CLOSED LOOP CONTROL OF BRUSHLESS DC MOTOR

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CLOSED LOOP CONTROL OF BRUSHLESS DC MOTOR

Report submitted to
College of Engineering and Technology, Bhubaneswar in partial fulfillment of the requirements for the degree

of

Bachelor of Technology
in Electrical Engineering

by

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DEPARTMENT OF ELECTRICAL ENGINEERING COLLEGE OF ENGINEERING AND TECHNOLOGY, BHUBANESWAR

CENTRAL TOOL ROOM AND TRAINING CENTRE, BHUBANESWAR MINISTRY OF MICRO, SMALL AND MEDIUM ENTERPRISES GOVERNMENT OF INDIA
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ACKNOWLEDGEMENT

The success and final outcome of the project required a lot of guidance and assistance from many people and we are extremely privileged to have got this all along completion of the project.

We take this opportunity to express our profound gratitude and deep regards to our guide **Mr. Debasis Paul** Sir and **Mr. Chittaranjan Das** Sir for their exemplary guidance, monitoring and constant encouragement throughout the course of this project. The blessing, help and guidance given by him time to time shall carry us a long way in the journey of life on which we are about to embark.

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We also take the opportunity to owe our gratitude to our college guide for the project **Mr. Ranjib Kumar Behera** Sir for giving us the necessary information and guidance, without which the project would not have seen the height of the day.

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DECLARATION

I hereby declare that my project under Skills and Hands-on project entitled "**CLOSED LOOP CONTROL OF BRUSHLESS DC MOTOR**" is being submitted for bona fide work of research carried out by me under the guidance of **Mr Ranjib Kumar Behera** (Asst. Professor, CET BHUBANESWAR)**, Mr Debasis Paul** (Get, CTTC BHUBANESWAR), **Mr Chittaranjan Das** (Get, CTTC BHUBANESWAR).

The results of the work have not been submitted by me for the award of any other degree.

SHASHWATA SWARUPA SAHOO

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CERTIFICATE

This is to certify that the under **Skills and Hands-on project** entitled, "**Closed Loop Control of Brushless DC Motor**" submitted by **Mr. Shashwata Swarupa Sahoo** to **Department of Electrical Engineering, College of Engineering and Technology, Bhubaneswar** is a record of bona fide Project work carried out by him under our supervision and guidance and fulfils the requirements of the regulation relating to the nature and standard of work for the award of degree of Bachelors in Technology.

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ABSTRACT

The project is designed to control the speed of a Brushless DC motor using closed loop control technique. Here, the temperature and humidity play the role of feedback. BLDC motor has various application used in industries like in drilling, lathes, spinning, elevators, electric bikes etc. The speed control of the DC motors is very essential.

This proposed system provides a precise and effective speed control system. The user can enter the desired speed and the motor will run at that exact speed as the temperature and humidity change.

Based on the principle of PWM speed can be controlled. This is achieved by keeping BLDC motor on closed loop feedback by giving RPM reference to the microcontroller (ARDUINO UNO) upon a shaft. An LCD duly interfaced to the microcontroller to display the temperature and humidity.

The desired speed in percentage of full speed is fed with the help of keypad. The controller delivers desired pulse width to automatically adjust the DC power to the motor for required speed. The above operation is carried out by using one opto-isolator and an NPN transistor for driving the BLDC motor with DHT11 (temperature and humidity sensing) sensor for getting the speed reference to the microcontroller.

This project which has been designed mainly includes components like Motor Driver L298N, Arduino UNO microcontroller, DHT11 temperature and humidity sensor, potentiometer and SMPS.

Further, keeping the efficiency, mechanical advantages and lightweight of the motor in mind, the project can be enhanced to a fully fledged fuzzy logic control of a BLDC motor for industrial applications. It can also be developed for an intelligent cruise control used in modern automobiles these days.

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CHAPTER 1 - INTRODUCTION

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors), or synchronous DC motors, are synchronous motors powered by DC electricity via an inverter or switching power supply which produces an AC electric current to drive each phase of the motor via a closed loop controller. The controller provides pulses of current to the motor windings that control the speed and torque of the motor.

The construction of a brushless motor system is typically similar to a permanent magnet synchronous motor (PMSM), but can also be a switched reluctance motor, or an induction (asynchronous) motor.

A motor converts supplied electrical energy into mechanical energy. Various types of motors are in common use. Among these, brushless DC motors (BLDC) feature high efficiency and excellent controllability, and are widely used in many applications. The BLDC motor has power-saving advantages relative to other motor types.

1. Motors are Power Delivery Machines

Actuators and motors are among the devices that convert electrical signals into motion. Motors exchange electrical energy to mechanical energy.

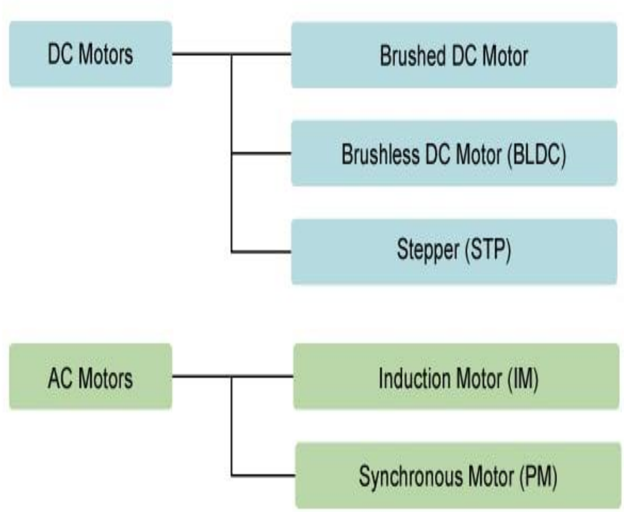

Fig 1.1 Types of motors

The simplest type of motor is the *brushed DC motor*. In this type of motor, electrical current is passed through coils that are arranged within a fixed magnetic field. The current generates magnetic fields in the coils; this causes the coil assembly to rotate, as each coil is pushed away from the like pole and pulled toward the unlike pole of the fixed field. To maintain rotation, it is necessary to continually reverse the current—so that coil polarities will continually flip, causing the coils to continue “chasing” the unlike fixed poles. Power to the coils is supplied through fixed conductive *brushes* that make contact with a rotating *commutator*; it is the rotation of the commutator that causes the reversal of the current through the coils. The commutator and brushes are the key components distinguishing the brushed DC motor from other motor types.

Motors differ according to their power type (AC or DC) and their method for generating rotation.

2. Construction of BLDC Motor

BLDC motors can be constructed in different physical configurations. Depending on the stator windings, these can be configured as single-phase, two-phase, or three-phase motors. However, three-phase BLDC motors with permanent magnet rotor are most commonly used.

