Chapter 1: Introduction

Content

1.1: Overview

Air-conditioning devices, works on gas cooling cycle, which consists of a compressor, condenser, evaporator, and the expansion valve, and because air conditioning is working in summer and winter; adding valve to invert the cooling cycle to the heating cycle.

Air-conditioners are divided into three main types: the first one is window air conditioner, which is the most commonly used air conditioner for single rooms. In this type all the components, namely the compressor, condenser, expansion valve or coil, evaporator and cooling coil are enclosed in a single box. This unit fitted in a slot made in the wall of the room, or more commonly a windowsill.

The second type is packaged air conditioner; used to cool more than two rooms or a larger space at home or office. There are two possible arrangements with the package unit. the first one, all the components, namely the compressor, condenser; which can be air-cooled or water-cooled, expansion valve and evaporator are housed in a single box. The cooled air is flow by a high capacity blower, and it flows through the ducts laid through various rooms. In the second cycle, the compressor and condenser housed in one casing. The compressed gas passes through individual units, compressed of the expansion valve and cooling coil, located in various rooms.

Thirdly, Central Air Conditioning System, which used for cooling large spacious buildings, houses, offices, hotels, gyms, movie theaters and factories, etc...
If the whole building is to be air conditioned, HVAC engineers find that putting individual units in each room is very expensive, so installing a central air conditioning system is a better option. A central air conditioning system is consist of a huge compressor that produces hundreds of tons of conditioned air. Cooling big halls, malls, huge spaces, galleries and so on.

Air-conditioners works by two control systems: traditional control & Inverter control. Traditional control operates with fixed compressor speed, which means high operation cost with low conditioning efficiency. For the inverter control system, it runs with a controlled compressor speed by controlling the voltage and frequency.

There are two types of inverter air conditioning compressors; the first one operates with three phase alternating current source, while the second on operates with direct current source.

HVAC technicians faces difficulties in servicing the inverter type air-conditioning system, this due to, if the inverter unit failed, then the panel should be replaced by the same type and model. Which means limited servicing capabilities.

This project will work on addressing this issue by designing a universal unit that can operates several types of inverter air conditioners.

1.2: Problem Statement.

Based on a questionnaire filled by HVAC technicians, Lecturers & Trading companies, we concluded that there are many problems that need solutions Shown in table :(1.1).

	Problems that will be solved through this project
1-	A huge maintenance cost in comparison to the cost of the device
3-	Replacing the panel inverter by another make

Table (1.1): problems need solutions

1.3: Motivation

The local market needs a replacing inverter boards, that is rare and it is difficult to replace the boards of any model by another brand.

1.4: Needed Technology

High technology needed to be able to arrange the sequence of our system, worked with high precision systems like Inverter to drive the compressor also the microcontrollers to connection and control of all parts, used human machine interface (HMI), in addition to that some software programs such as Proteus and lap view program.

1.5: Project Description

This project contains two main boards of the HVAC, Indoor and Outdoor board, in the indoor board human machine interface, communication parts and the fan driver. While Outdoor board contains rectifier, insulation component, protection circuits, filters and multi power drives boards.

1.6: Time Table

Task	Weeks															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Problem Statement																
Collecting background data & questionnaire analysis																
Block Diagram																
Drawing the module by Proteus, Circuit Maker & Arduino																
Simulation model and monitoring system																
Dynamic analyses And experiments																
Analyzing data																

Table (1.2): Time table for the first semester.

Task	Weeks															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Set and review goals of project																

Select the refrigeration cycle																
take readings																
Analyzing data																
Building the controller and drivers																
Test the controller and drivers																
Write the project report																
Writing documentation																
Printing documentation out																

Table (1.3): Time table for the second semester.

1.7: Expected Outcomes

Universal low cost alternative board that can be replaced on various types of modern inverter air conditioners.

1.8: Estimated cost:

	Part name	Cost (NIS)
1	Driver device	300
2	Electronic parts	300
3	Connecters & PCB	200
	Total cost	800

Table (1.4): Estimated cost for first module

Chapter 2: previous studies.

Content Page

2.1: Tradition Air Condition

Traditionally, the compressor, which used in an air conditioning system, is an ON or OFF type, it works either at the maximum capacity or none at all. It ON when the room thermostat calls for cooling and OFF when the desired temperatures has been achieved. This cycle repeated with the change of load in the room.

2.2: Inverter Air Condition

The inverter air conditioning is the latest technology in the HVAC field, which is becoming more popular due to its environmental friendly and energy savings approach. In addition, it Provides comfort to users comparing to other traditional systems.

2.3: Energy Saving

Unlike ordinary Conventional air conditioners, inverter air conditioners controls the speed of compressor to adjust cooling and heating. When indoor temperature reaches the desired levels, inverter air conditioner operate the compressors at low speeds and maintain the desired temperature, thus saving electricity consumption by about 44% compared to conventional systems.

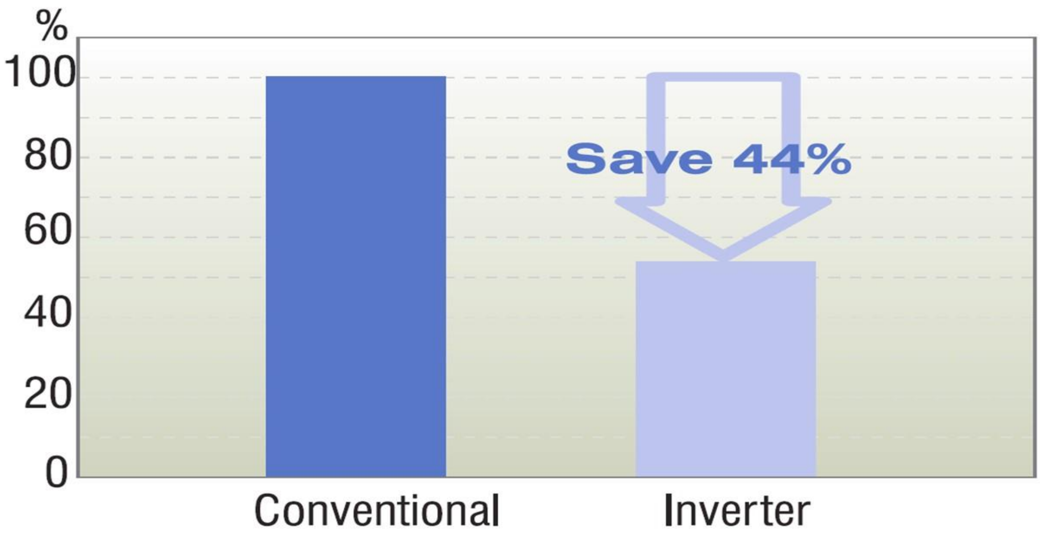

Figure (2.1): Energy Saving

2.4: Heat of Inverter Compressor.

The inverter air conditioner uses a DC Inverter compressor due to its optimized refrigeration effect, low noise and high efficiency. DC compressor are much more efficient especially at low loads compared with conventional constant speed AC comps.

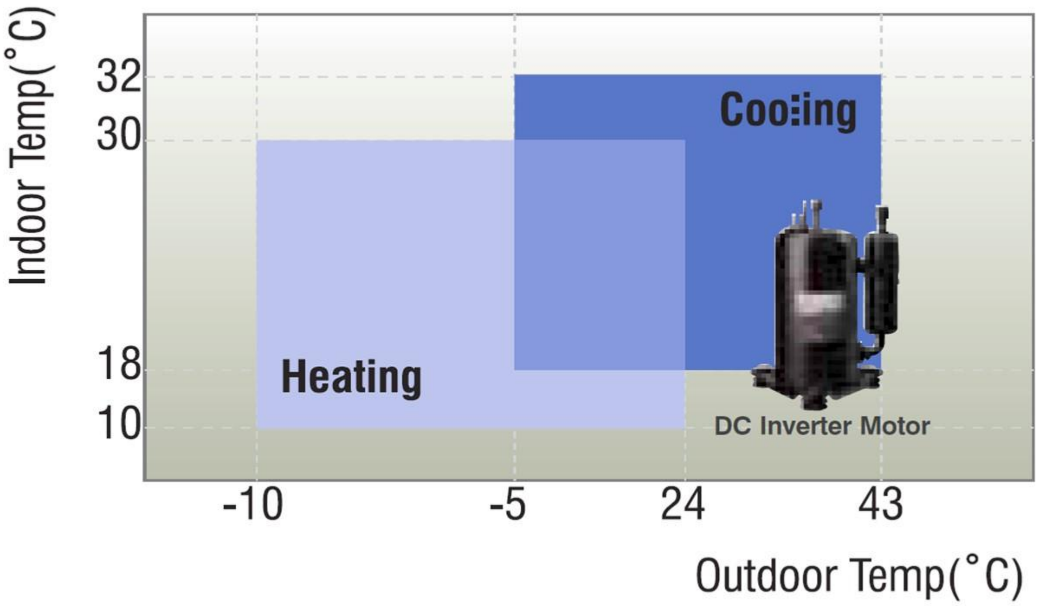

Figure (2.2): Heat of Inverter Compressor.

2.5: Powerful Heating Capacity.

With a wide operating range in both heating and cooling modes, inverter air conditioners will cool or heat room even in extreme outdoor temperature conditions. Heating can be sustained even when the outdoor temperature is -10°C by Inverter technology.

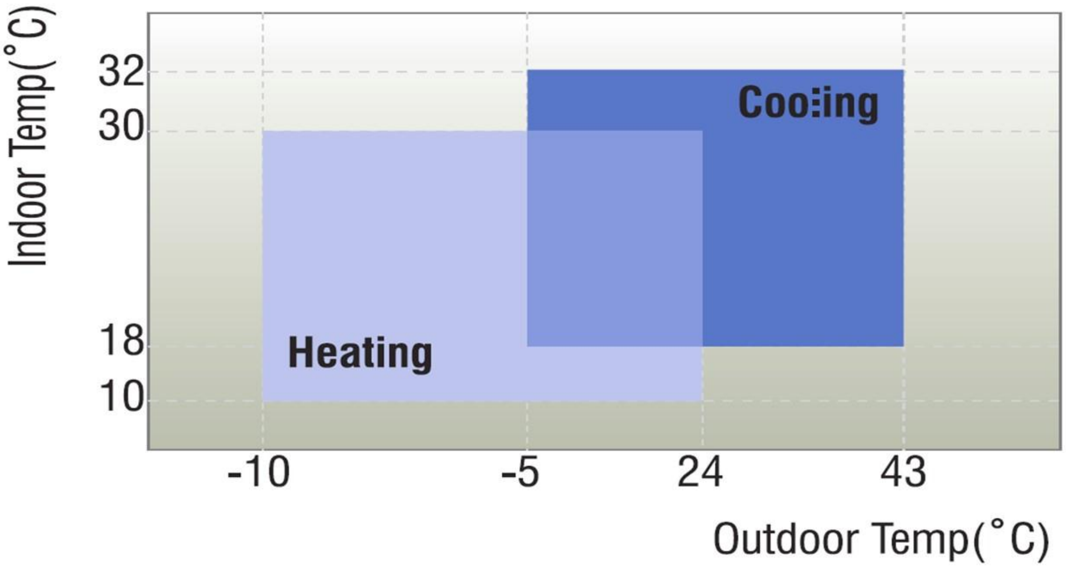

Figure (2.3): Powerful Heating Capacity.

