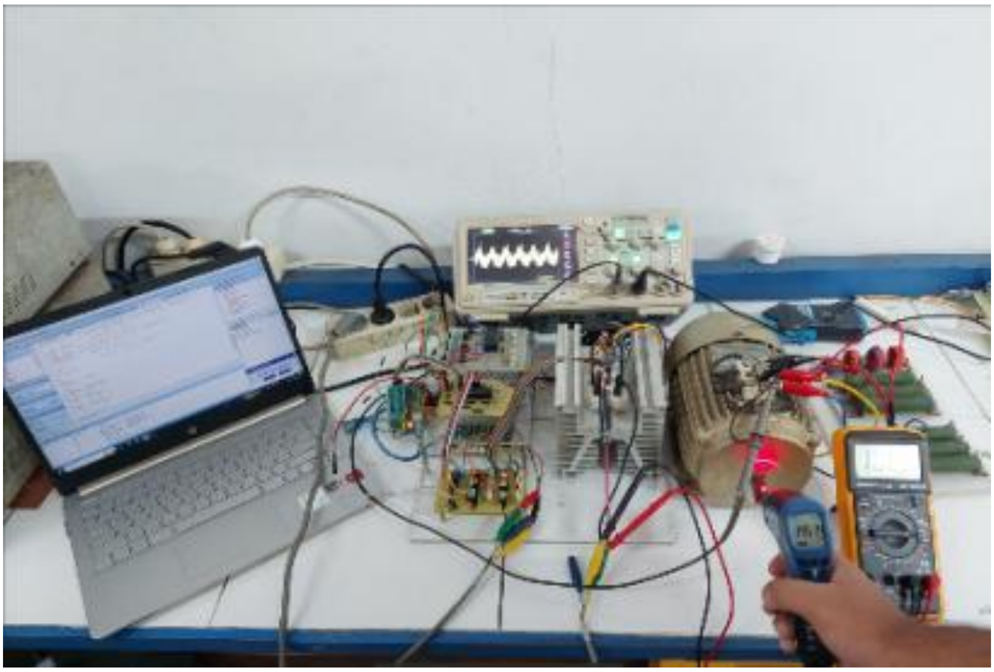

Figure 13. Hardware implementation

Figure 14 shows the phase voltage output on three-phase inverters based on simulation. This simulation becomes the reference for hardware implementation. In this simulation, the inverter is operated under resistive and inductive loads. Here, the resistive value is 25Ω, and the inductive value is 3mH.

