

## Design and implementation of a driver circuit for three-phase induction motor based on STM32F103C8T6

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### Article Info

#### Article history:

Received Jun 17, 2022

Revised Aug 18, 2022

Accepted Oct 14, 2022

#### Keywords:

Driver circuit

Pulse width modulation

STM32F103C8T6

Three-phase induction motor

Three-phase inverter

### ABSTRACT

A three-phase induction motor is an electrical machine that can be used for many industrial applications. A three-phase driver circuit, also known as a three-wire series circuit or three-wire delta circuit is an electrical power system. These motors typically rely on power supplied using electric cables, which carry alternating currents. The three-phase motor inverter driver circuit is a simple circuit consisting of three half-wave rectifiers, which are connected in a bridge. When the input voltage level of the DC power supply to the inverter is high enough, this arrangement can provide a large current through the induction motor. This paper will show how to build a three-phase inverter driver circuit from scratch for a three-phase induction motor by using (transistors and diodes) for photovoltaic application. The paper will guide people through each step with diagrams and schematics that make it easy for anyone to understand every part of this project and ensure people's safety by learning how these components work before putting them into their own design. The focus of this project will be on the use of STM32F103C8T6 as microcontrollers to generate the pulse width modulation (PWM) signals.

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## 1. INTRODUCTION

Electronic transducers are now widely used in a range of applications and enable variable speed driving of induction motors by adjusting the frequency of the applied voltages. As a consequence of substantial technological improvement in the field of power electronics in recent years. This amount of use indicates the ability of these transducers to enhance the efficiency of dynamic or static features and limit the specifications of machines [1]–[5]. Which is the scenario in the electromechanical switching series because of the inverter's high ability to ensure adaptive voltage and frequency change.

For the smooth operation of the speed and direction controller, several researchers have presented many types of controllers. The occurrence of torque ripples is dictated by a dip in torque between two consecutive phases, as stated in [6]–[8]. In [9]–[12] the authors proposed a model-based killed flux controller. Typically, the design of control system components for high-order systems includes significant computational problems and time-consuming activities. As a result, high-requirement controllers must be designed for such systems through appropriate order-reduction of the model [13]–[17].

In MATLAB/Simulink, the interpretation of sinusoidal pulse width modulation (SPWM) and SVPWM-based inverters was estimated using the metrics of speed organization, torque ripple, and total deformation of harmonics [17], [18]. We find AC signals that are used as control variables in AC systems to assess the system's performance. Performance is significantly enhanced when these ac control signals are switched out for DC values (referred to as AC/DC frame translation) since DC signals are more straightforward and have larger bandwidth. The foundation of this transformation theory is the conversion of AC signals to DC values, manipulation of these DC values, and subsequent return of the values to the AC domain and conversion of the values back to AC signals. There are a large number of electronic circuits that are used to control single-phase and three-phase induction motor motors. Each circuit differs from the other by the difference in the type of electric controller or the type of the inverter circuit and often these circuits are not available to everyone or it the difficulty of obtaining the main schematics with the control program.

In this paper, we designed a new, low-cost and easy-to-use circuit by using the STM32F103C8T6 as a microcontroller [19], which can be used to write the control program by using Arduino IDE [20]. Moreover, the design of a three-phase inverter with a driver circuit was designed to be easy to use for everyone, especially students and researchers. The final printed circuit board (PCB) circuit was designed by using an open-source PCB circuit design program. The complete system of the three-phase induction motor driver circuit consists of the following main major parts, all of which are open-source, inexpensive electronic components.

## 2. HARDWARE REQUIRED

In this section, all the necessary electronic items on the market that are available to everyone that will be used in this paper will be presented and discussed. STM32F103C8T6 will be used as a microcontroller in the final circuit design. IRF840 will be used for the power switch and IR2112S TRPBF as IGBT driver IC. MC7805CDTG and LD1117S33TR will be used as voltage regulators ICs.

### 2.1. STM32F103C8T6 microcontroller

STM32F10x is a low-cost, high-performance ARM Cortex® -M3 based microcontroller. It offers advanced features and peripherals, which make it ideal for embedded applications. The STM32F103xx series is one of the most popular platforms for emerging IoT applications such as connected home or smart city solutions.