2.6: Quick Cooling & Heating.

Inverter air conditioners can operate their compressors faster to give them more powerful performance. This results in being able to attain the desired temperature much faster in both heating and cooling modes than conventional air conditioners.

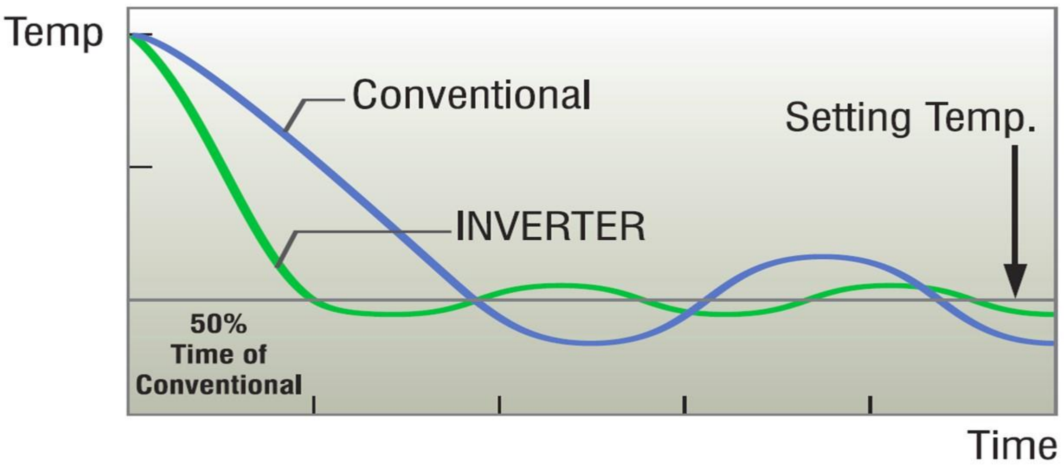

Figure (2.4): Quick Cooling & Heating.

2.7: Pleasant Feeling.

When the air conditioner is initially activated to either heat or cool, the compressor will operate at maximum speed to reach the desired temperature quickly. Once the desired temperature achieved, unlike conventional air conditioners that turn the compressor on and off, inverter units adjust and constantly vary the compressor speed to maintain the desired temperature with minimal fluctuation to ensure that your comfort is not compromised.

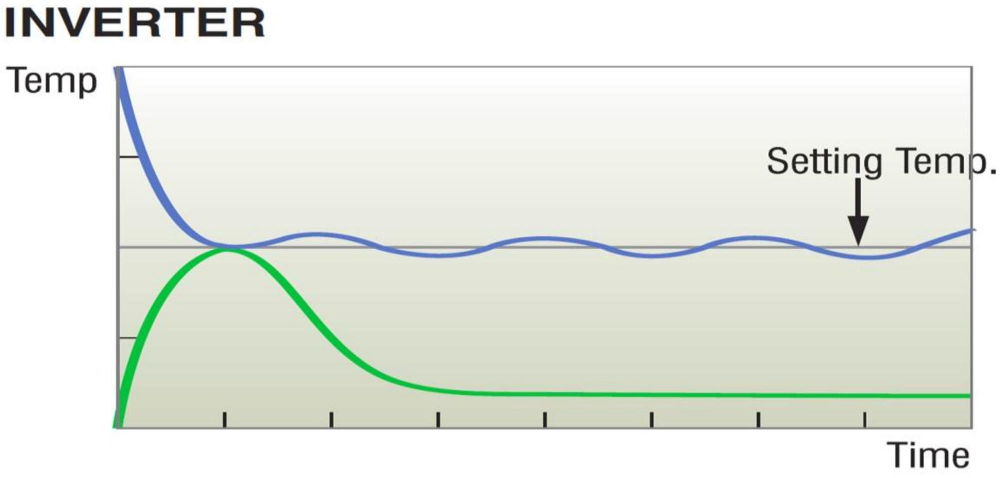

Figure (2.5): Pleasant Feeling.

2.8: Quiet Operation.

Inverter air conditioners are optimally designed to operate with the minimal noise level with the use of a DC compressor.

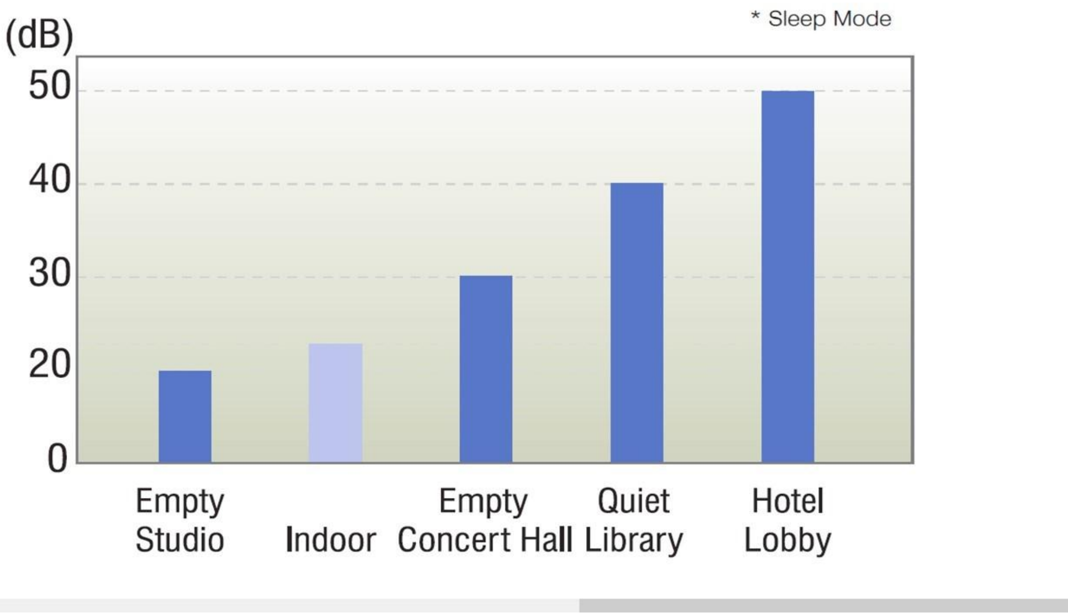

Figure (2.6): Quiet Operation.

Chapter 3: Air Condition Electromechanical Principle.

Content	Page

3.1: Mechanical part Introduction.

The refrigeration cycle or heat pump cycle is the model that describes the transfer of heat from regions of lower temperature to regions of higher temperature. This defines the operational principles behind refrigerators, air conditioners, heaters, and other "heat pumping" devices.

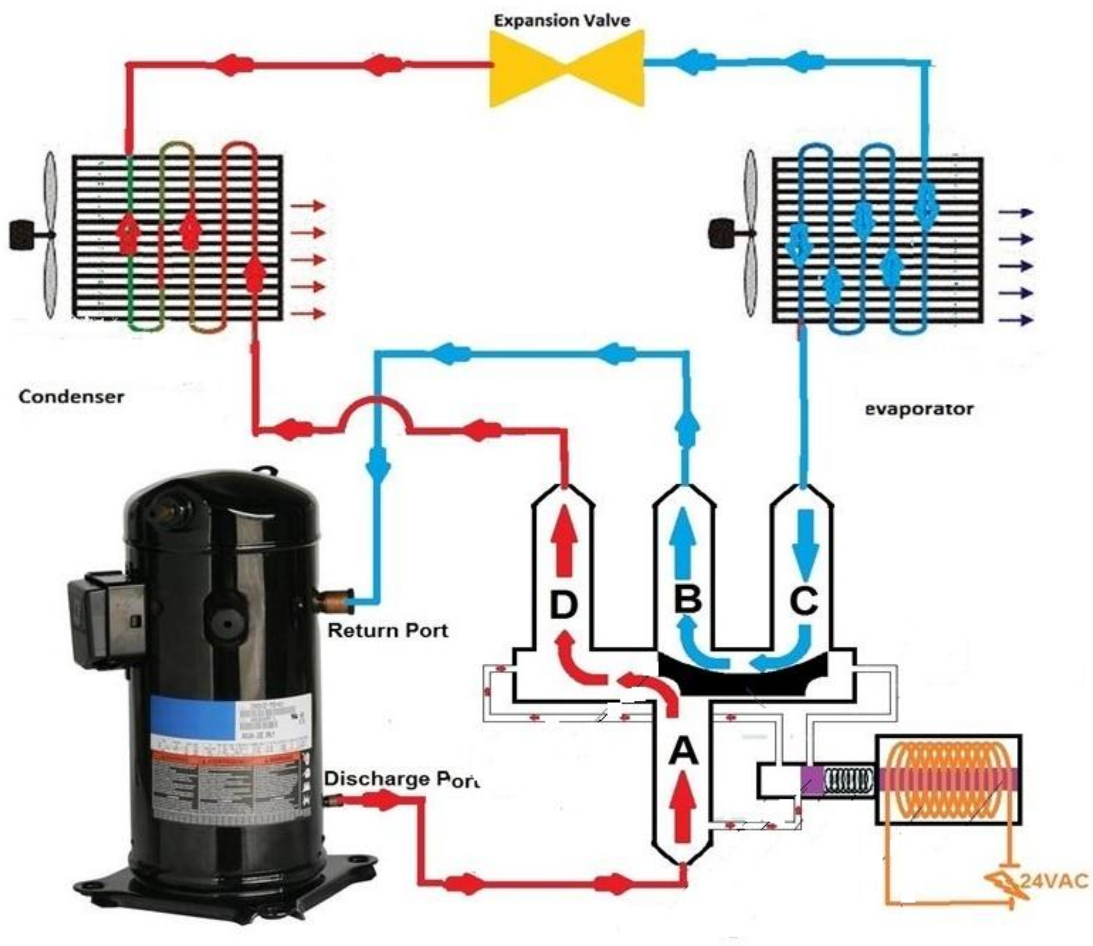

Figure (3.1): Refrigerant Cycle.