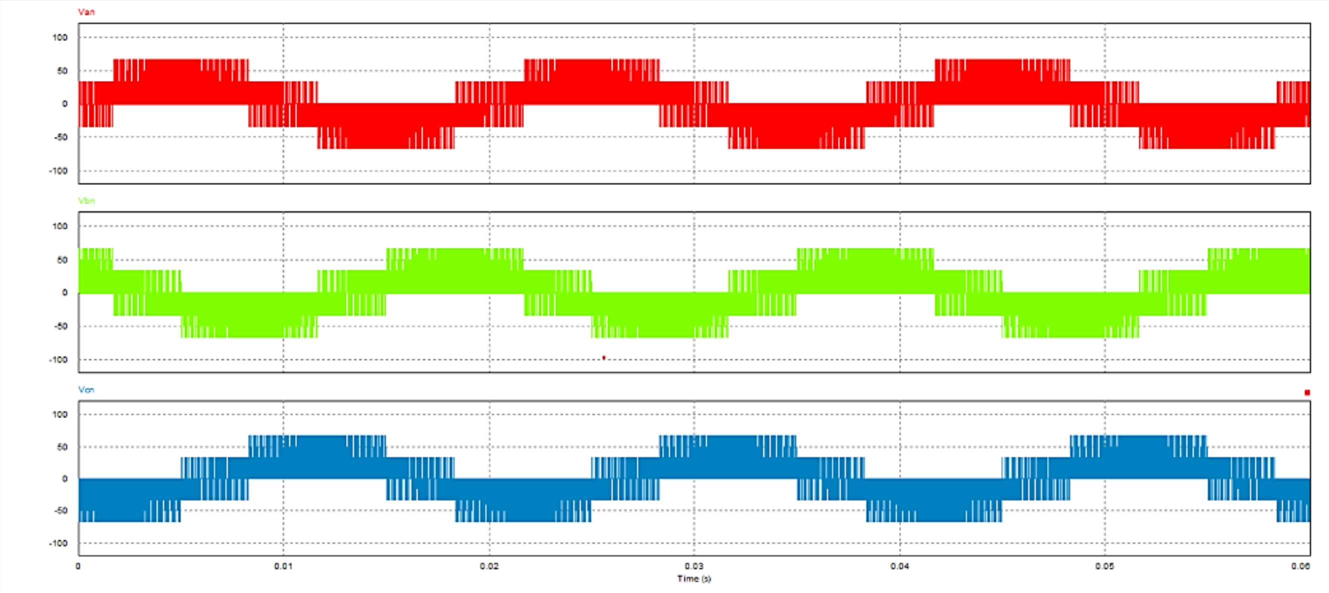

Figure 14. Phase voltage output of three-phase inverter

After the inverter output is determined by simulation, the inverter output is tested in a real application. Each driver had a different signal input when we implemented the IR2132 and TLP250 drivers. Figure 15 shows the input signal for the IR2132 driver. When using the IR2132 driver, no deadtime adjustment is needed for the input signal because the driver's hardware provides the deadtime setting. The internal deadtime value is found to be 0,8 µS.

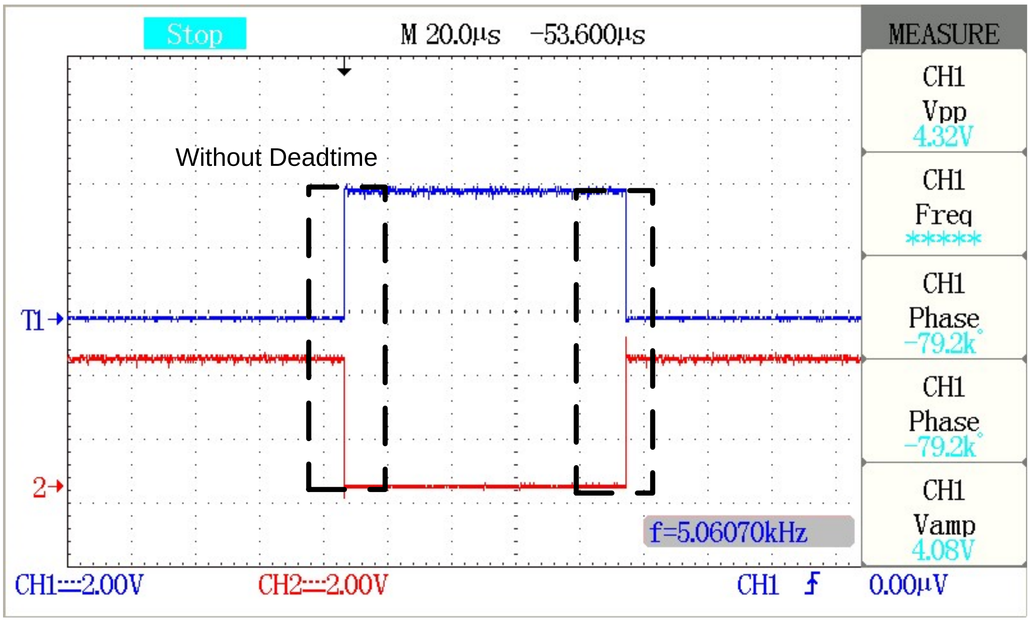

Figure 15. The input signal for the IR2132 driver

The output signal is equipped with a delay time to prevent heat from the switching process between the IGBT's upper and lower legs. From this heat, a short circuit is produced, thus causing the inverter not to work safely. There is a different result when the TLP250 driver is used. In this case, a deadtime setting must be applied to the software.