This 32-bit microcontroller board has built-in 2D acceleration via video processing unit (VPU1) which can support MPEG2 decoding at up to 25 fps or MPEG4 encoding at up to 30 fps. It supports one time boot, on-chip debug store (OCDS), low power modes and 256 byte electrically erasable programmable read-only memory (EEPROM) for data retention during application development process. Atmel's STM32F103C8T6 is an ARM® Cortex™-M3 based with 256 K flash, 16 K RAM and a USB 2.0 connector. It has 51 general-purpose input/output (GPIO) pins, 10 analog I/O pins, 37 digital I/O pins, 128×8 software selectable I/O pins, 3.3 v operating voltage, 64/128 flash memory (KB), 20 KB SRAM, 72 MHz max frequency (clock speed) and inter-IC (I2C), serial-peripheral interface (SPI), universal asynchronous receiver/transmitter (UART), controller area network (CAN), USB communication, and see Figure 1(a) [20].

### 2.2. IRF840 power metal oxide semiconductor field effect transistor

The IRF840 is a general-purpose metal oxide semiconductor field effect transistor (MOSFET) semiconductor power switch designed for controlling DC loads. It has high power capacity and fast switching, making it suitable for use in battery chargers, uninterruptible power supplies (UPS), inverters, and other high-power applications [21]. The IRF840 is also offered with an SOT23 surface mount package that can be used to provide low-power circuit protection applications such as input overvoltage protection on the low voltage side of transformer isolated supply circuits. The small size of the SOT23 package enables these devices to be conveniently located near sensitive circuitry or out on a PCB track side, see Figure 1(b).

### 2.3. IR2112STRPBF metal oxide semiconductor field effect transistor

Power MOSFET and insulated gate bipolar transistor (IGBT) drivers with individually referenced high and low output channels comprise the IR2112(S), see Figure 1(c). Because of the distinct high-voltage integrated circuit (HVIC) and latch-resistant complementary metal-oxide-semiconductor (CMOS) technology, a ruggedized monolithic design is achievable. Up to 3.3 V logic, the logic inputs are suitable for CMOS or low power Schottky transistor logic (LSTTL) model outputs. To reduce driver cross-conduction, the output drivers make use of a high pulse current buffer stage. High-frequency applications may be used more easily since the propagation delays are matched. In a high-side configuration, the floating channel may drive an N-channel power MOSFET or IGBT rated for 600 volts [22].

#### 2.4. MC7805CDTG voltage regulators

The 7,805 voltage regulator is necessary for a lot of circuits. It was designed to regulate a steady 5 V output from a wall adapter with incongruities in input voltage. A common application is converting 12 volts from an automotive battery to 5 volts for powering micro-controller circuits. The 7,805 is one of the most popular voltages because it provides stable and reliable power on inexpensive, readily available components. It can convert as much as 1 ampere at up to 35 watts of power and 10 amperes at over 150 watts into regulated, constant voltage at up to 25% duty cycle, see Figure 1(d) [23].

#### 2.5. LD1117S33TR voltage regulators

LD1117 is a low-voltage regulator with an adjustable release ( $V_{REF}=1.25$  V) and an output current of up to 800 mA. Fixed versions of the following output voltages are available: 1, 2, 5, 1, 8, 2, 85, 3, 3, and 5 volts. The device is presented in the formats SOT-223, DPAK, SO-8 and TO-220. The SOT-223 and DPAK surface mount packages have amended thermal properties while also taking up less space. Excellent competence is guaranteed by the negatif positif negatif (NPN) pass transistor. In reality, in contrast to positif negatif positif (PNP), the quiescent current in this scenario flows largely into the load. Only a standard 10 F minimum capacitor is needed for stability. The regulator may achieve an extreme tolerance for the output voltage of less than 1% at 25 °C gratitude for on-chip trimming. End-to-end adjustable LD1117 conforms to other standard. Figure 1(e) shows that adjustable voltage regulators have better tolerance and loss than fixed voltage regulators [24]. Deferent values of resistances and capacitors for the design of the full circuit, see Figure 1(f). Some of these resistors are used on the low-voltage side of the driver circuit and others are on the high voltage side.

#### 2.6. Three-phase induction motor

An induction motor is a machine with electromagnetic components that induces currents in the rotor by electromagnetic forces. It is the most common type of AC motor. An induction motor's main components are stator coils, an iron core, and thin copper wire rotors called an armature. The stator coils are stationary with respect to the ground or another frame of reference, while the rotor moves inside them with respect to that frame, see Figure 1(g) [25].