3.2: Gas Compressor Motor:

Refrigerant compressors work by taking in low-pressure gas on the inlet and compressing it mechanically. This compression creates a high temperature, high-pressure gas - an essential step in the overarching refrigeration cycle, there are two types of compressor depending on the electrical source:

1. Variable Speed Induction Motor Compressor.
2. Variable Speed DC Motor Compressor.

Figure (3.2): Compressors type

3.3: Four Way Valve:

The 4-way Reversing Valve is the key component to provide heating and cooling from the system to the air-conditioned space by reversing the flow direction of refrigeration cycle.

Figure (3.3): 4 Way Valve

3.4: Condenser:

The purpose of the condenser in the cycle of compression refrigeration is to change the hot gas being discharged from the compressor to a liquid prepared for use in the evaporator. The condenser accomplishes this action by the removal of sufficient heat from the hot gas, to ensure its condensation at the pressure available in the condenser. The heat is shifted to another medium, like water or air, to cool the condenser.

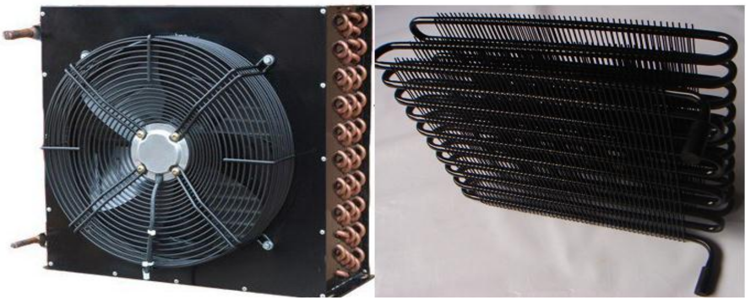

Figure (3.4): Condenser

3.5: Expansion Valves:

The expansion valves removes pressure from the liquid refrigerant to allow expansion or change of state from a liquid to a vapor in the evaporator.

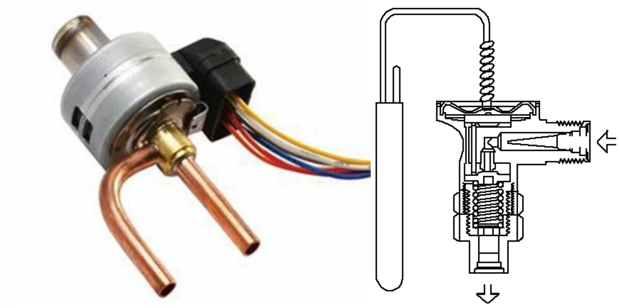

Figure (3.5): Expansion Valves

3.6: Evaporator:

The evaporator works the opposite of the condenser; here refrigerant liquid is converted to gas, absorbing heat from the air in the compartment.

Figure (3.6): Evaporator.

3.7: Electronic part Introduction:

The drives designed to control in motors speed, controlling the compressor speed makes the system more efficient.

There are two types of drivers in air conditioning systems:

1- DC-to-DC Chopper Driver (DC Compressors).
2- DC-to-AC Inverter Driver (BLDC Compressors).

3.8: Chopper Driver:

A chopper driver is a DC-to-DC converter, which main function is to create adjustable DC voltage source from fixed DC voltage sources using semiconductors.

3.8.1: Devices used in Chopper:

Low power application: IGBT, BJT, MOSFET etc…
High power application: Thyristor, Power IGBT & Power MOSFET

3.8.2: Chopper principle:

When the switch turned ON, the voltage source (VS) directly appears across the load as shown in figure (4.1) & figure (4.2), and then the moment the switch turned OFF, (VS) is disconnected from the load. So output voltage $V_O = 0$.

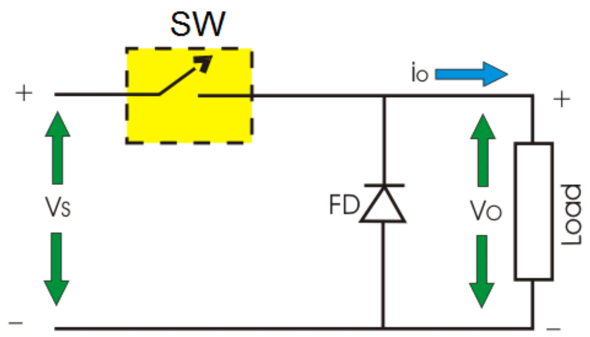

Figure (3.7) Chopper

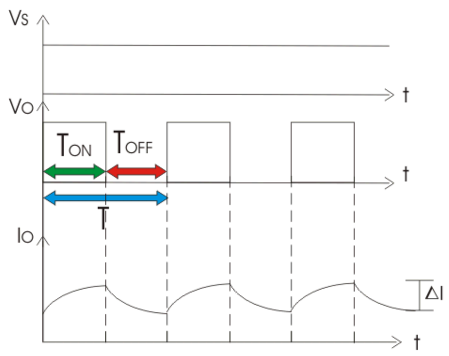

Figure (3.8) Switch mode

Voltage regulation achieved by averaging the Pulse width Modulation (PWM) signal, output voltage is represented by the following equation:

Voltage out (VO) = Voltage Source (Vs) * Duty cycle (D)

Where, D is duty cycle = T_{ON}/T.

3.9: brushless dc motor driver:

The brushless DC (BLDC) motor is becoming increasingly popular because, as the name implies, it does away with the wear-prone brushes used in traditional motors, replacing them with an electronic controller that improves the reliability of the unit. Moreover, a BLDC motor can be made smaller and lighter than a brush type with the same power output, making it suitable for applications.

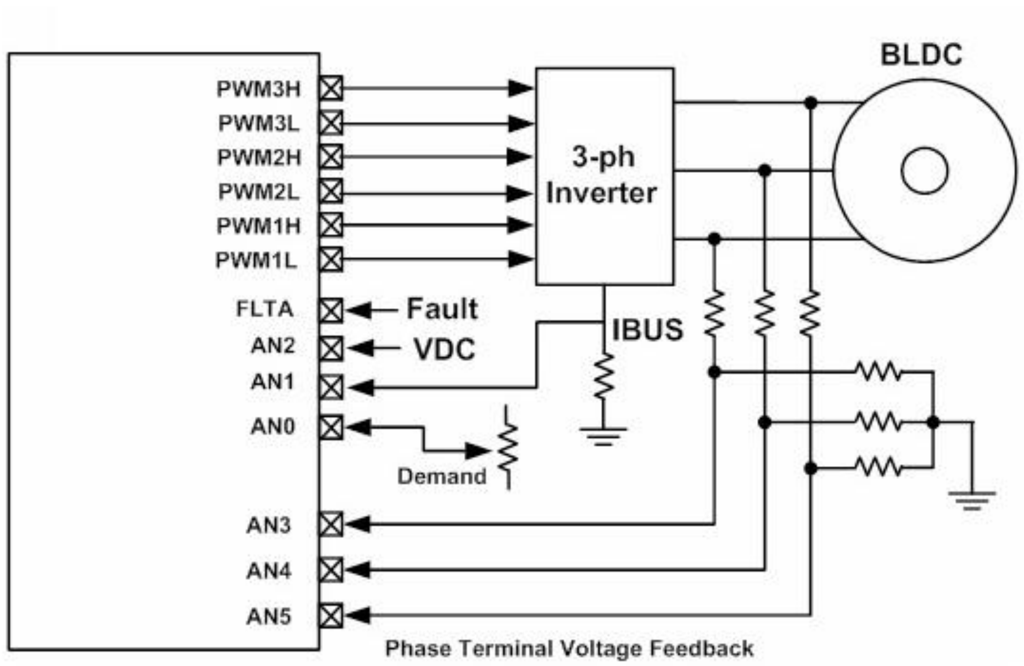

Figure (3.9) BLDC diagram

3.9.1: brushless dc motor principle:

BLDC motors are basically inside-out DC motors. In a DC motor the stator is a permanent magnet. The rotor has the windings, which are excited with a current. The current in the rotor is reversed to create a rotating or moving electric field by means of a split commutator and brushes. On the other hand, in a BLDC motor the windings are on the stator and the rotor is a permanent magnet. Hence the term inside-out DC motor. To make the rotor turn, there must be a rotating electric field. Typically a three-phase BLDC motor has three stator phases that are excited two at a time to create a rotating electric field. This method is fairly easy to implement, but to prevent the permanent magnet rotor from getting locked with the stator, the excitation on the stator must be sequenced in a specific manner while knowing the exact position of the rotor magnets. Position information can be gotten by either a shaft.

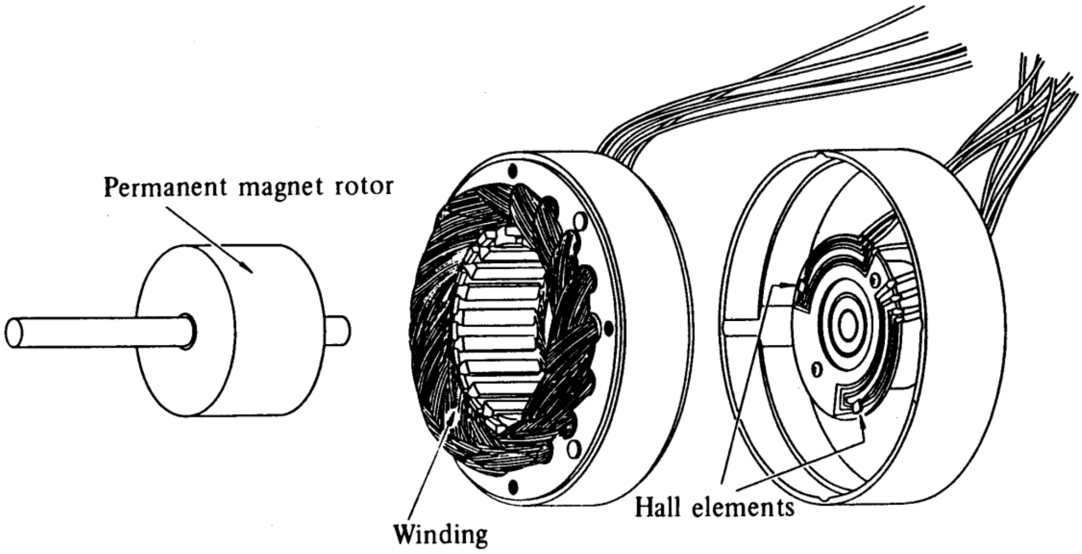

Figure (3.10) BLDC parts

encoder or, more often, by Hall effect sensors that detect the rotor magnet position. For a typical three phase ,BLDC motor there are six distinct regions or sectors in which two specific windings are excited.