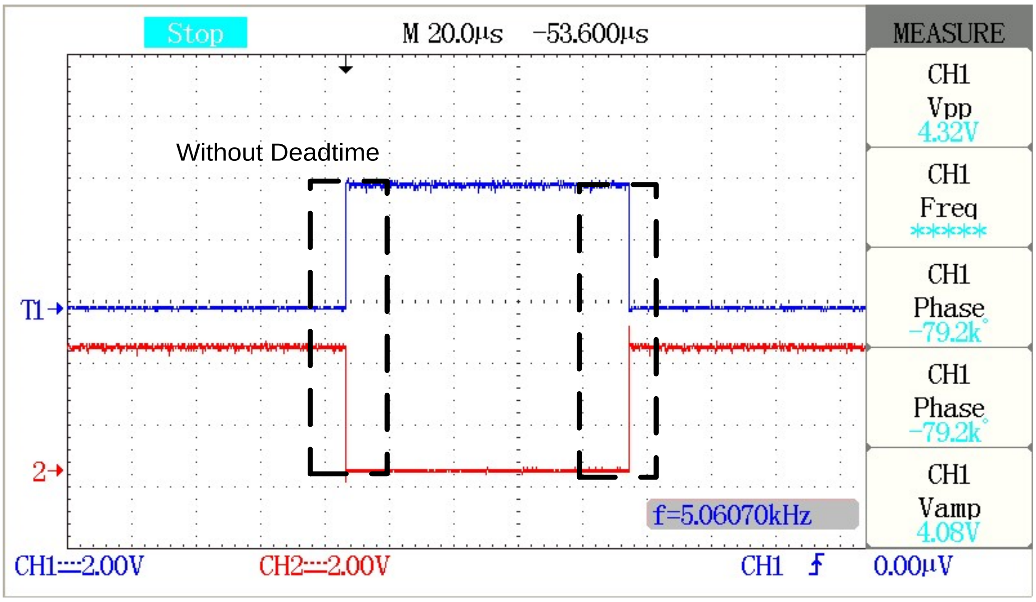

Figure 16. The input signal for the TLP250 driver

When the program on the microcontroller is compiled, the deadtime setting must be applied, too, because TLP250 does not have a deadtime feature. The input signal for the TLP250 driver is shown in Figure 16. Based on Figure 16, the input signal for TLP250 is known. It is found that a delay time value of 0.83 μS must be given. The deadtime value created refers to the internal deadtime in the IR2132 driver so the switching process can work safely.

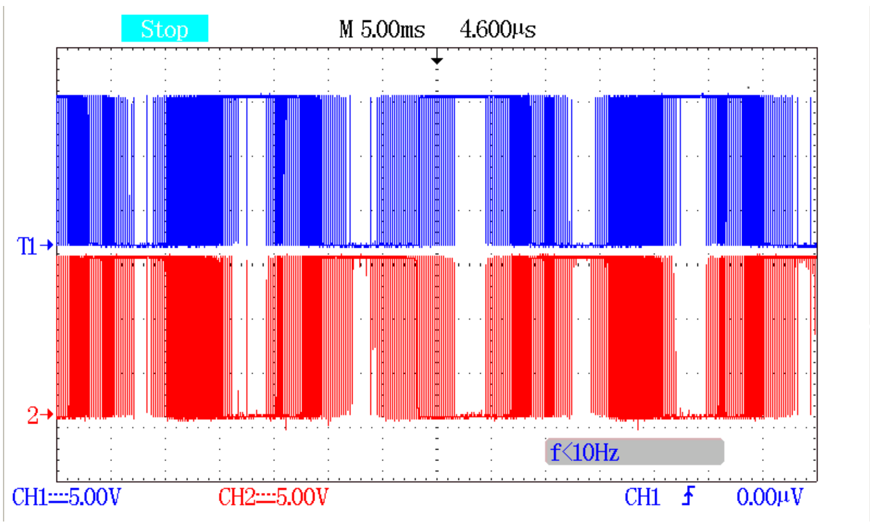

Figure 17. Experimental result of SPWM output waveform with IR2132 driver

Figure 17 is the SPWM wave output on the high and low sides of the IR2132 output pin. These waves have a frequency of 50 Hz. This frequency is kept at 50Hz so the induction motor can rotate at 1400rpm. The frequency value of 50Hz can be seen on an oscilloscope by calculating the time/div multiplied by the number of boxes in one period.