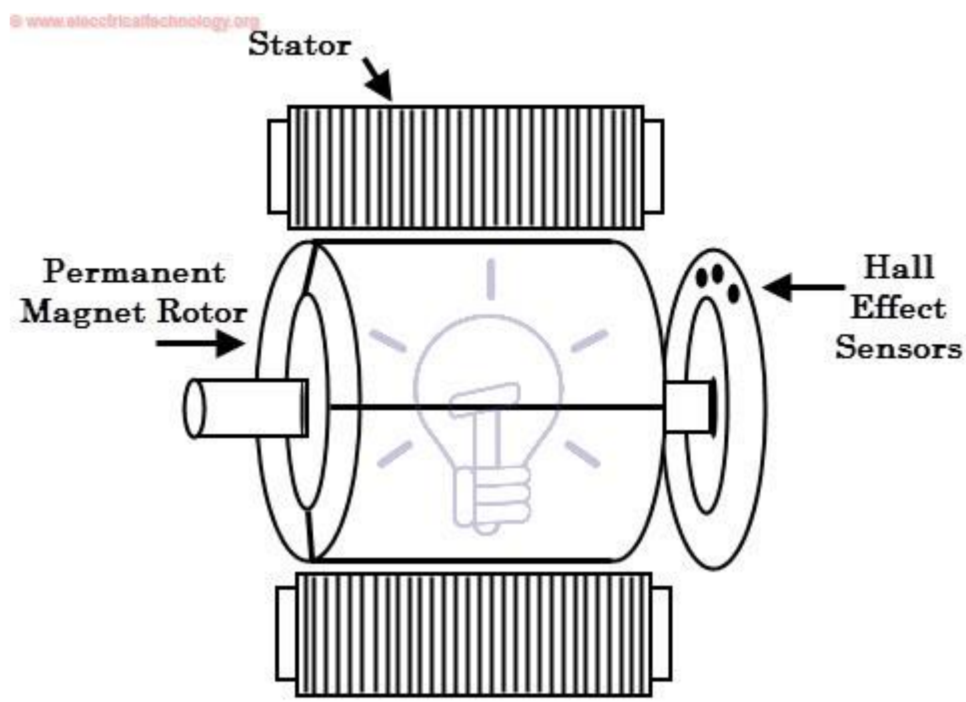

Fig. 1.2 Construction of BLDC motor

The construction of this motor has many similarities of three phase induction motor as well as conventional DC motor. This motor has stator and rotor parts as like all other motors.

Stator of a BLDC motor made up of stacked steel laminations to carry the windings. These windings are placed in slots which are axially cut along the inner periphery of the stator. These windings can be arranged in either star or delta. However, most BLDC motors have three phase star connected stator.

Each winding is constructed with numerous interconnected coils, where one or more coils are placed in each slot. In order to form an even number of poles, each of these windings is distributed over the stator periphery.

The stator must be chosen with the correct rating of the voltage depending on the power supply capability. For robotics, automotive and small actuating applications, 48 V or less voltage BLDC motors are preferred. For industrial applications and automation systems, 100 V or higher rating motors are used.

Rotor

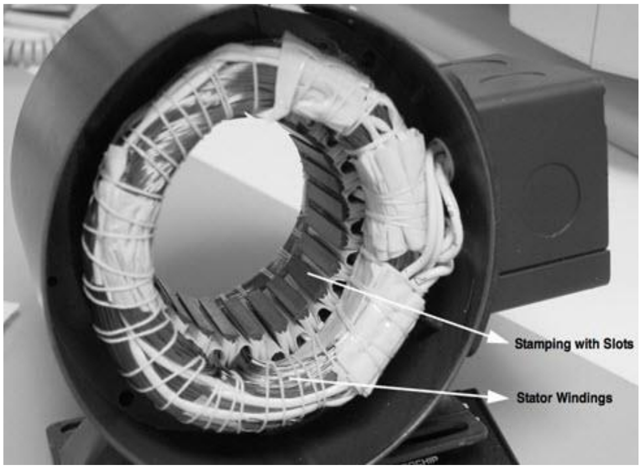

Fig. 1.3 Rotor construction

BLDC motor incorporates a permanent magnet in the rotor. The number of poles in the rotor can vary from 2 to 8 pole pairs with alternate south and north poles depending on the application requirement. In order to achieve maximum torque in the motor, the flux density of the material should be high. A proper magnetic material for the rotor is needed to produce required magnetic field density.

3. Working Principle and Operation of BLDC Motor

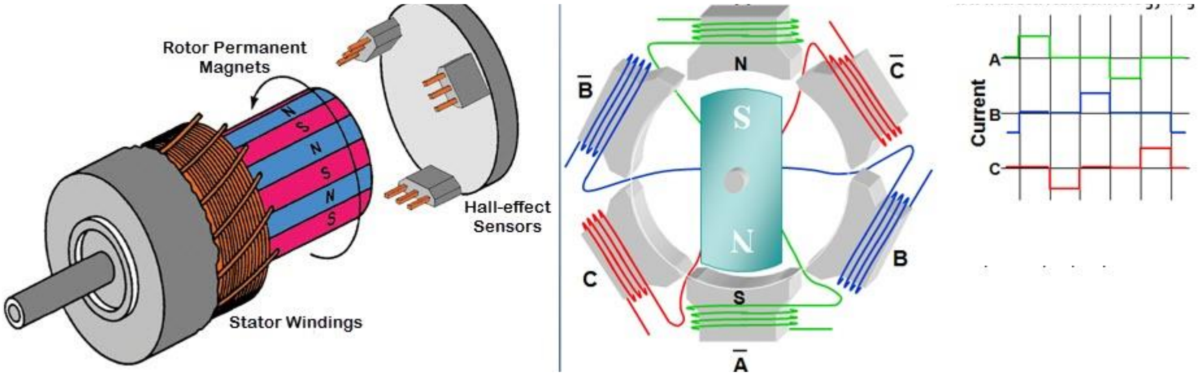

Fig.1.4 Working and operation of BLDC motor

BLDC motor works on the principle similar to that of a conventional DC motor, i.e., the Lorentz force law which states that whenever a current carrying conductor placed in a magnetic field it experiences a force. As a consequence of reaction force, the magnet will experience an equal and opposite force. In case BLDC motor, the current carrying conductor is stationary while the permanent magnet moves.

When the stator coils are electrically switched by a supply source, it becomes electromagnet and starts producing the uniform field in the air gap. Though the source of supply is DC, switching makes to generate an AC voltage waveform with trapezoidal shape. Due to the force of interaction between electromagnet stator and permanent magnet rotor, the rotor continues to rotate.

Considering the figure below in which motor stator is excited based on different switching states, with the switching of windings as High and Low signals, corresponding winding energized as North and South poles. The permanent magnet rotor with North and South poles align with stator poles causing motor to rotate.

It can be observed that motor produces torque because of the development of attraction forces (when North-South or South-North alignment) and repulsion forces (when North-North or South-South alignment). By this way motor moves in a clockwise direction.

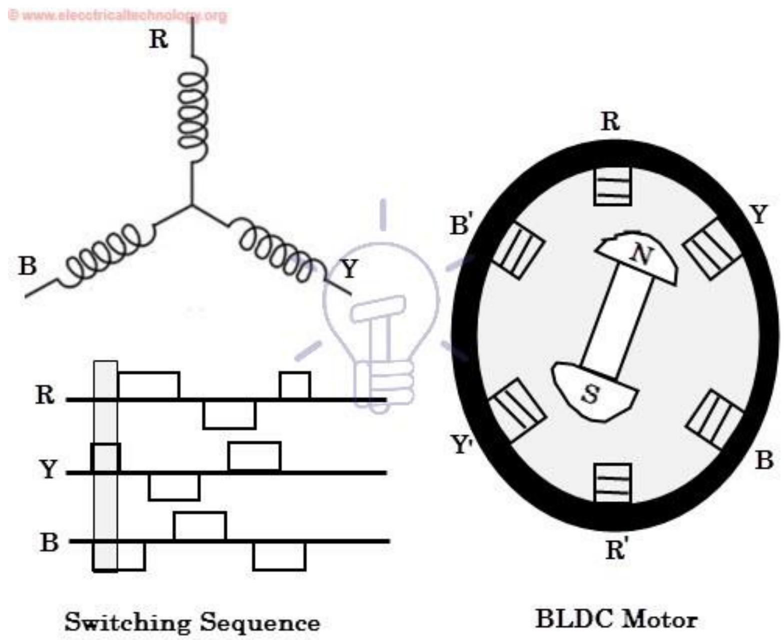

Fig. 1.5 Principle of production of torque

Based on this signal from sensor, the controller decides particular coils to energize. Hall-effect sensors generate Low and High level signals whenever rotor poles pass near to it. These signals determine the position of the shaft.