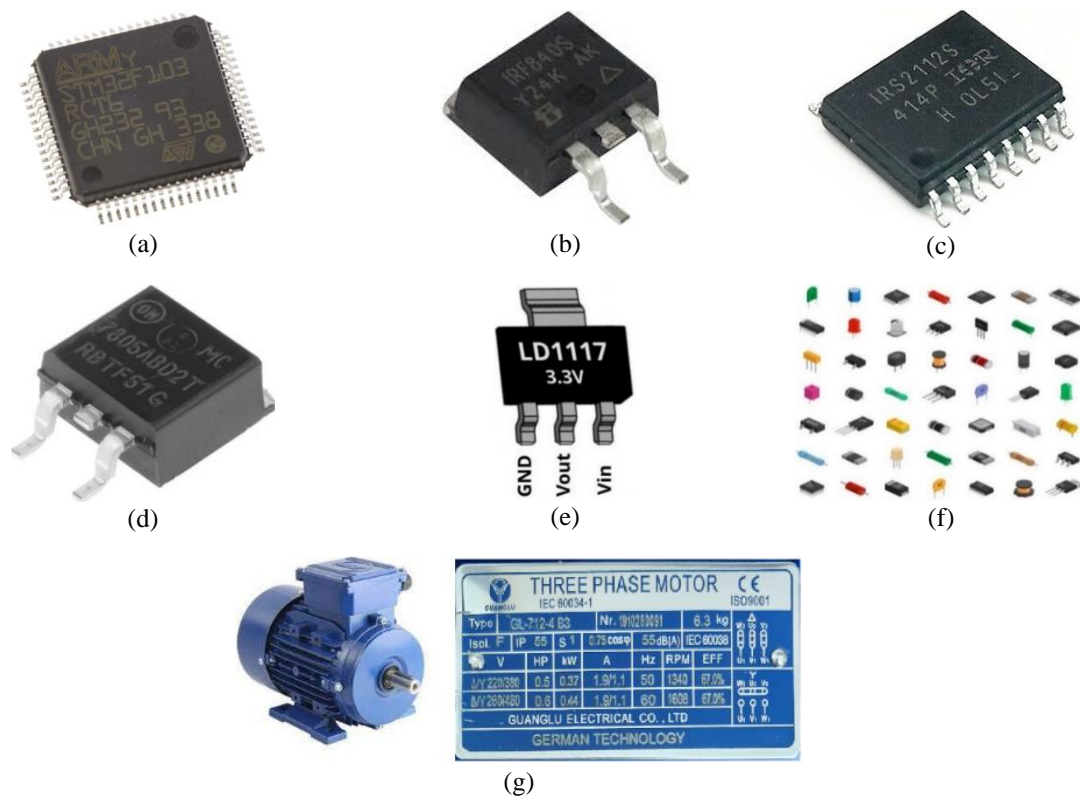


Figure 1. System hardware components (a) STM32F103C8T6, (b) IRF840 power MOSFET, (c) IR2112STRPBF, (d) MC7805CDTG voltage regulators, (e) LD1117S33TR, (f) electronic components, and (g) three phase induction motor

### 3. SYSTEM ARCHITECTURE

The electrical and electronic components need to be tested independently before the system can be entirely developed and built. The Diagrams in this part will be used to show the practical aspects of each electrical component in this section. Finally, the hardware for the final system design is given. Figure 2 shows how the PWM pins on the STM32F103C8T6 are used to generate six PWM signals to drive the three-phase inverter circuit, plus the digital pins for the purpose of controlling the direction of rotation and speed of the induction motor.

The IRF840 MOSFET transistor is seen in the circuit schematic for a three-phase inverter in Figure 3. A DC input voltage is transformed into an AC output voltage using this circuit. To provide a three-phase AC supply, it includes three arms that are typically 120 degrees apart. The switches in the inverter have a rate of 50%, occur every  $T/6$  of the time, and have a  $60^\circ$  angle interval.