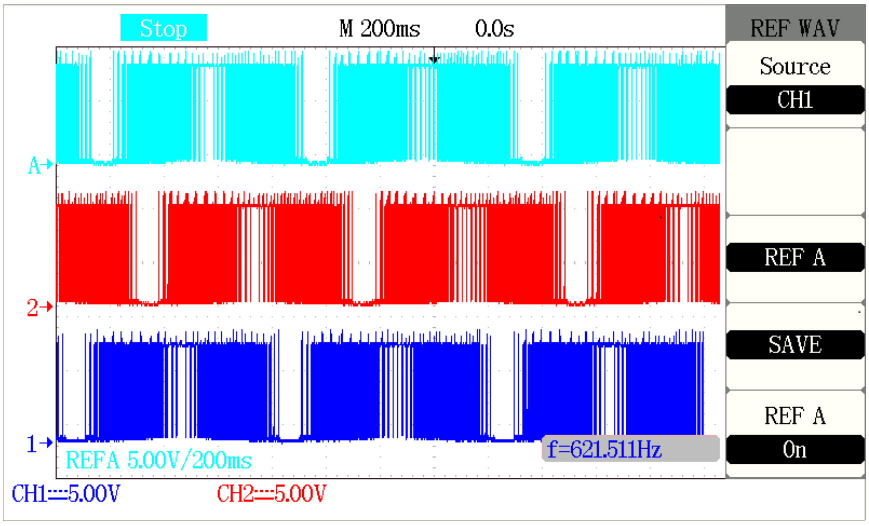

Figure 18. Experimental result of SPWM output waveform with TLP250 driver

Figure 18 shows the SPWM waveform output with the TLP250 driver. In the picture, the SPWM signal is shown on the high side. The first image is the high-side output for the first leg. Then, the second leg and the last SPWM signal are needed to regulate the third leg on the high side. As a result, the SPWM output signals are shifted by 120°.

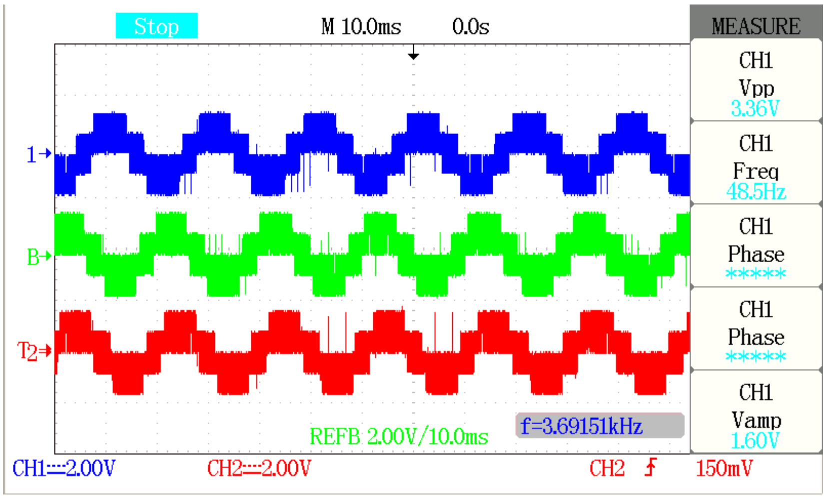

Figure 19. Experimental result of output phase voltage waveform with IR2132 driver

After knowing the SPWM wave output produced at the output of the IR2132 and TLP250 drivers, the inverter is tested to see the voltage and current output results. Figure 19 shows the inverter voltage output using the SPWM method with the IR2132 driver. In this test, the resistive load given is 20 Ω.

Figure 20 shows the result of the inverter voltage output under resistive load, and the driver is the TLP250 driver. When using this driver, the deadtime setting is provided by a software setting on a micro-controller.