CHAPTER 2 - COMPONENT LIST

Sl. No.	COMPONENT NAME	SPECIFICATION	QUANTITY
1.	ADRUINO UNO	UNO	1
2.	BLUETOOTH MODULE	HCO5	1
3.	MOTOR DRIVER CIRCUIT	L293D	2
4.	MOTOR SPEED CONTROL DRIVE	L298N	1
5.	SENSOR (TEMP & HUMIDITY)	DHT11	2
6.	RELAY	1C TYPE,5V	5
7.	BRUSHLESS DC MOTOR	12V,60RPM	3
8.	ADRUINO ADAPTOR	12V,2A	1
9.	POWER SUPPLY JACK		5
10.	SMPS	12V,5A	1
11.	RAINBOW WIRE	5MTR	
12.	M-M JUMPER		20
13.	M-F JUMPER		20
14.	LCD DISPLAY	16*2,JHD162A	1
15.	MALE HOLDER PIN		10
16.	FEMALE HOLDER PIN		10
17.	SINGLE STRAND WIRE(RED)	3MTR	
18.	SINGLE STRAND WIRE(BLACK)	3MTR	
19.	TRANSISTOR(NPN)	BC547	5
20.	3 PIN POWER CABLE	230V AC,5AMP	1

CHAPTER 3 - COMPONENT DETAILS

1. Arduino Uno (ATMEGA MICROCONTROLLER)

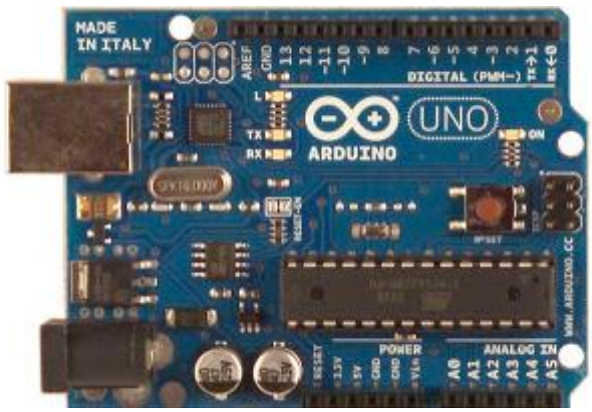

Fig. 3.1.1 ARDUINO UNO microcontroller

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions.

Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and VIN pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- ✓ VIN. The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- ✓ 5V. the regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- ✓ 3V3. a 3.3volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- ✓ GND. Ground pins.

Memory

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM.

Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead()functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.
- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

- I^2C: A4 (SDA) and A5 (SCL). Support I^2C (TWI) communication using the Wire library.
- There are a couple of other pins on the board:

- AREF. Reference voltage (0 to 5V only) for the analog inputs. Used with analogReference().
- Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega8U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '8U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Uno's digital pins.

The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C.0

Programming

The Arduino Uno can be programmed with the Arduino software (download). Select "Arduino Uno from the Tools > Board menu (according to the microcontroller on your board). The ATmega328 on the Arduino Uno comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

The ATmega8U2 firmware source code is available . The ATmega8U2 is loaded with a DFU bootloader, which can be activated by connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2. You can then use Atmel's FLIP software (Windows) or the DFU programmer (Mac OS X and Linux) to load a new firmware. Or you can use the ISP header with an external programmer (overwriting the DFU bootloader).

Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino Uno is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of theATmega8U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.

This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

The Uno contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110ohm resistor from 5V to the reset line;

USB Over current Protection

The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and over current. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics

The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Four screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

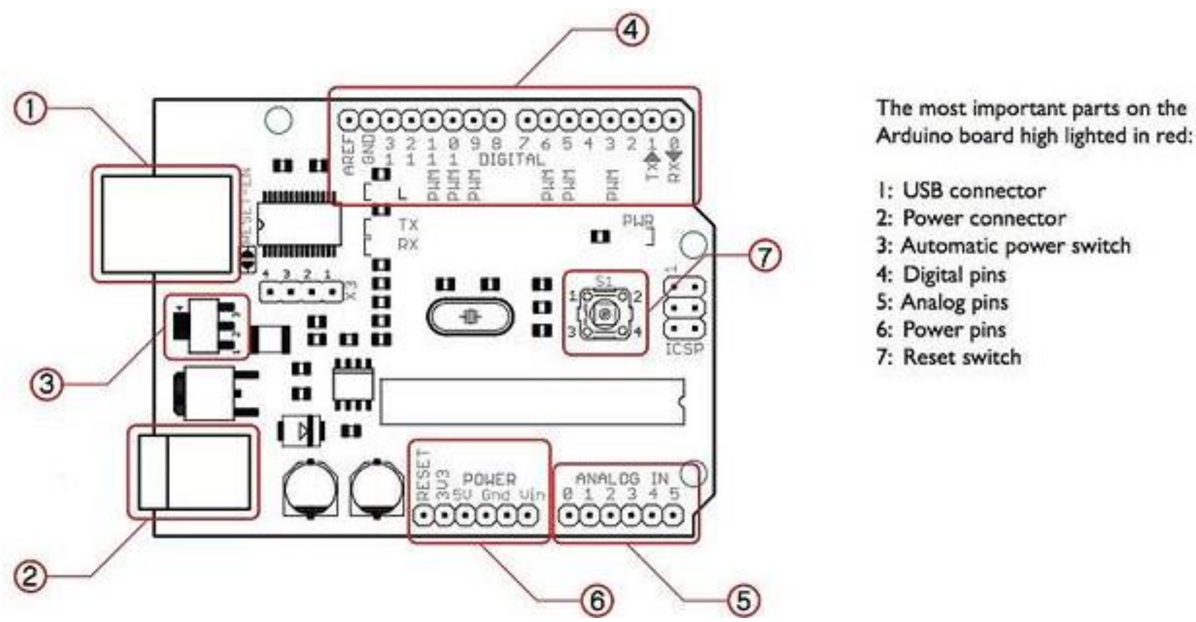

Fig. 3.1.2 Pin diagram of ARDUINO UNO

2. <u>L298N Motor Controller</u>

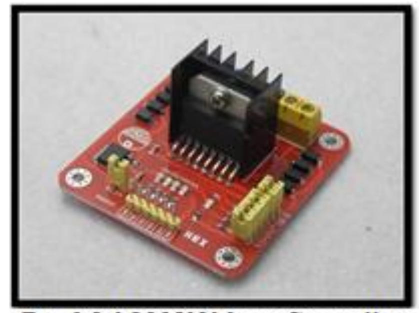

Fig. 3.2.1 L298N Motor Controller

TheL298N consists of four independent power amps with 5-volt digital inputs and four high current, high voltage power amplifiers capable of driving single DC motors, and both unipolar and bi-polar stepper motors.