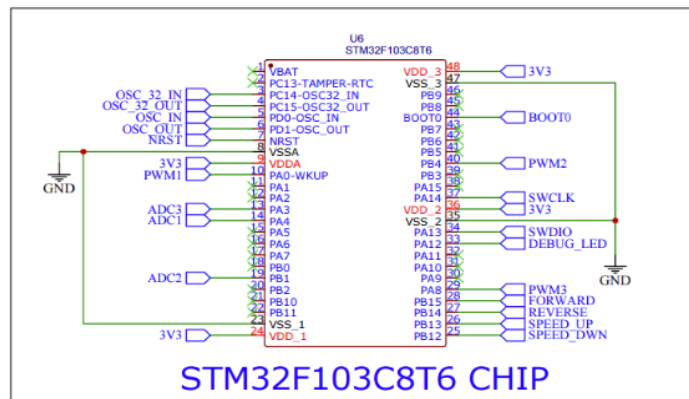


Figure 2. STM32F103C8T6 circuit diagram for generate PWM signals

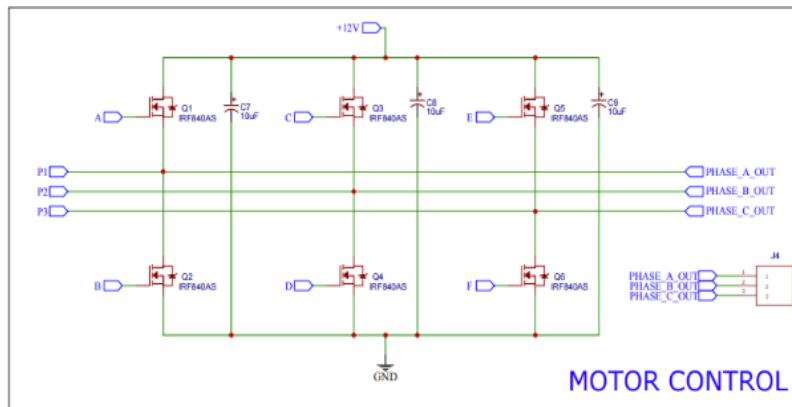


Figure 3. Three phase circuit diagrams for IRF840AS MOSFET transistor

A 5 volt regulator circuit that only requires three parts is shown in Figure 4(a). It is a straightforward, affordable, and simple method to obtain a current of up to 1 A and a voltage of more than 5 V. This circuit may also serve as a power source for breadboards. A circuit for 3.3 V @ 800 mA DC regulated supply is shown in Figure 4(b). This circuit employs the LM1117 low-dropout linear regulator. A voltage regulator with a low dropout of 3.3 V at 800 mA load current is the LM1117-3.3.

High and low side driver circuit diagram IR2112 popular integrated circuits and transistors is shown in Figure 5. The IR2112(S) is an IGBT and power MOSFET driver with separately referenced high and low output channels that operate at high voltages and speeds. Exclusive HVIC and latch-resistant CMOS technologies make it feasible to create robust monolithic architecture. A normal CMOS or LSTTL output may be used with logic Input down to logic 3.3 V In drives output, via driver conduction is minimized by using a high pulse current buffer step. To make using high-frequency applications simpler, the propagation delays are matched. In a 14-DIP package, the floating channel can be used to power N-channel power

MOSFET or IGBT in high bypass configuration, operating up to 600 V. Figure 5(a) is shown the driver circuit diagram for phase A, Figure 5(b) is shown the driver circuit diagram for phase B and Figure 5(c) is shown the driver circuit diagram for phase C.

Figure 6(a) shows how to connect some electronic components necessary, such as capacitors, diodes and crystal oscillator to complete the final circuit of the three-phase inverter board. Figure 6(b) shows the terminals used how to connect the external switches that are used to change the direction of the motor (right - left) as well as control the speed of the induction motor. After all the electronic parts used in our project were shown, we assembled them and wrote one program to run them. Figure 7(a) presents the final PCB design of the entire system circuit and the driver circuit to drive the three-phase induction motor and the final hardware implantation circuit is presented in Figure 7(b).