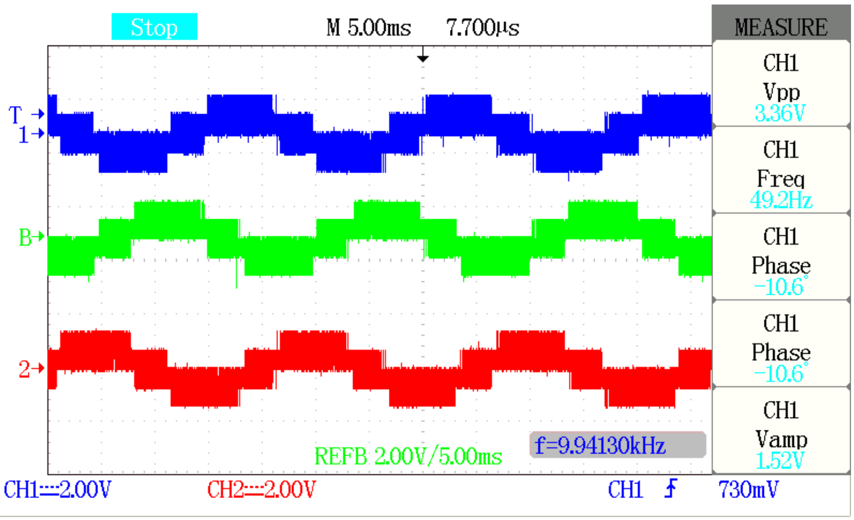

Figure 20. Experimental result of output phase voltage waveform with TLP250 driver

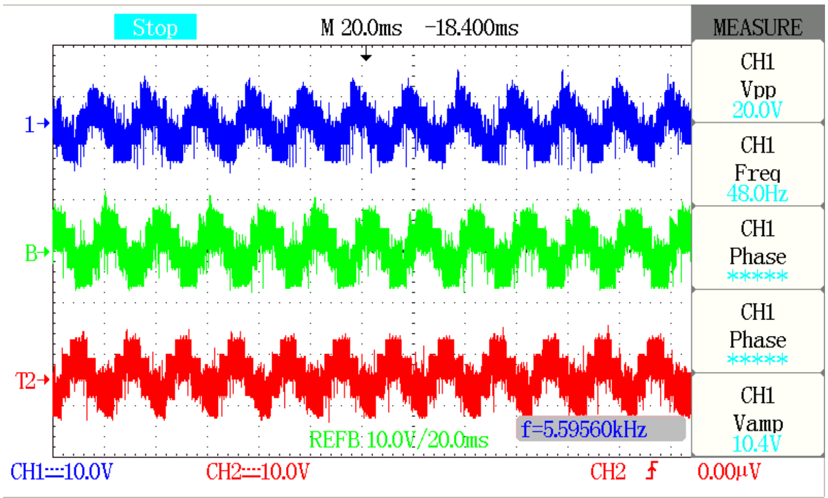

Figure 21. Experimental result of output phase voltage waveform under induction motor load with IR2132 driver

Figure 21 is the result of the phase voltage output of the inverter under an induction motor load with a rated power of 1⁄2 HP. The results shown here are using the IR2132 driver.

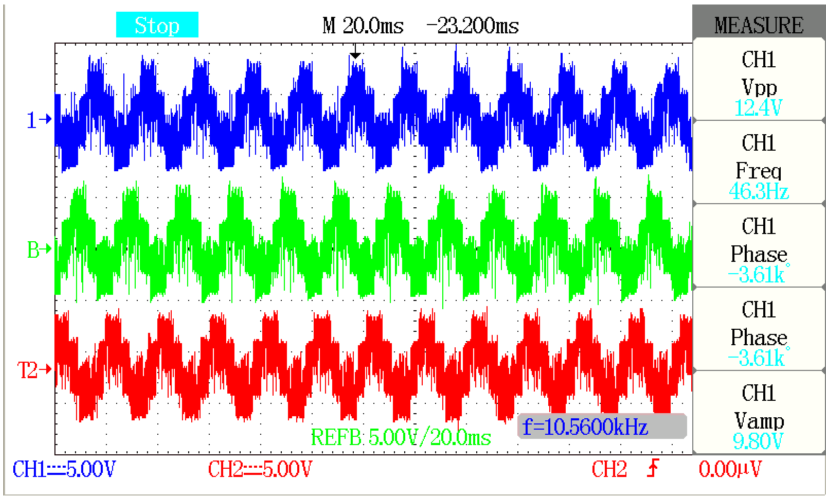

Figure 22. Experimental result of output phase voltage waveform under induction motor load with TLP250 driver

Figure 22 shows the inverter's phase voltage output with an induction motor load. The voltage output results produced using the TLP250 driver do not significantly differ from the IR2132 driver.