The four amplifiers are usually used in pairs forming an H-bridge to switch polarity for to control the direction of a single DC motor or as two pairs of H-bridges a bi-polar stepper motor. This part seems to be the favorite of hobby robot builders.

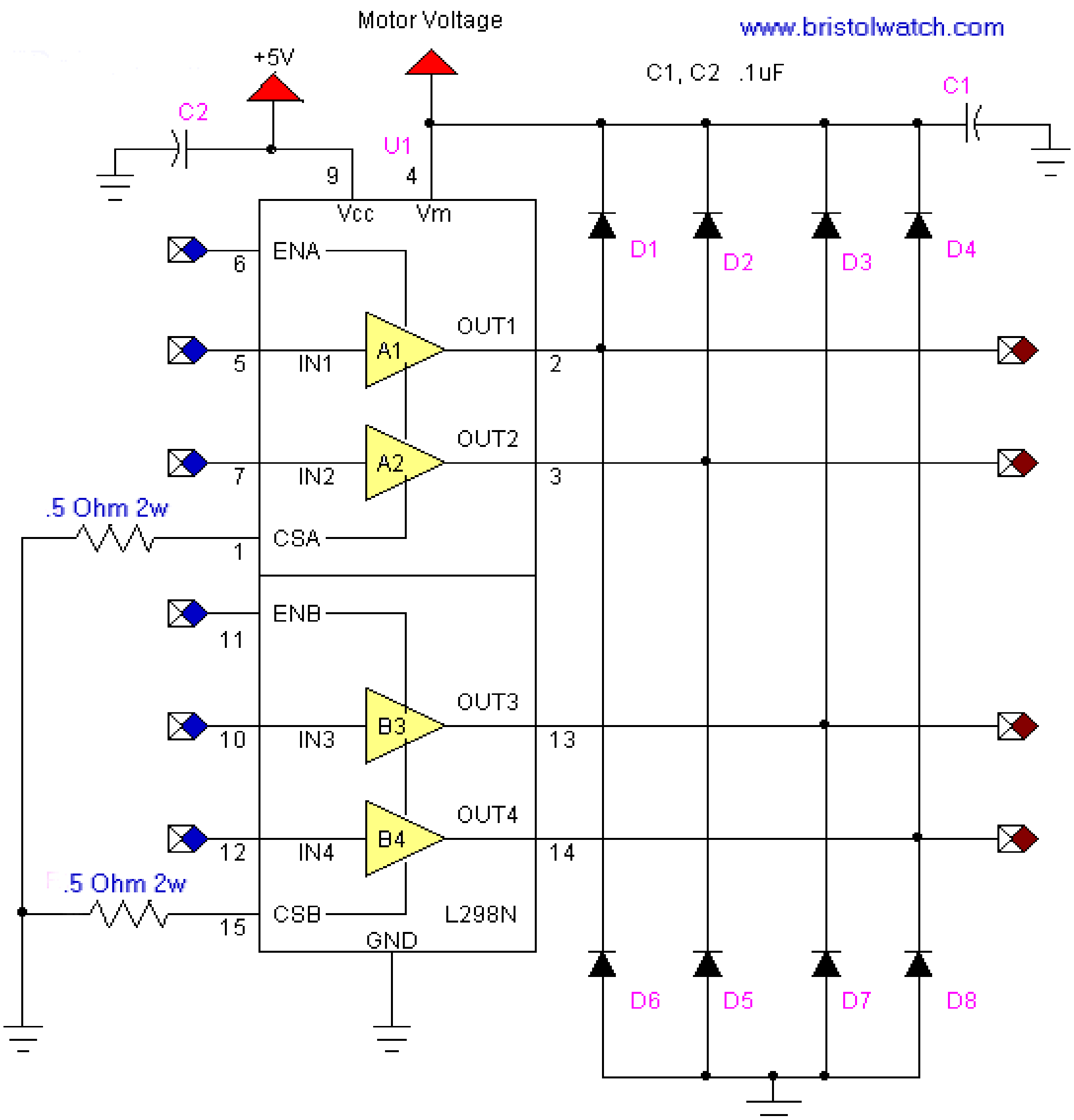

Fig. 3.2.2 Basic circuit configuration L298N

3. <u>TEMPEARTURE AND HUMIDITY CONTROL</u>

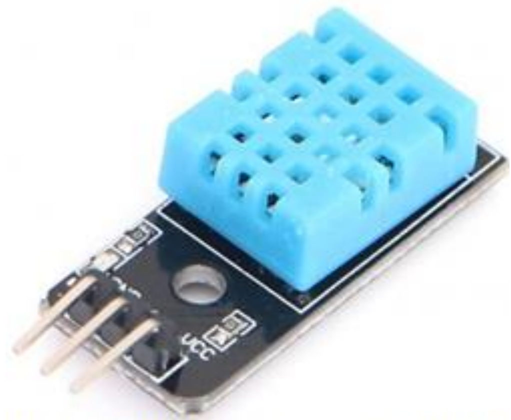

Fig. 3.2.2 DHT11 Temperature and Humidity Sensor

The DHT11 Temperature and Humidity Sensor features a calibrated digital signal output with the temperature and humidity sensor capability. It is integrated with a high-performance 8-bit microcontroller. Its technology ensures the high reliability and excellent long-term stability. This sensor includes a resistive element and a sensor for wet NTC temperature measuring devices. It has excellent quality, fast response, anti-interference ability and high performance.

Each DHT11 sensors features extremely accurate calibration of humidity calibration chamber. The calibration coefficients stored in the OTP program memory, internal sensors detect signals in the process, and we should call these calibration coefficients. The single-wire serial interface system is integrated to become quick and easy. Small size, low power, signal transmission distance up to 20 meters, enabling a variety of applications and even the most demanding ones. The product is 4-pin single row pin package. Convenient connection, special packages can be provided according to users need.

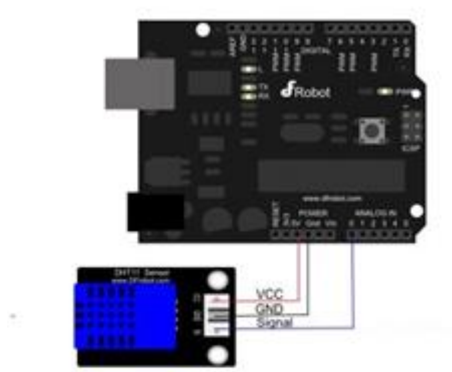

Fig. 3.3.2 Pin diagram of DHT11

Specification

- Supply Voltage: +5 V
- Temperature range :0-50 °C error of ± 2 °C
- Humidity :20-90% RH ± 5% RH error