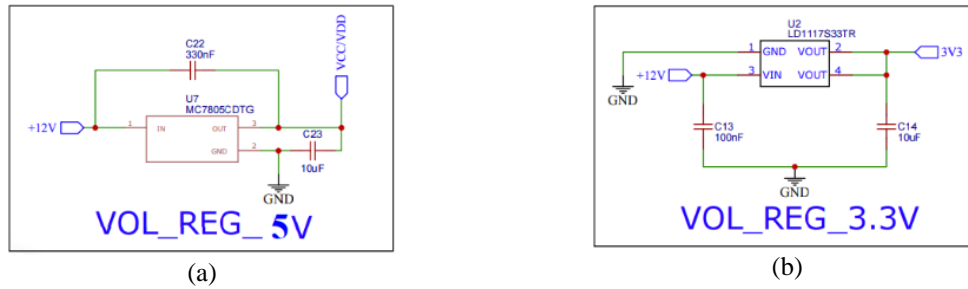


Figure 4. Voltage regulator circuit diagram (a) 5 V output and (b) 3.3 V output

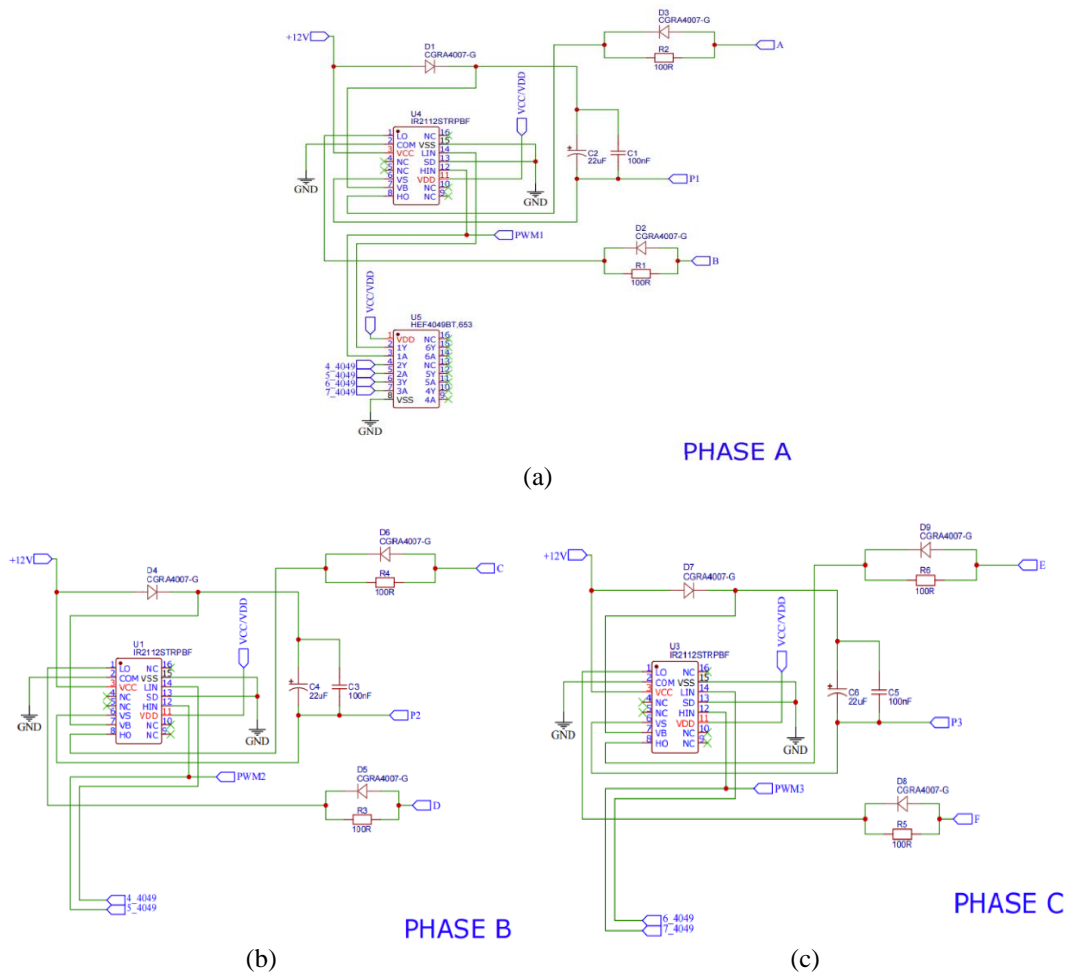


Figure 5. IR2112 driver circuit diagram (a) phase A with HEF4049BT Hex IC INVERTER, (b) phase B, and (c) phase C