Figure 23 shows the inverter voltage output using the IR2132 driver when the induction motor is loaded. The voltage measured on the oscilloscope is the line voltage.

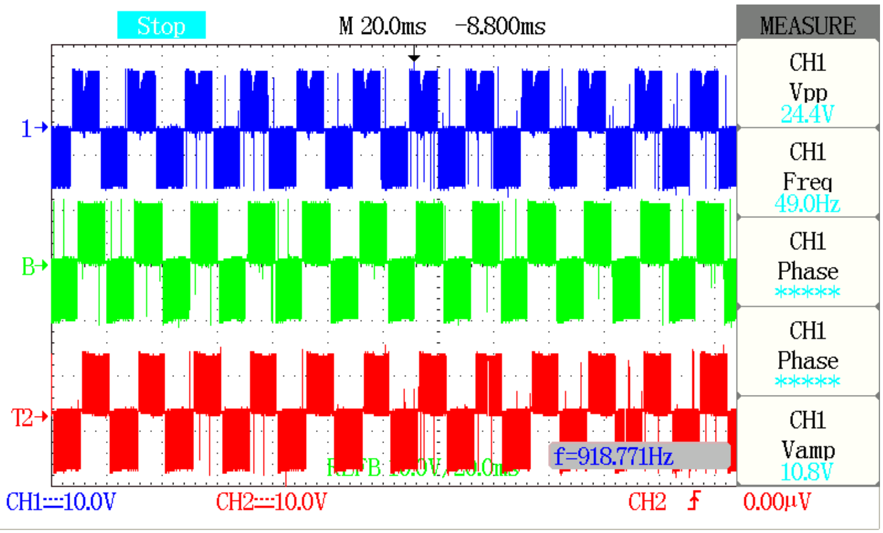

Figure 23. Experimental result of output line voltage waveform under induction motor load with IR2132 driver

Figure 24 shows the results of the voltage and current output on the inverter for an induction motor load. The driver used is the IR2132 driver. With this SPWM method, the current waveform output is sinusoidal. Because it is an inductive load, the current waveform is left behind the voltage waveform.

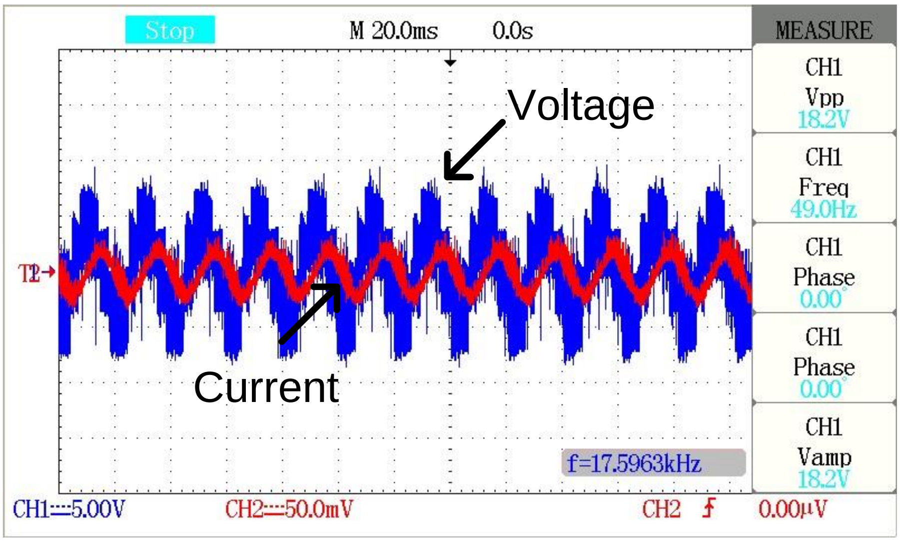

Figure 24. Experimental result of output phase voltage and current waveform under induction motor load

Figure 25 shows the condition of the induction motor speed. The motor speed is read as 1467 rpm using a tachometer in this condition. This speed was reached by the specific voltage given to the inverter.