3.10: Rectifier

A rectifier converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. A four diodes used to create a Single-Phase Full-Wave Rectifiers.

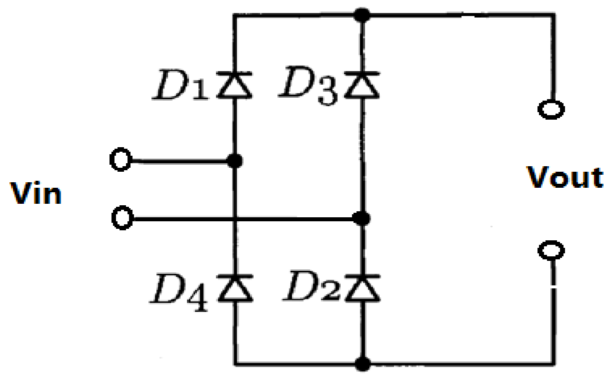

Figure (3.11): Full-Wave Rectifiers

of the transformer secondary voltage, the current flows to the load through diodes D1 and D2. During the negative half cycle, D3 and D4 conduct. The voltage and current waveforms of the bridge rectifier are shown in Fig (3.12).

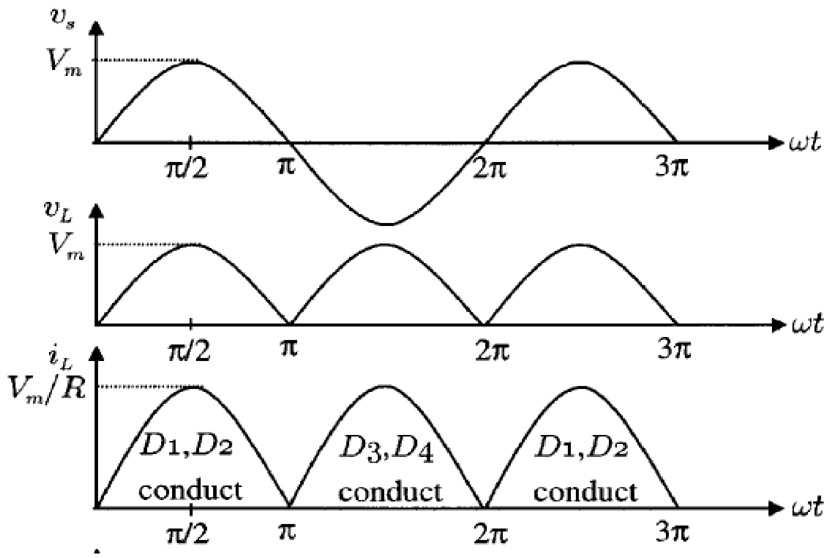

Figure (3.12): Full-Wave Rectifiers wave

During the positive half cycle, the current flows to the load through diodes D1 and D2. During the negative half cycle, D3 and D4 conduct. The voltage and current waveforms of the bridge rectifier . angular frequency of the source $\omega = 2\pi/T$

Indicate that $v_L(t) = V_m|\sin\omega t|$ for both the positive and negative half-cycles.

$$V_{dc} = \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t \, d(\omega t)$$

$$\text{Full-wave } V_{dc} = \frac{2V_m}{\pi} = 0.636\, V_m$$

Chapter 4: Project Analysis

4.1: Data analysis

Data collection done through the distribution of a questionnaire for the local market, then data analysis shows the following results:

Questions		Yes	No
1.	Does the inverter air conditioner most failures comes from misuse?	86%	14%
2.	Does servicing the inverter air conditioner worthy in comparison to its price?	84%	16%
3.	Does the HVAC technician, qualified enough to service the inverter air conditioners?	6%	94%
4.	Is it possible to replace the inverter air conditioner panel with another type?	4%	96%
5.	To what extent is it difficult to find an inverter air conditioner replacement panels?	4%	96%

Table (4.1): questionnaire analysis

Samples	Specialization	Frequency
HVAC technicians	Maintenance HVC	50%
HVAC Trading Companies	Sale and installation of air conditioning systems	12%
HVAC Lecturers	Teaching refrigeration and air conditioning systems	38%

Table (4.2): The target of questionnaire

After analyzing the questionnaires, we found some points that needs addressing.

1- Device misuse, the can be addressed through holding awareness workshops, disseminating brochures
2- HVAC servicing technicians needs more knowledge in the field of electronic panels repair .

In our graduation project, we will address the remaining points.

4.2: Block Diagram:

The outputs of the split inverter HVAC arranged as a sequence depending on the priority of operation, the operation starts by a signal from the remote control, then the main MCU starts a self-test system (input and output), after that the main MCU urges the fan & compressor to operate.

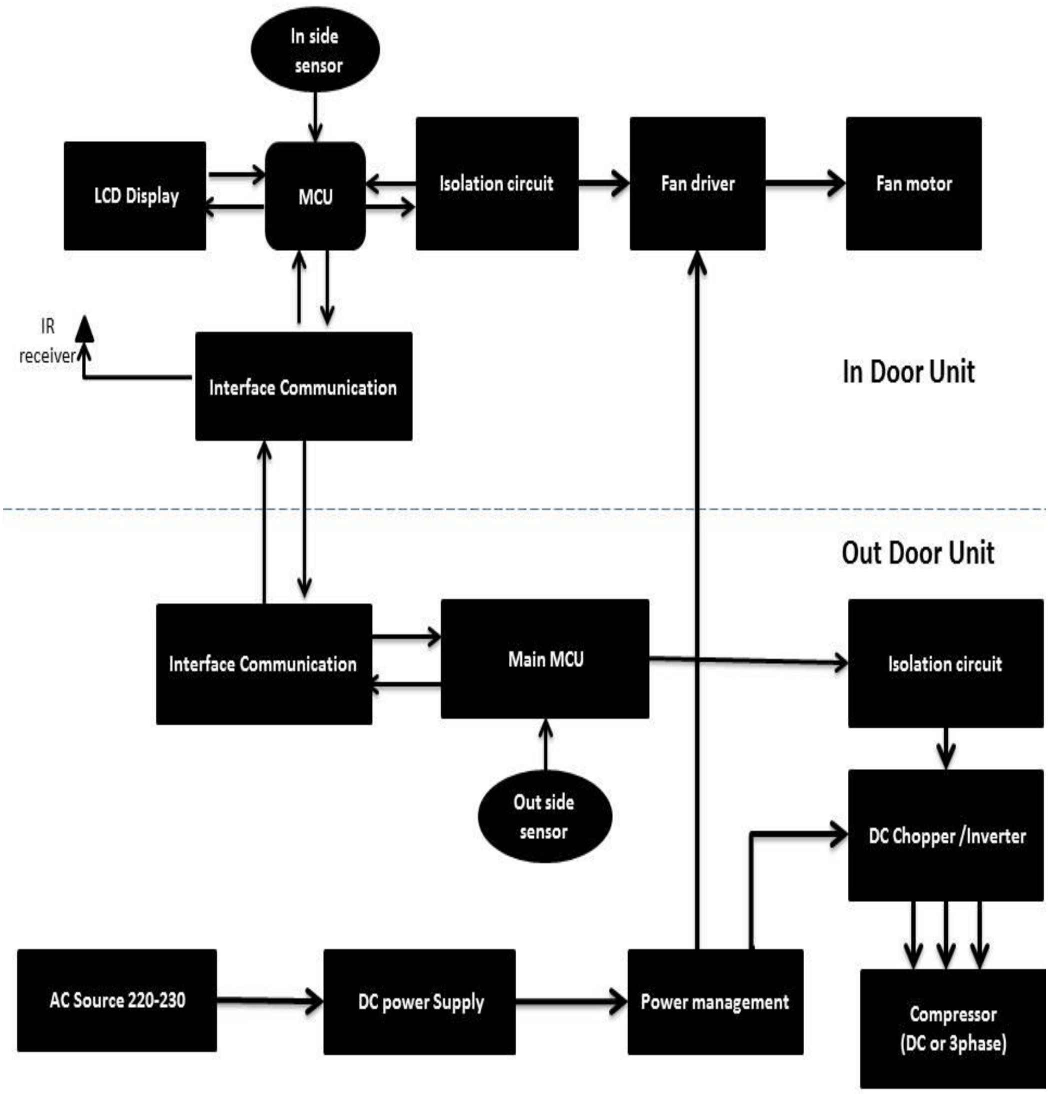

Figure (4.1): The general block diagram

As shown in figure (4.1) there are several outputs: dc motor, cooling fans, and 3phase motor.

After running a cooling or heating cycle, the heat exchanger works directly, to maintain room temperature. Every moment the system checks the heat of the room, evaporator & radiator in order to control compressor speed.

4.3: Flow chart:

As shown in figure (4.2) which describes the steps of heating or cooling operations.