4. <u>Arduino Adapter</u>

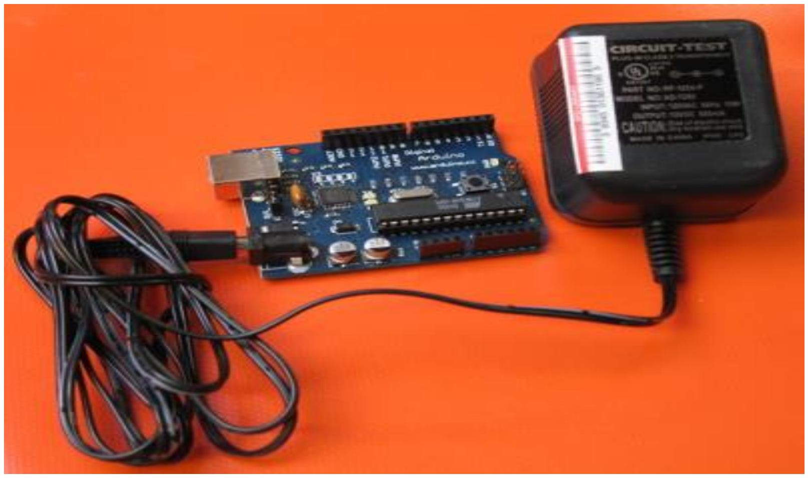

Fig. 3.4.1 ARDUINO adapter

- The off-the shelf Arduino adapter:
- is a DC adapter (i.e. it has to put out DC, not AC);
- should be between 9V and 12V DC
- must be rated for a minimum of 250mA current output
- must have a 2.1mm power plug on the Arduino end, and
- the plug must be "centre positive", that is, the middle pin of the plug has to be the + connection.

5. <u>Switched-mode power supply</u>

Fig. 3.5.1 SMPS

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power) to DC loads. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. Ideally, a switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time. In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weights are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor.

6. Jump wire

Fig. 3.6.1 jump wire

A jump wire is an electrical wire or group of them in a cable with a connector or pin at each end (or sometimes without them – simply "tinned"), which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering.

Individual jump wires are fitted by inserting their "end connectors" into the slots provided in a breadboard, the header connector of a circuit board, or a piece of test equipment.

Types

There are different types of jumper wires. Some have the same type of electrical connector at both ends, while others have different connectors. Some common connectors are: A) Solid tips B)Crocodile clips C)Banana connectors D)Registered jack E)RCA connectors

7. Stranded wire

Fig. 3.7.1 stranded wire

Stranded wire is composed of a number of small wires bundled or wrapped together to form a larger conductor. Stranded wire is more flexible than solid wire of the same total cross-sectional area. Stranded wire tends to be a better conductor than solid wire because the individual wires collectively comprise a greater surface area. Stranded wire is used when higher resistance to metal fatigue is required. Such situations include connections between circuit boards in multi-printed-circuit-board devices, where the rigidity of solid wire would produce too much stress as a result of movement during assembly or servicing; A.C. line cords for appliances; musical instrument cables; computer mouse cables; welding electrode cables; control cables connecting moving machine parts; mining machine cables; trailing machine cables; and numerous others.

At high frequencies, current travels near the surface of the wire because of the *skin effect*, resulting in increased power loss in the wire. Stranded wire might seem to reduce this effect, since the total surface area of the strands is greater than the surface area of the equivalent solid wire, but ordinary stranded wire does not reduce the skin effect because all the strands are short-circuited together and behave as a single conductor. A stranded wire will have higher resistance than a solid wire of the same diameter because the cross-section of the stranded wire is not all copper; there are unavoidable gaps between the strands (this is the circle packing problem for circles within a circle). A stranded wire with the same cross-section of conductor as a solid wire is said to have the same equivalent gauge and is always a larger diameter.

However, for many high-frequency applications, *proximity effect* is more severe than skin effect, and in some limited cases, simple stranded wire can reduce proximity effect. For better performance at high frequencies, litz wire, which has the individual strands insulated and twisted in special patterns, may be used.

8. Transistor

A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power. It is composed of semiconductor material usually with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals controls the current through another pair of terminals. Because the controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal. The transistor is the fundamental building block of modern electronic devices.

Most transistors are made from very pure silicon or germanium, but certain other semiconductor materials can also be used. A transistor may have only one kind of charge carrier, in a field effect transistor, or may have two kinds of charge carriers in bipolar junction transistor devices. Compared with the vacuum tube, transistors are generally smaller, and require less power to operate. Certain vacuum tubes have advantages over transistors at very high operating frequencies or high operating voltages.

Transistors are categorized by

- semiconductor material: the metalloids germanium and silicon—in amorphous, polycrystalline and monocrystalline form—, the compounds gallium arsenide and silicon carbide, the alloy silicon-germanium, the allotrope of carbon graphene etc.
- structure: BJT, JFET, IGFET (MOSFET), insulated-gate bipolar transistor;

- electrical polarity (positive and negative): n–p–n, p–n–p (BJTs), n-channel, p-channel (FETs);

NPN

NPN is one of the two types of bipolar transistors, consisting of a layer of P-doped semiconductor (the "base") between two N-doped layers. A small current entering the base is amplified to produce a large collector and emitter current. That is, when there is a positive potential difference measured from the base of an NPN transistor to its emitter (that is, when the base is high relative to the emitter), as well as a positive potential difference measured from the collector to the emitter, the transistor becomes active. In this "on" state, current flows from the collector to the emitter of the transistor. Most of the current is carried by electrons moving from emitter to collector as minority carriers in the P-type base region. To allow for greater current and faster operation, most bipolar transistors used today are NPN because electron mobility is higher than hole mobility.

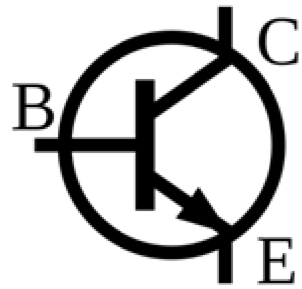

Fig. 3.8.1 NPN symbol

PNP

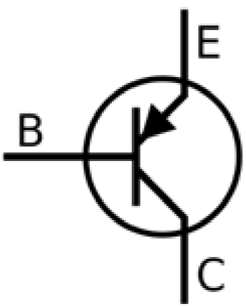

Fig. 3.8.1 PNP symbol

The other type of BJT is the PNP, consisting of a layer of N-doped semiconductor between two layers of P-doped material. A small current leaving the base is amplified in the collector output. That is, a PNP transistor is "on" when its base is pulled low relative to the emitter. In a PNP transistor, the emitter–base region is forward biased, so holes are injected into the base as minority carriers. The base is very thin, and most of the holes cross the reverse-biased base–collector junction to the collector.

9. 16x2 Character LCD Display (JHD)

A Liquid Crystal Display commonly abbreviated as LCD is basically a display unit built using Liquid Crystal technology. When we build real life/real world electronics based projects, we need a medium/device to display output values and messages. The most basic form of electronic display available is 7 Segment display – which has its own limitations. The next best available option is Liquid Crystal Displays which comes in different size specifications. Out of all available LCD modules in market, the most commonly used one is 16×2 LCD Module which can display 32 ASCII characters in 2 lines (16 characters in 1 line). Other commonly used LCD displays are 20×4 Character LCD, Nokia 5110 LCD module, 128×64 Graphical LCD Display and 2.4 inch TFT Touch screen LCD display.

Fig. 3.9.1 JHD162A

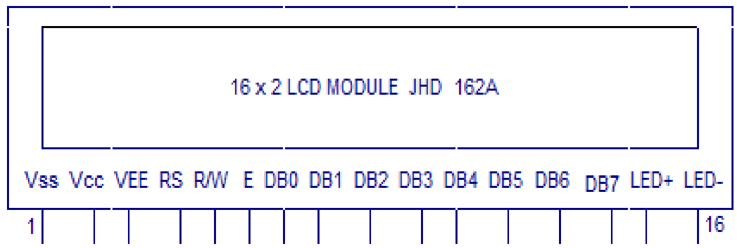

Fig. 3.9.2 PIN DIAGRAM OF JHD162A

The name and functions of each pin of the 16×2 LCD module is given below.