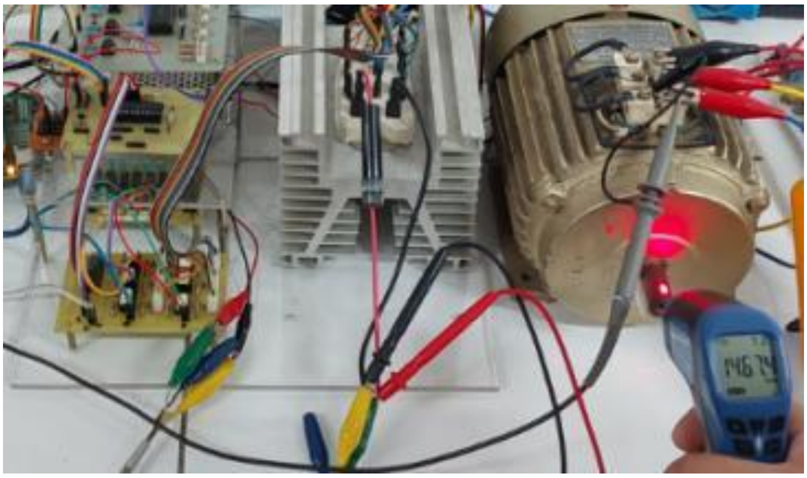

Figure 25. Experimental result of prototype speed measurement

When the TLP250 driver is applied, the voltage and current output are not much different from the voltage and current output on the IR2132 driver. Figure 26 presents the inverter when the TLP250 driver is used. As an inductive load, the induction motor made the current waveform appear after the voltage. This condition is stated as lagging.

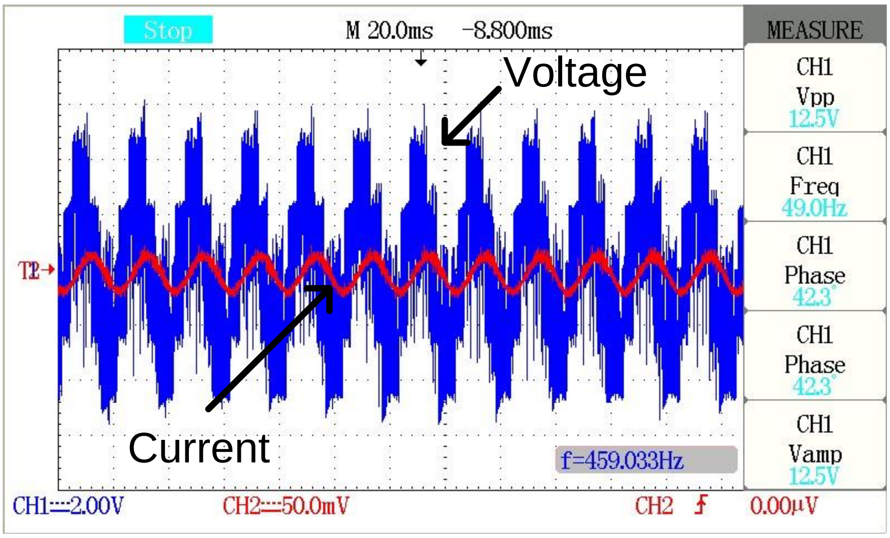

Figure 26. Experimental result of output phase voltage and current waveform under induction motor load

4. Conclusions

From the results and discussions stated above, several conclusions are met. First, the IR2132 and TLP250 drivers have similar capability of forwarding IGBT Gate control signals. However, in its application, the TLP250 requires an additional program algorithm on the microcontroller to adjust the deadtime settings to prevent short circuit possibility. However, when the IR2132 driver is used, the device provides an internal deadtime. Second, the TLP250 voltage source must be isolated. Third, these two drivers can also be used for inverters to drive induction motors. Fourth, during testing, both drivers produced an output for the inverter to drive the motor at a speed of around 1400 rpm.

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Declaration of Competing Interest: The authors declare that they have no known competing of interest.

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