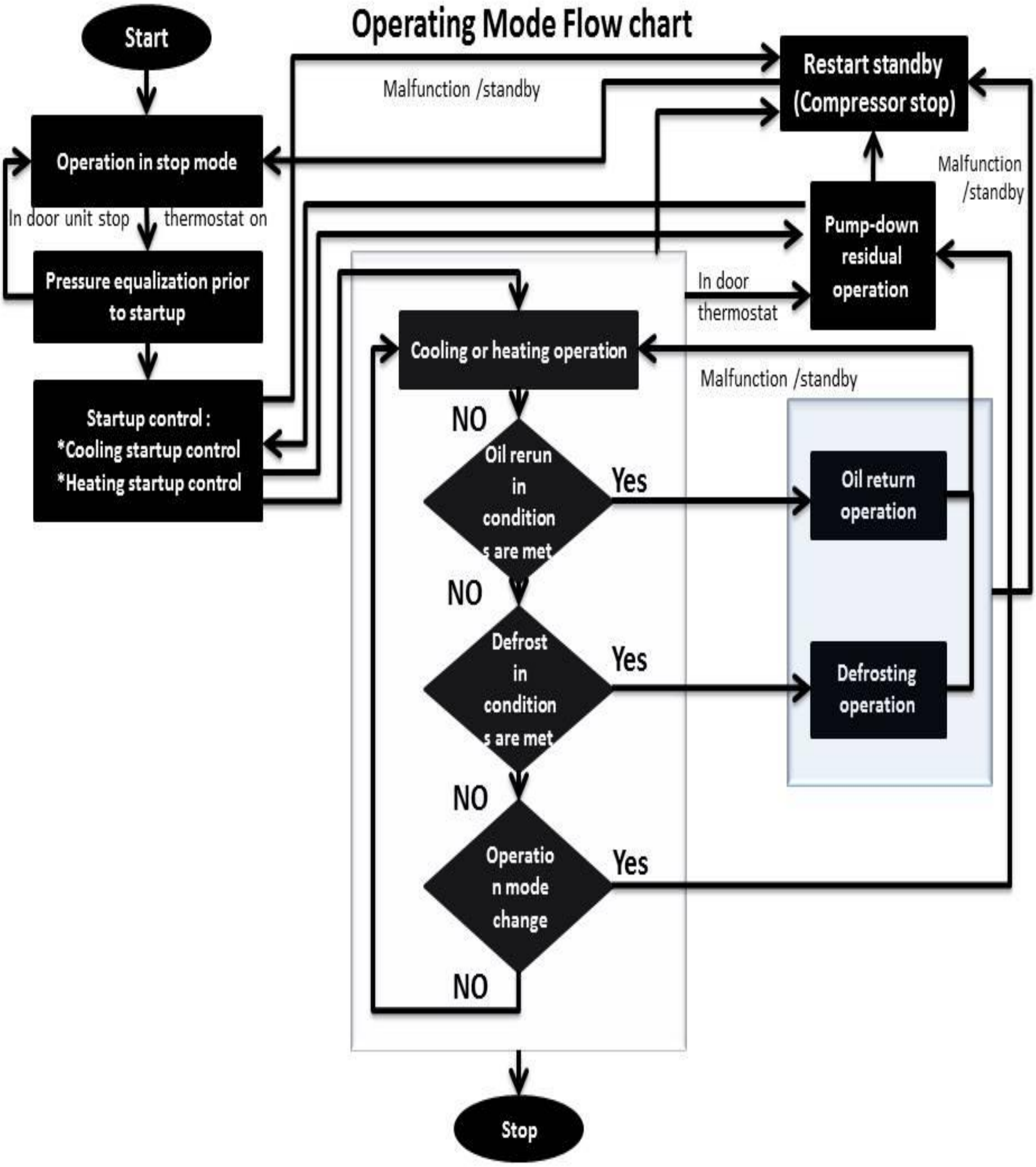

Figure (4.2): Flow chart

From the graph, it is clear to us that the system operations, cooling, heating, defrosting and returning the oil back, all arranged in sequence, any system failure returns error signal. Operations sequence help in preventing system failure, then maximizing efficiency.

4.4: power supply Circuit Design:

In modern split air conditioner multi type of power , AC source to in door and outdoor fans ,low power DC to control unit and digital ,and high power for power circuits, dc chopper and BLDM driver .

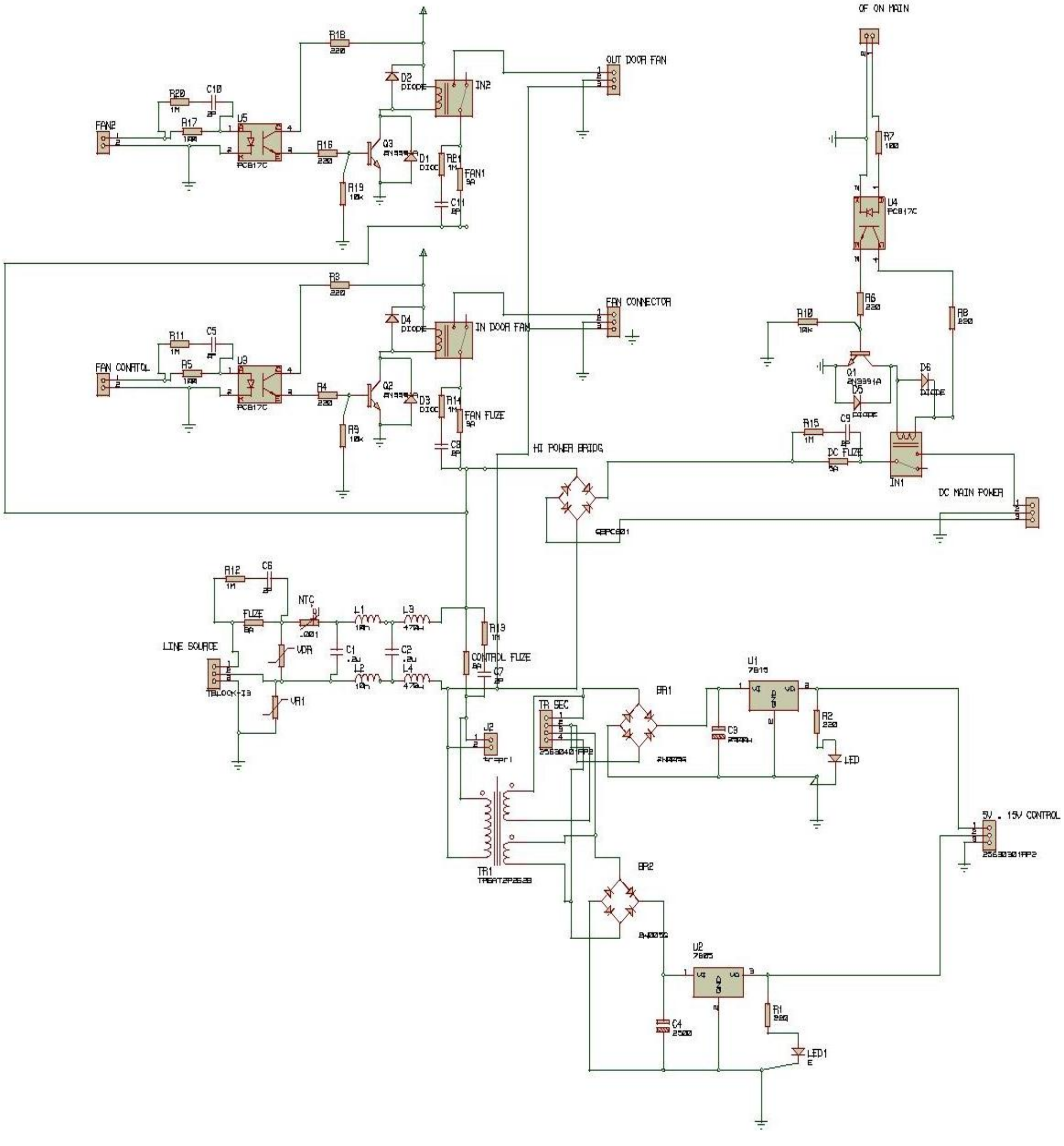

Figure (4.3): power supply Circuit Design

4.4.1: AC filter Circuit Design:

An LC filter with the same amount of ripple attenuation and the same size capacitor creates much less DC voltage drop than an RC filter. The key difference is that the inductance of the choke reacts to AC signals but presents, ideally, a short circuit to DC. A real-world choke creates only a slight DC voltage drop due to internal winding resistance.

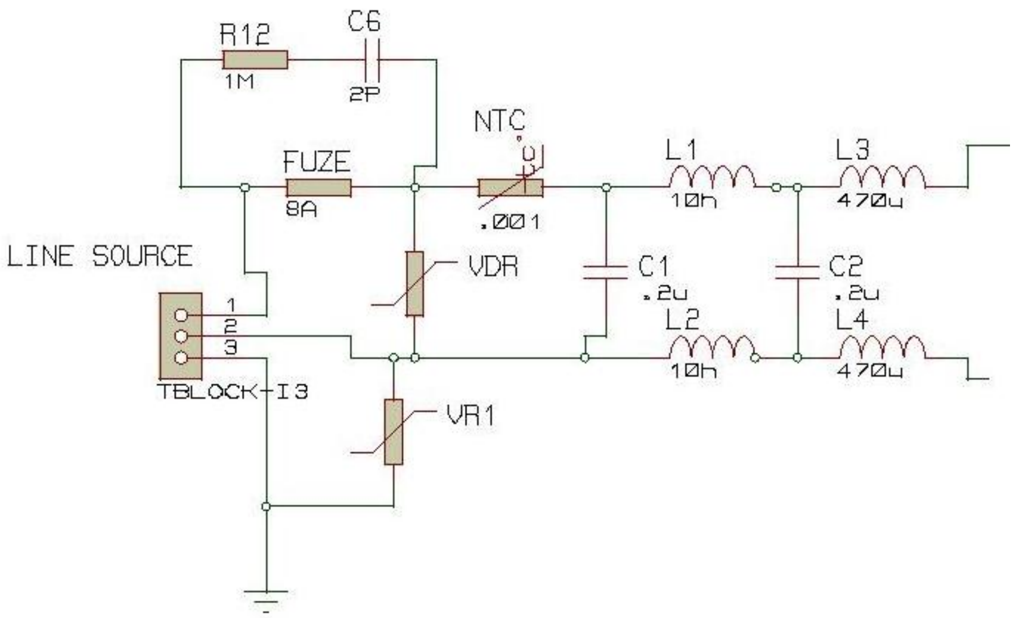

Figure (4.4): AC filter Circuit Design

Figure (4.5): AC filter

4.4.2: isolation Circuit Design:

Optocouplers are used to isolate signals for protection and safety between a safe and a potentially hazardous or electrically noisy environment. The interfacing of the optocoupler between digital or analogue signals needs to be designed correctly for proper protection. The following examples help in this area by using DC- and AC-input phototransistor optocouplers.