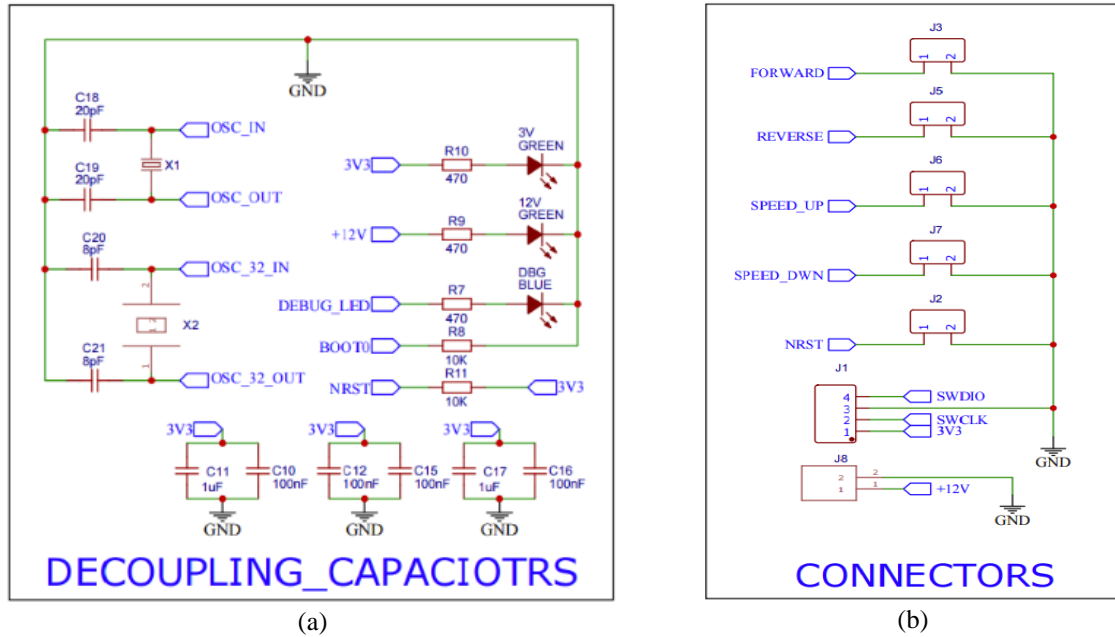


Figure 6. Schematic diagram (a) decoupling capacitors circuit diagram and (b) connectors circuit diagram for switches

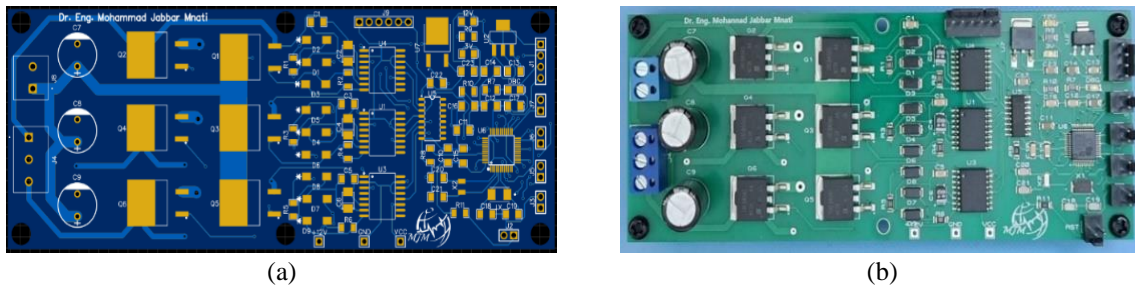


Figure 7. PCB circuit (a) PCB top layer circuit layout designed by using (easy EDA software) and (b) final hardware circuit after printing

#### 4. RESULTS AND DISCUSSION

The final simulation for the three-phase inverter and induction motor was done in the MATLAB/Simulink program and the values of voltage and current were as in Figure 8. The final hardware setup of the system is presented in the Figure 9. This figure is present the full driver circuit with three-phase inverter, three phase induction motor and DC input power supply.

- The operating the device does not require any great experience, because it was designed to work easily, especially when working on it by students, while providing all safety means in terms of operation and extinguishing.
- The devices were turned on and their performance tested, reaching a speed of 1,000 rpm during the test because the motor tested under open loop. In the future it may be used and test it under closed loop for research.