- Pin1(Vss):Ground pin of the LCD module.
- Pin2(Vcc): Power to LCD module (+5V supply is given to this pin)
- Pin3(VEE):Contrast adjustment pin. This is done by connecting the ends of a 10K potentimeter to +5V and ground and then connecting the slider pin to the VEE pin. The voltage at the VEE pin defines the contrast. The normal setting is between 0.4 and 0.9V.
- Pin4(RS):Register select pin.The JHD162A has two registers namely command register and data register. Logic HIGH at RS pin selects data register and logic LOW at RS pin selects command register. If we make the RS pin HIGH and feed an input to the data lines (DB0 to DB7), this input will be treated as data to display on LCD screen. If we make the RS pin LOW and feed an input to the data lines, then this will be treated as a command (a command to be written to LCD controller – like positioning cursor or clear screen or scroll).
- Pin5(R/W): Read/Write modes. This pin is used for selecting between read and write modes. Logic HIGH at this pin activates read mode and logic LOW at this pin activates write mode.
- Pin6(E): This pin is meant for enabling the LCD module. A HIGH to LOW signal at this pin will enable the module.
- Pin7(DB0) to Pin14(DB7): These are data pins. The commands and data are fed to the LCD module though these pins.
- Pin15(LED+): Anode of the back light LED. When operated on 5V, a 560 ohm resistor should be connected in series to this pin. In arduino based projects the back light LED can be powered from the 3.3V source on the arduino board.
- Pin16(LED-): Cathode of the back light LED.

Specifications of JHD162A LCD Display:

- Model JHD162A
- Display: 16 * 2 character
- Outline: 80.0 x 36.0 x 14.5
- VA: 64.5 x 14.5
- Controller: SPLC780D
- Character: 2.95 x 4.35

- Driver: 1 / 16
- LCD: STN Yellow Green
- Backlight: Yellow Green LED

10. POTENTIOMETER

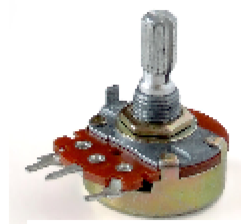

Fig. 3.10.1 potentiometer

A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat.

Potentiometers are commonly used to control electrical devices such as volume controls on audio equipment. Potentiometers operated by a mechanism can be used as position transducers, for example, in a joystick. Potentiometers are rarely used to directly control significant power (more than a watt), since the power dissipated in the potentiometer would be comparable to the power in the controlled load.

11. PULSE WIDTH MODULATION

Pulse Width Modulation (PWM) is a fancy term for describing a type of digital signal. Pulse width modulation is used in a variety of applications including sophisticated control circuitry.

The supply voltage is chopped at a fixed frequency with a duty cycle depending on the current error. Therefore, both the current and the rate of change of current can be controlled. The two phase supply duration is limited by the two phase commutation angles. The main advantage of the PWM strategy is that the chopping frequency is a fixed parameter; hence, acoustic and electromagnetic noises are relatively easy to filter. There are also two ways of handling the drive current switching: hard chopping and soft chopping. In the hard chopping technique, both phase transistors are driven by the same pulsed signal: the two transistors are switched-on and switched-off at the same time. The soft chopping approach allows not only a control of the current and of the rate of change of the current but a minimization of the current ripple as well. In this soft chopping mode, the low side transistor is left ON during the phase supply and the high side transistor switches according to the pulsed signal. In this case, the power electronics board has to handle six PWM signals. The duty cycle determines the speed of the motor.

The desired speed can be obtained by changing the duty cycle. The PWM in microcontroller is used to control the duty cycle of BLDC motor

Average voltage = D * Vin

The average voltage obtained for various duty cycles is also mentioned and as the duty cycle percentage decreases average voltage also decreases from the supply voltage. Duty cycle is defined as the percentage of time the motor is ON. Therefore, the duty cycle is given as

Duty Cycle = 100% x Pulse Width/Period

Where, Duty Cycle in (%)

Pulse Width = Time the signal is in the ON or high state (sec)

Period = Time of one cycle (sec).

Chapter 4- ARDUINO PROGRAM

```
#include<DHT.h>
#include<LiquidCrystal.h>
LiquidCrystal lcd(12,11,10,13,8,7);//Lcd(RS,EN,D4,D5,D6,D7)
#define DHTPIN A0
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);
#define enA 5
#define in1 3
#define in2 9
#define button 4
int rotDirection = 0;
int pressed = false;
void setup()
{
        Serial.begin(9600);
        dht.begin();
        pinMode(enA, OUTPUT);
        pinMode(in1, OUTPUT);
        pinMode(in2, OUTPUT);
        pinMode(button, INPUT_PULLUP);
        // Set initial rotation direction
        digitalWrite(in1, LOW);
        digitalWrite(in2, HIGH);
          lcd.begin(16,2);
        lcd.setCursor(0,1);
}
void loop()
       {
        float humidity=dht.readHumidity();
        float temperature=dht.readTemperature();
        lcd.setCursor(0,0);
        lcd.print("Temp.=");
        lcd.print(temperature);
        lcd.print(" C");
        lcd.setCursor(0,1);
        lcd.print("Humid.=");
        lcd.print(humidity);
        lcd.print(" %");
       if(isnan(humidity)||isnan(temperature))
        {
                return;
       }
       delay(100);
```

```
if(temperature<16)                          //temperature=analogRead(A0)
          {
           analogWrite(in1, HIGH);
            analogWrite(in2, HIGH);
           }
          else
          {
          int pwmOutput = map(humidity, 0, 100 , 0 , 200); // Map the potentiometer value from 0
         to 255
          analogWrite(enA, pwmOutput);
          Serial.print(humidity);
          Serial.print(" ");
          Serial.print(temperature);
          Serial.print(" ");
          Serial.println(pwmOutput);
            if (digitalRead(button) == false)              // Read button - Debounce
          {
            pressed = !pressed;
           }
          while (digitalRead(button) == false);
          delay(20);
          if (pressed == false  & rotDirection == 0)
         {
            digitalWrite(in1, HIGH);
            digitalWrite(in2, LOW);
            rotDirection = 1;
            delay(20);
          }
         if (pressed == true & rotDirection == 1)
         {
         digitalWrite(in1, LOW);
          digitalWrite(in2, HIGH);
         rotDirection = 0;
         delay(20);
         }
  }
}
```