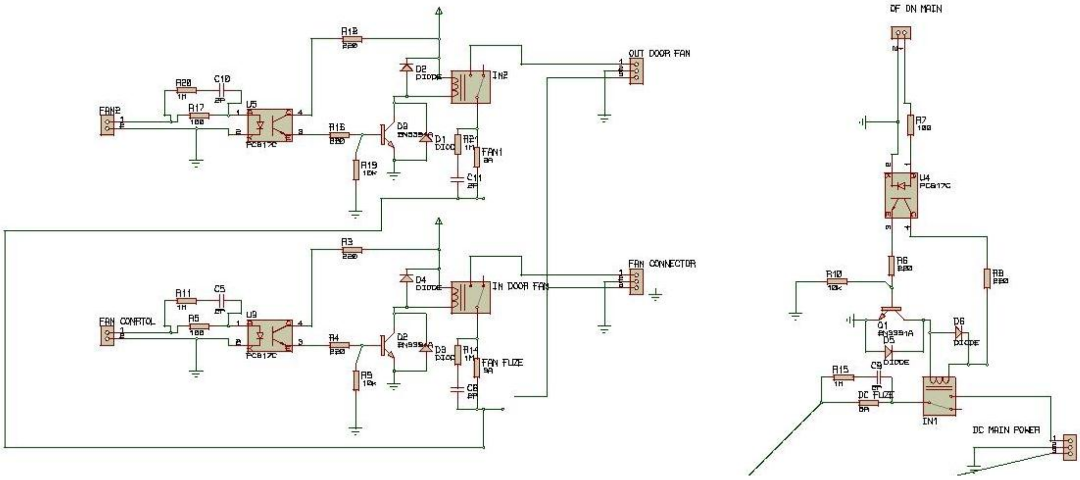

Figure (4.6): isolation Circuit Design

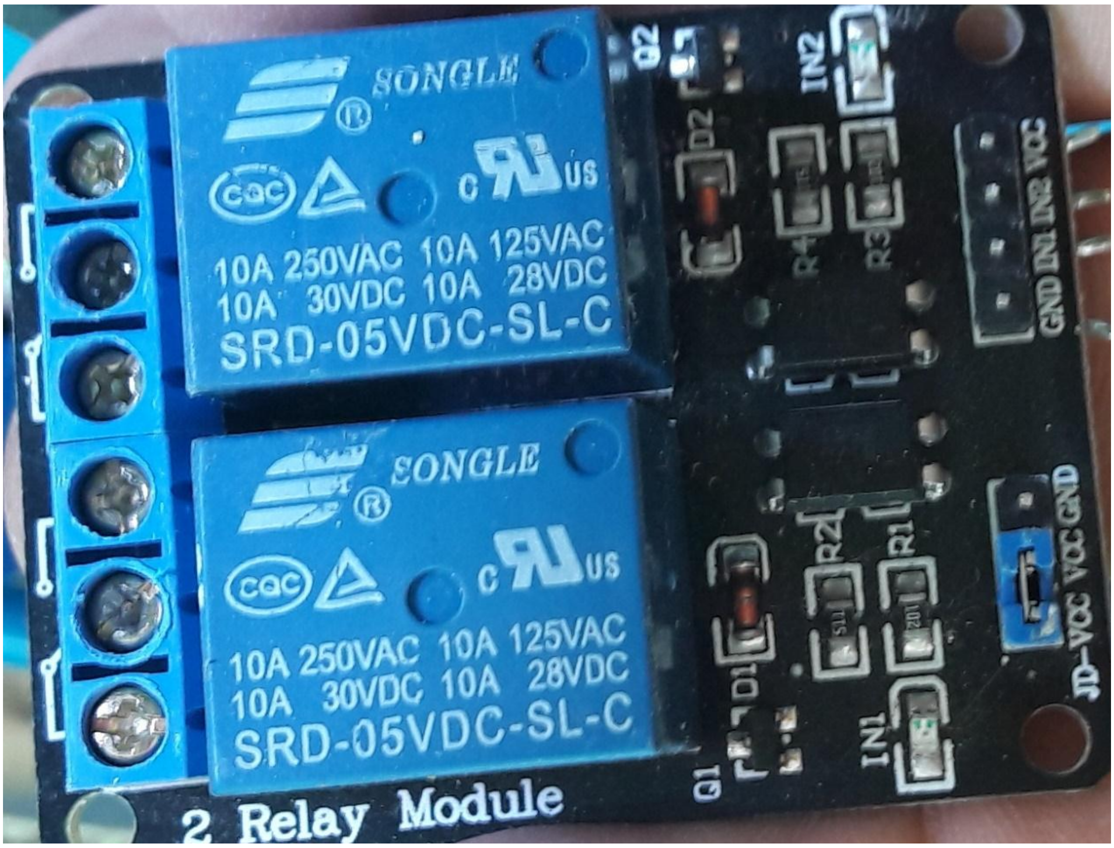

Figure (4.7): isolation Circuit

4.5: dc chopper Circuit Design:

To control speed of the DC compressor , Converting the unregulated DC input to a controlled DC output with a desired voltage level.

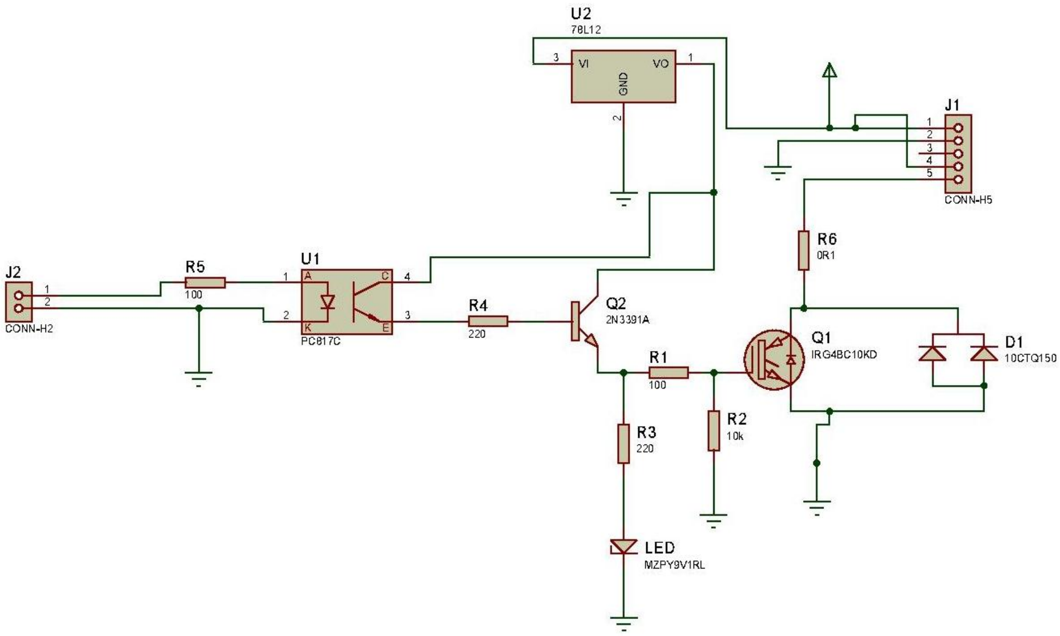

Figure (4.8): dc chopper Circuit Design

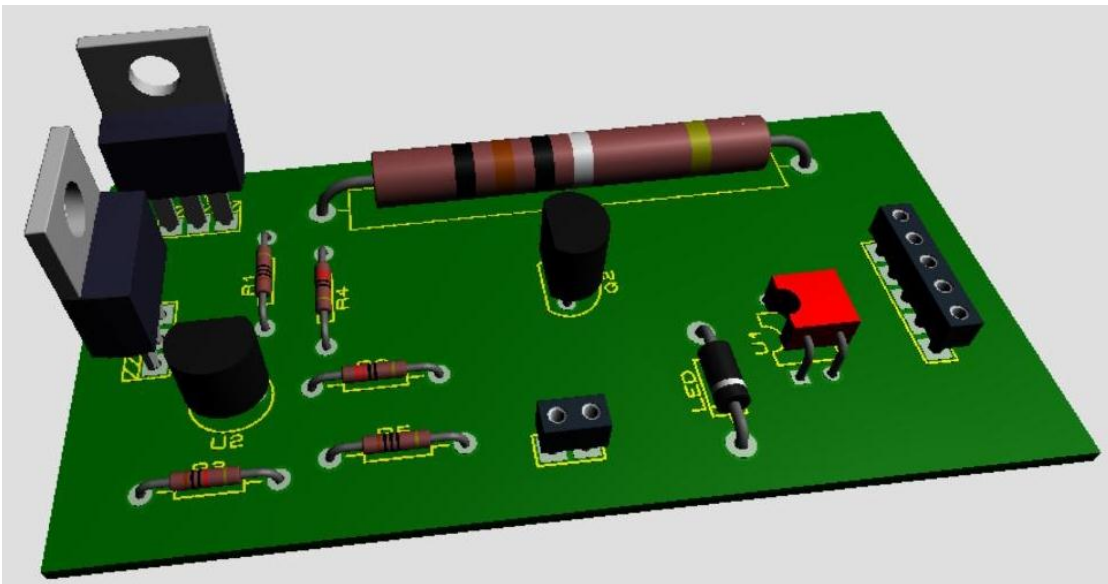

Figure (4.9): dc chopper board

4.6: brushless sensor less dc motor driver circuit Design:

The dsPIC30F2010 has six PWM outputs that can driven with the PWM signal. The three windings can be driven ON High, driven ON Low or not driven at all by using six switches, IGBTs or MOSFETs.