The driver circuit is designed for ease of use and control of a three-phase motor using an inexpensive driving circuit, especially for students. The user only needs to apply high voltage DC (more than 150 V DC) and then turn on the driver circuit, then the motor will be start to operate at a low speed. The four external switches that are connected with the driver circuit, as shown in the final circuit diagram control the speed and direction of the motor. The flowchart in Figure 10 is present the operation instruction of the full system.

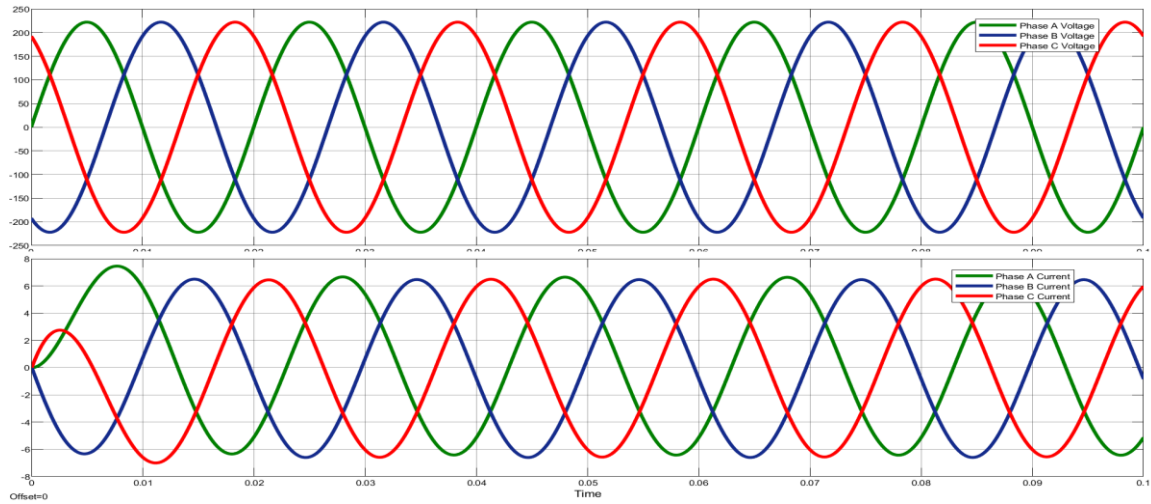


Figure 8. The final simulation results (three phase voltage and current)



Figure 9. The final hardware setup of the proposed system

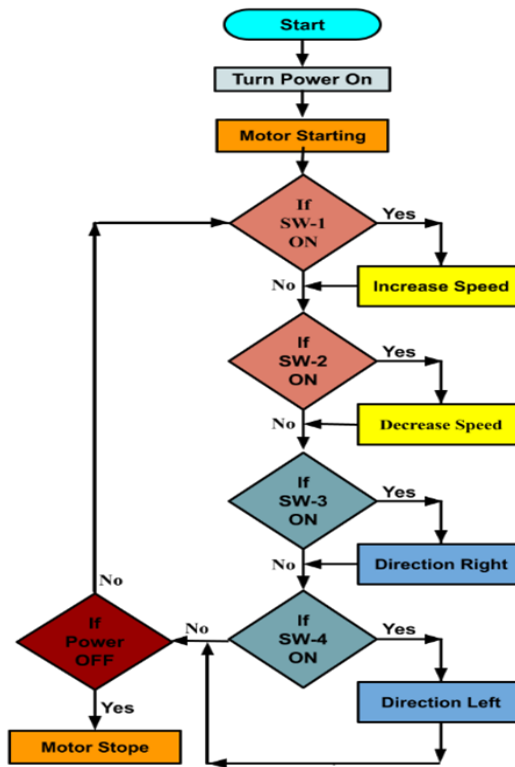


Figure 10. The flowchart of the final program

## 5. CONCLUSION




This paper demonstrated how to construct a three-phase inverter driver circuit from the ground up for a three-phase induction motor using (power transistors, diodes, and other components) for photovoltaic applications. The paper helps people through each stage with diagrams and schematics that will make it simple for anyone to grasp every aspect of the project. Also, this circuit provides protection and safety for people by teaching them how to use these components before incorporating them into their own designs. The final electronic circuit was tested and proved its efficiency in controlling the speed and direction of a three-phase induction motor by using STM32F103C8T6 as microcontrollers to generate the PWM signals.

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