CHAPTER 5 - E CAD DESIGN

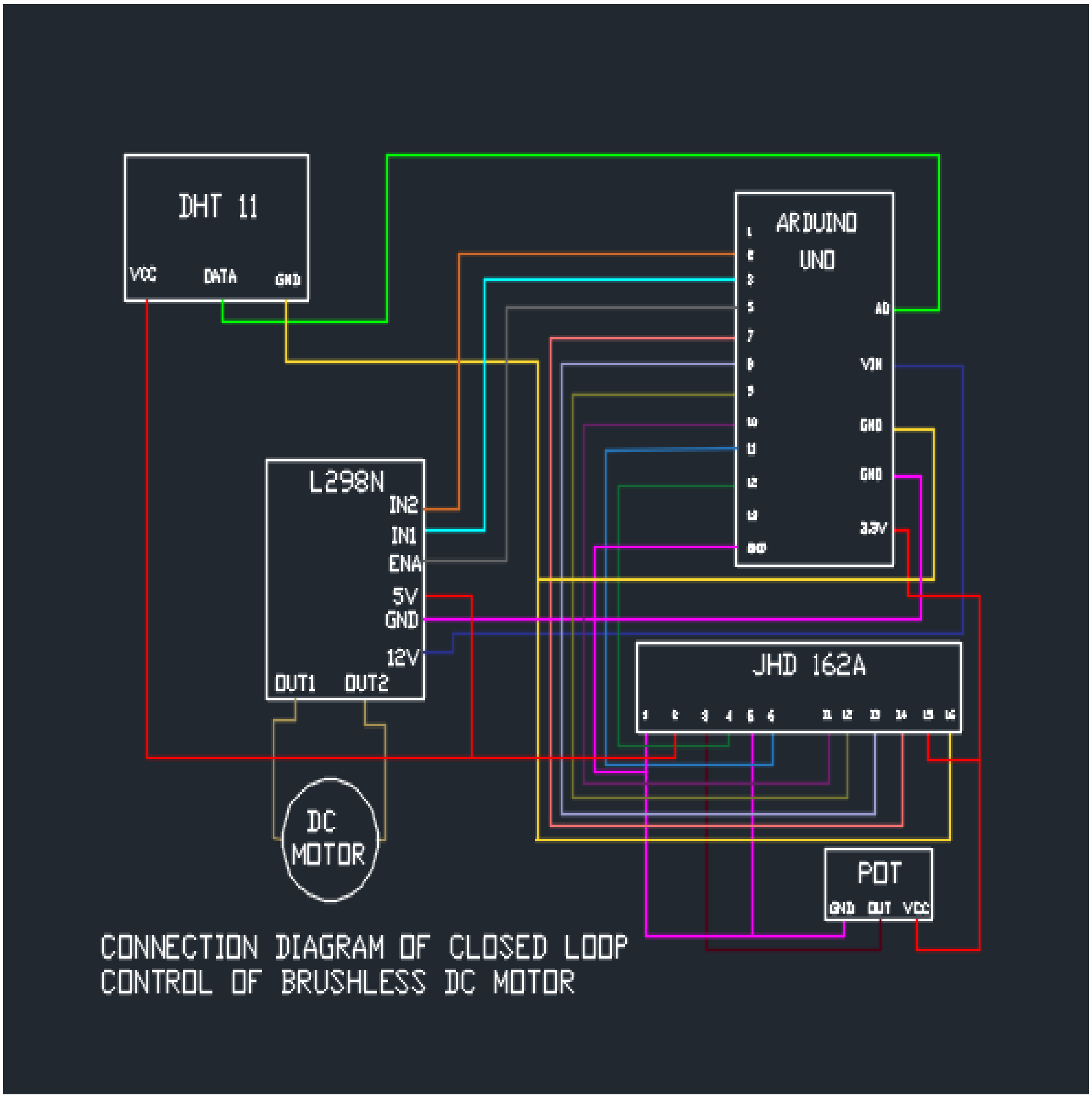

Fig. 5.1 Wiring diagram of 'Closed Loop Control of Brushless DC Motor'

CHAPTER 6 - WORKING DESCRIPTION

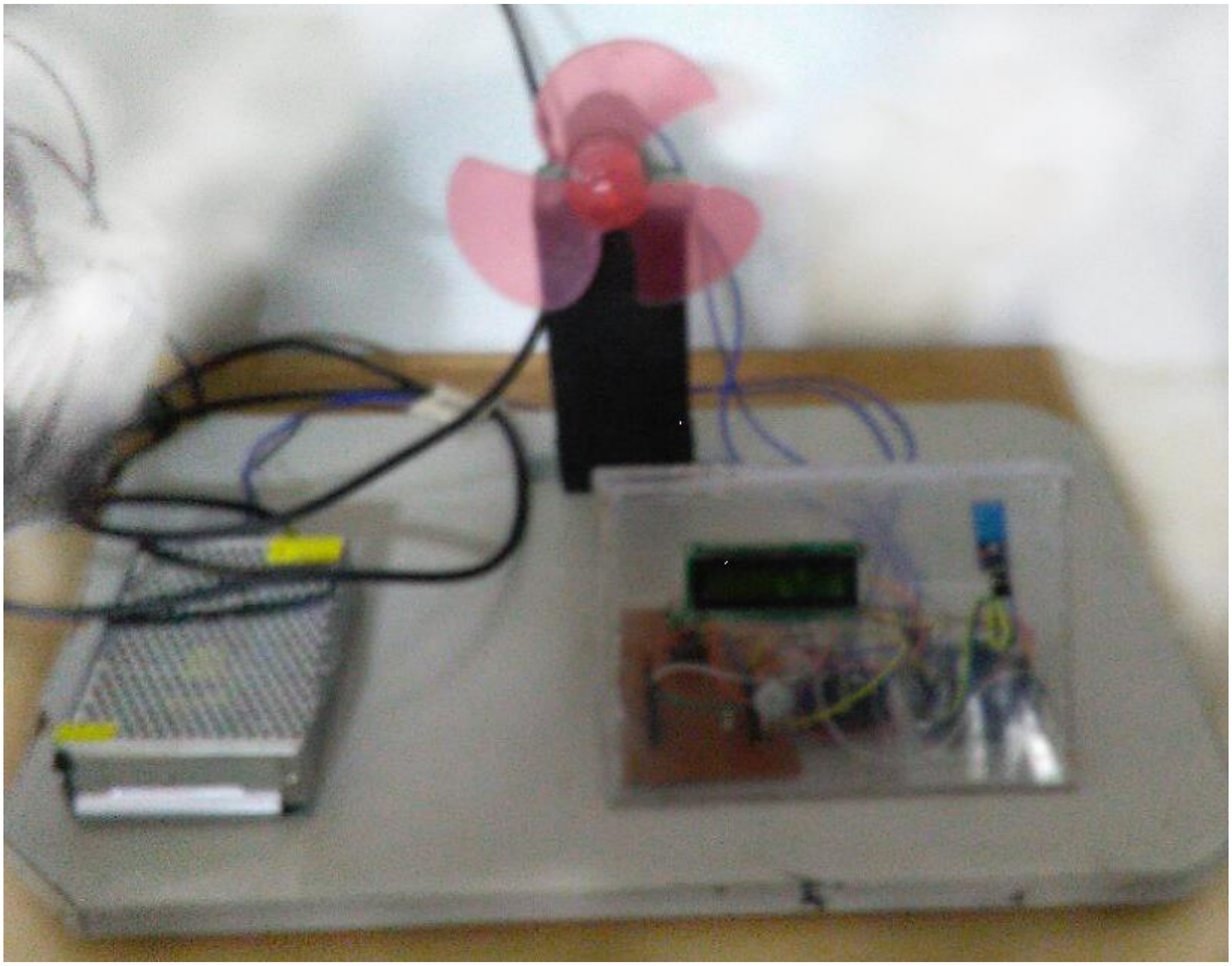

Fig. 6.1 Project model in stationery state

The project is designed to control speed of a DC motor an Arduino development board. Speed of the DC motor is directly proportional to the voltage applied across its terminals. Hence, if the voltage across the motor terminal is varied, then the speed can also be varied.