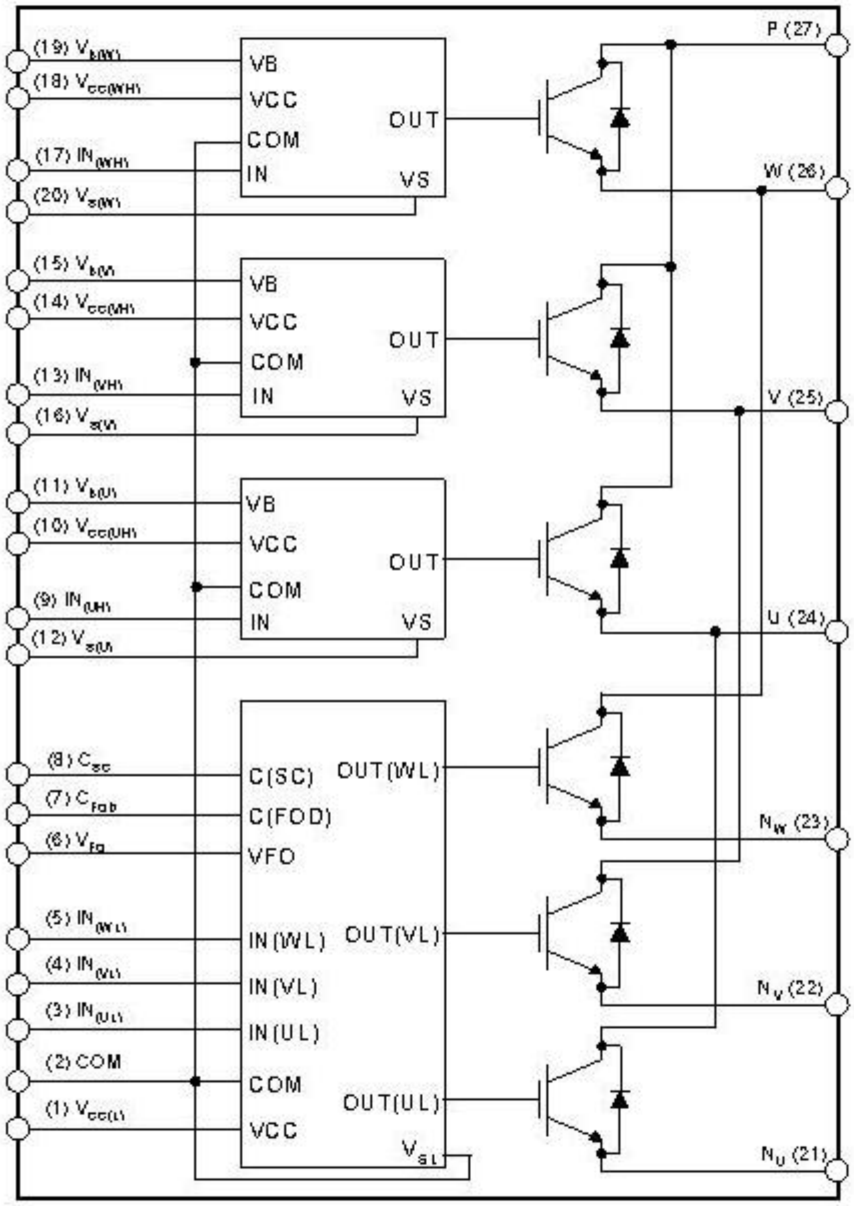

Figure (4.10): three phase driver diagram

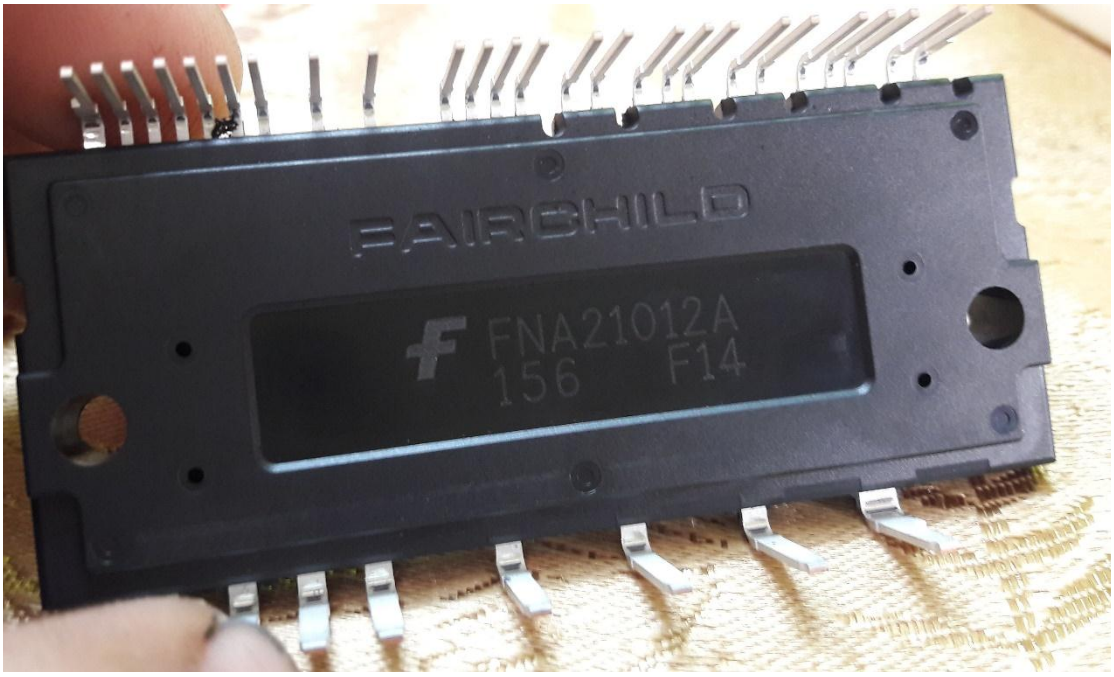

Figure (4.11): three phase driver

When one leg of the winding is connected for example, to the high side, the variable duty cycle signal PWM can be injected on the low side driver. This has the same effect as having a PWM signal on the high side and connecting the low side to VSS or GND.When driving the PWM signal, PWM is provided by the dsPIC30F2010's dedicated Motor Control (MC) PWM. The MCPWM module has been designed specifically for motor control applications .The MCPWM has a dedicated 16-bit PTMR time base register. This timer is incremented by a user defined clock tick, which can be as low as TCY. The user also decides the period required for the PWM by selecting a value and loading it in the PTPER registers. The PTMR is compared to the PTPER value at every TCY. When there is a match, a new period is started. The duty cycle is controlled similarly, by loading a value in the three duty cycle registers. Unlike the period compare, the value in the duty cycle register is compared at every TCY/2 interval .

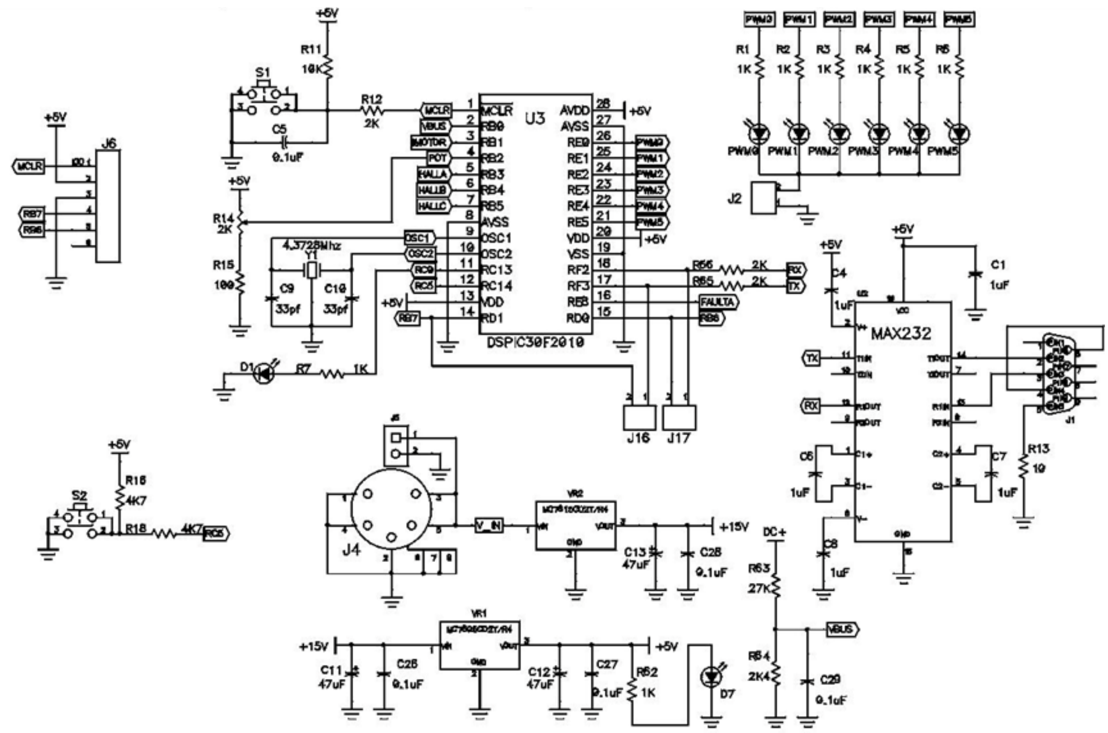

Figure (4.12): BLDC control circuit

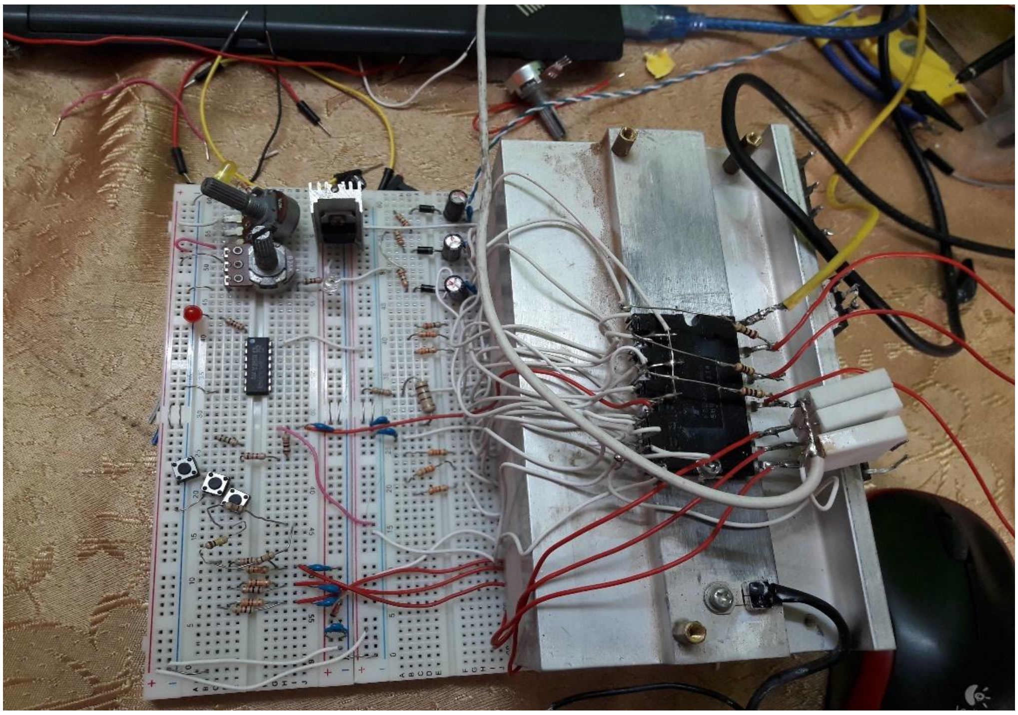

Figure (4.13): BLDC circuit

If there is a match between the PTMR value and the PDCx value, then the corresponding duty cycle output is driven low or high as dictated by the PWM mode selected. The three outputs from the duty cycle compare are channeled to a complementary output pair where one output is high while the other is low, and vice versa. The two outputs can also be configured as independent outputs. When driven as complementary outputs, a dead time can be inserted between the time the high level goes low and the low level goes high. This dead time is hardware configured and has a minimum value of TCY. Dead time insertion prevents inadvertent shoot-thru in output drivers.

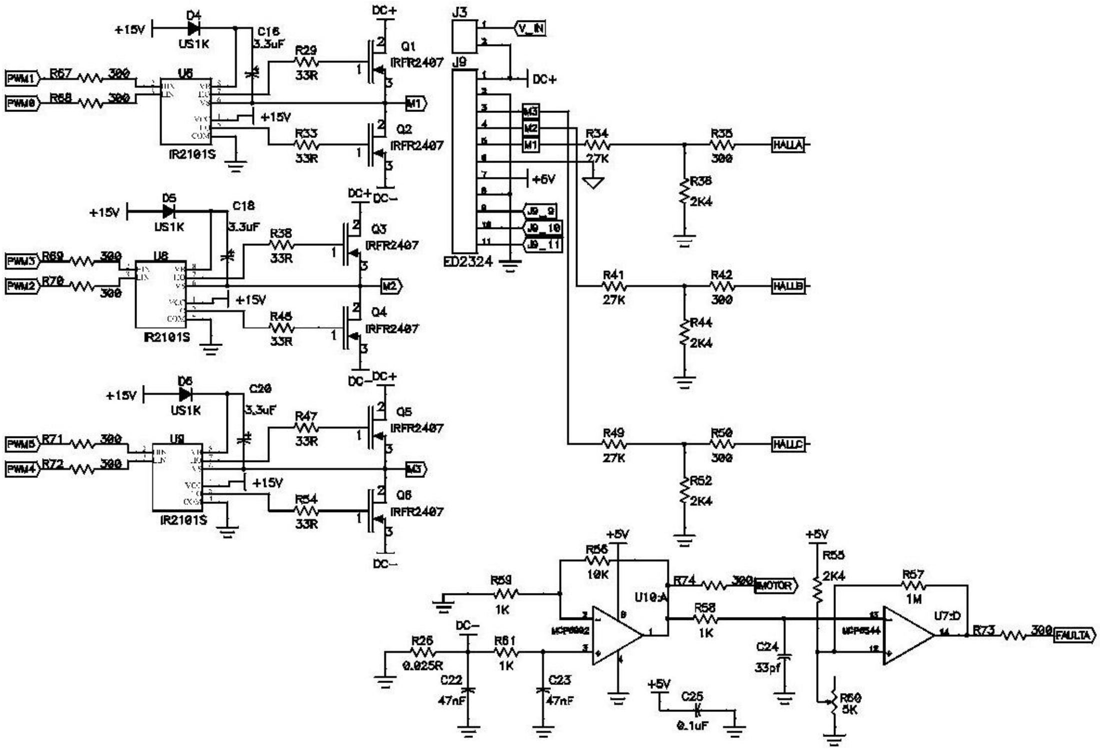

Figure (4.14): Bake EMF

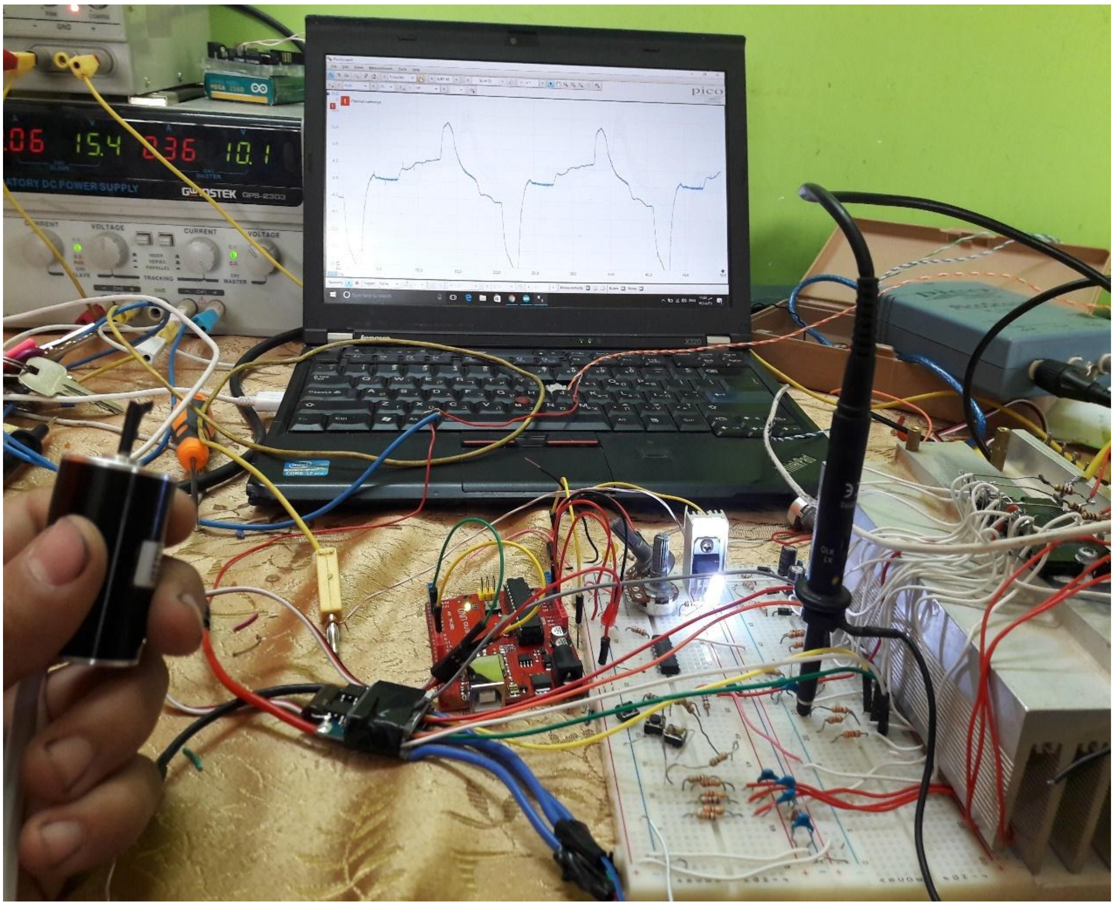

Figure (4.15): output signal

4.7: Control Circuit Design:

Control circuit describes the operating basics, where the Arduino considered the main part of the control circuit, which contains a microcontroller.

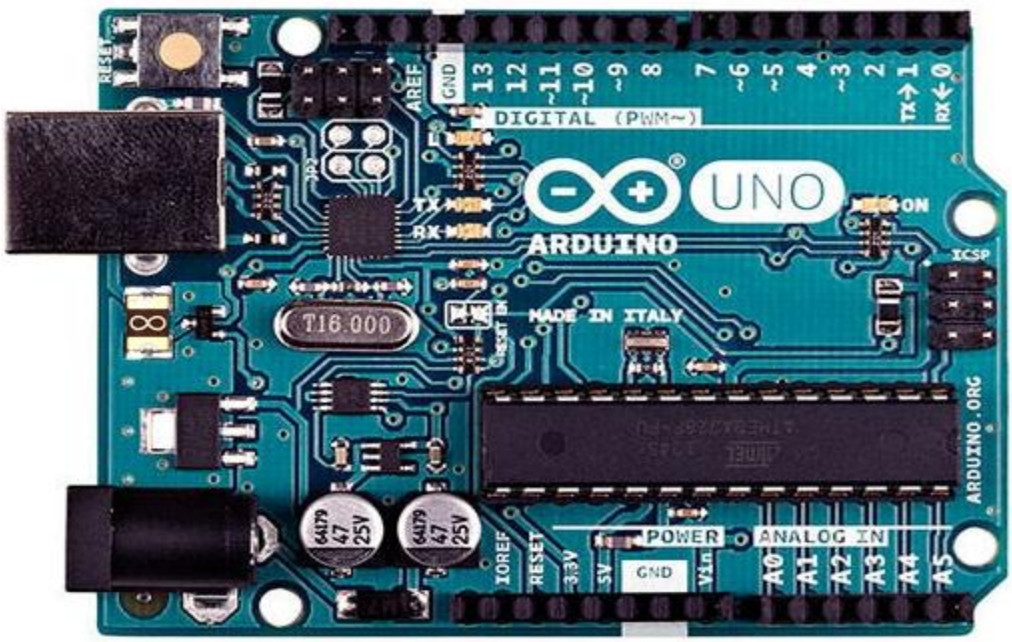

Figure (4.16): Arduino UNO

When selecting the replacing kit, we should consider motor type (DC or 3phase), and the air condition power (One T.O.R, Tow T.O.R and Three T.O.R).

4.8: HMI Implementation

The HMI is the screen, which used to connect between the system operations and the user in the operation. It consists of several screens: the main screen in the indoor unit can show the user the actual temperature, and airflow. The other screen in the remote control, the user can be determine the reference temperature and airflow.

Chapter 5: Conclusions & Recommendations

Conclusions:

Universal Kit for Split Inverter Air Conditioner low cost, alternative board that can be replaced on various types of modern inverter air conditioners, contains two main boards of the split inverter HVAC, Indoor and Outdoor board, in the indoor board human machine interface, communication parts and the fan driver. While Outdoor board contains rectifier, insulation component, protection circuits, filters and multi power drives boards.

Challenges:

1. scarcity pieces, and pad quality .
2. The synchronize motor signal with feed pack.
3. BLDC motor control.
4. The harmonic in inverter.
5. the practical information from local market.

Results:

The Universal Kit for Split Inverter Air Conditioner improved, with low cost and high effeminacy. so, we solved the main Problems, huge maintenance cost in comparison to the cost of the device and Replacing the panel inverter by another make.so the project can help the air conditioner technical to find another solution.

Can convert any traditional split air condition to inverter controlling, so get the positive thing in inverter air condition ,like, Energy Saving, Heat of Inverter Compressor, Powerful Heating Capacity, Quick Cooling & Heating, Pleasant Feeling and Quiet Operation.

Future plans:

Produce the board in local and word markets, add some Improvements like phone control , and self user manual .

Recommendations:

1- holding awareness workshops, disseminating brochures for split inverter air condition used.
2- HVAC servicing technicians needs more knowledge in the field of electronic panels repair.
3- The technicians can maintenance the split inverter air condition at the lowest cost by purchasing our product.

References

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Appendices