DHT11 sensor is used to read the temperature and humidity to control fan speed. This sensor is very easy to use and having very good accuracy compared to other sensors. We have used L298N motor driver IC for controlling DC fan/motor with Arduino. It can drive 2 DC motors and we can also control the speed by providing PWM signals. This project uses the above principle to control the speed of the motor by varying the duty cycle of the pulse applied to it (popularly known as PWM control). The project has two input buttons interfaced to the Arduino board, which are used to control the speed of the motor. PWM (Pulse Width Modulation) is generated at the output by the microcontroller as per the program.

The program is written in Arduino programming language. In the program we have set different conditions to run the DC fan. If the temperature is less than 16°C, then the DC fan will remain off and details will be displayed on the LCD. If the temperature is greater than 16°C, then the DC fan will start working at low speed. Then, consequently as the humidity or the temperature changes, the speed of fan changes accordingly. A motor-driver IC is interfaced to the Arduino board for receiving PWM signals and delivering desired output for speed control of a small DC motor.

As the SMPS gives supply to the system, the DHT11 senses the temperature and humidity of the surrounding and gives signal to the ARDUINO in which the program has been uploaded from the computer. Accordingly the ARDUINO gives signal to L298N motor driver and the driver runs the motor in that speed. Any change in temperature or humidity changes the speed of the motor. The LCD display shows the instant temperature and humidity at which the motor is working. The potentiometer has been used to increase or decrease the brightness of the LCD display unit. The instant speed, temperature and humidity plot of the motor can be viewed on the computer screen.

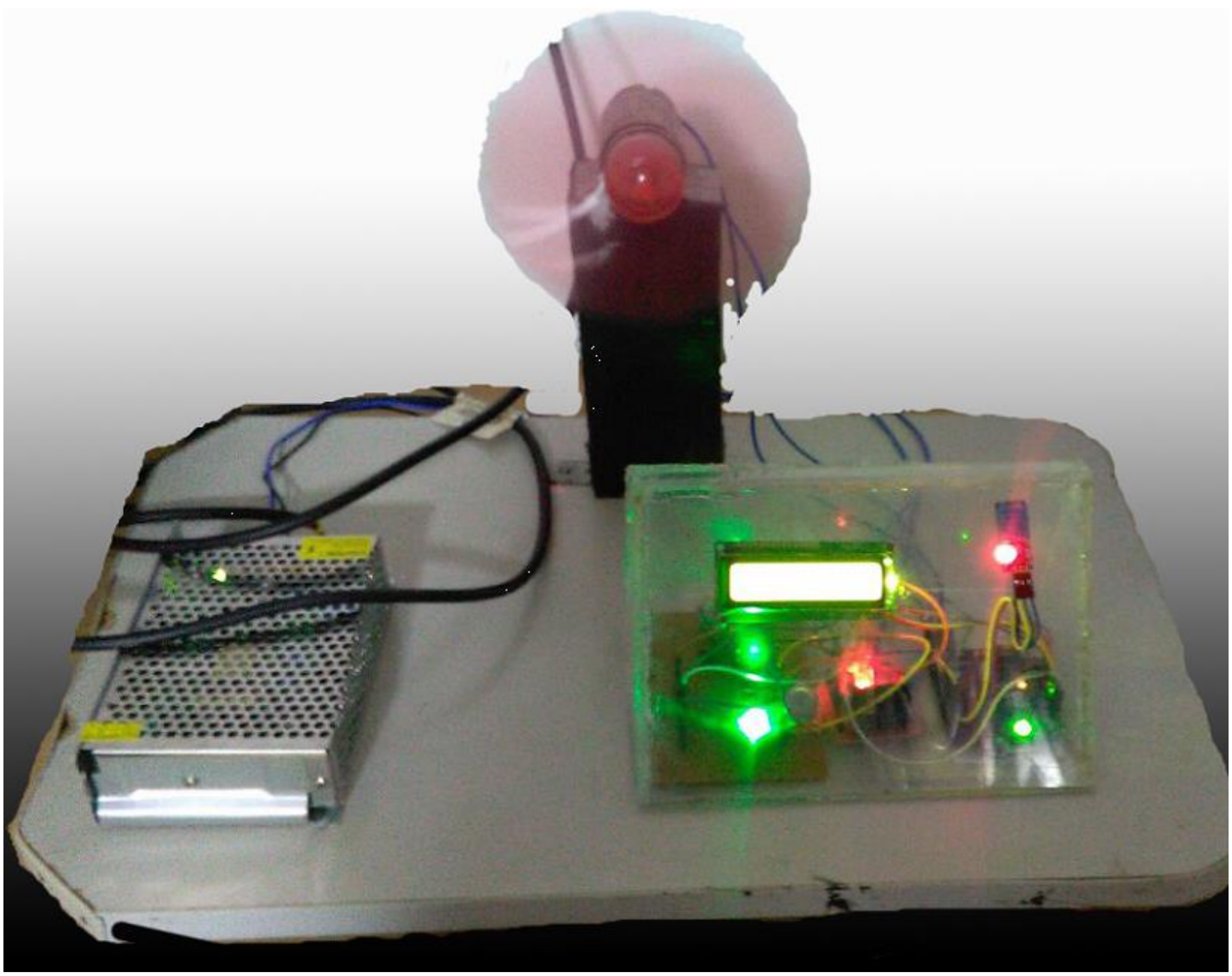

Fig. 6.2 Project model in working state

CHAPTER 7 - ADVANTAGES OF BLDC MOTOR

BLDC motor has several advantages over conventional DC motors and some of these are

1. It has no mechanical commutator and associated problems
2. High efficiency due to the use of permanent magnet rotor
3. High speed of operation even in loaded and unloaded conditions due to the absence of brushes that limits the speed
4. Smaller motor geometry and lighter in weight than both brushed type DC and induction AC motors
5. Long life as no inspection and maintenance is required for commutator system
6. Higher dynamic response due to low inertia and carrying windings in the stator
7. Less electromagnetic interference
8. Quite operation (or low noise) due to absence of brushes

CHAPTER 8 - DISADVANTAGES OF BLDC MOTOR

1) These motors are costly
2) Electronic controller required control this motor is expensive
3) Not much availability of many integrated electronic control solutions, especially for tiny BLDC motors
4) Requires complex drive circuitry
5) Need of additional sensors

CHAPTER 9 – APPLICATIONS OF BLDC MOTOR

Brushless DC motors (BLDC) have a wide variety of applications requirements such as varying loads, constant loads and positioning applications in the fields of industrial control, automotive, aviation, health care equipments, etc. Some specific applications of BLDC motors are

- Computer hard drives and DVD/CD players
- Electric vehicles, hybrid vehicles, and electric bicycles
- Industrial robots, CNC machine tools, and simple belt driven systems
- Washing machines, compressors and dryers
- Fans, pumps and blowers

CHAPTER 10 – CONCLUSION

The system once fully functional will enable wireless control and monitoring of the parameters of an electrical drive. This paper presents the speed control method of BLDC Motor via Bluetooth technology. As the results of experiments, speed response and performance evaluation has been verified with different speed. Future scope of wireless automation includes usage of flexible networks of microcontroller based systems to control and monitor a bank of electrical appliances in industrial and residential arenas. These networks would not be restricted to Bluetooth but would also use Wireless Fidelity (Wi-Fi), Radio Frequency Identification (RFID) and Zigbee etc.

CHAPTER 11 – REFERENCES

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