

Remote Control of BLDC Motor

Sasmita Behera¹, Prabhat Kumar Muduli²

¹Asst. Professor, Dept. of Electrical & Electronics Engg. Veer Surendra Sai University of Technology, Odisha, India.

E-mail: sasmitabehera2000m@gmail.com

²Student, Dept. of Electrical & Electronics Engg., Veer Surendra Sai University of Technology, Odisha, India.

E-mail: pkumarmuduli@gmail.com

Abstract: The electrical devices today demand better efficiency, less maintenance and lower carbon emission. Brushless DC (BLDC) motor has drawn attention for its high efficiency as compared to AC induction motor. This type of motor represents the most recent end of a long evolution of motor technology. It is known for its increased efficiency, enhanced reliability, decreased noise, and extended lifetime over brushed DC motors. In this paper, a speed control scheme of BLDC motor using Hall Effect sensor is proposed. Pulse Width Modulation (PWM) technique is used for control by pre-programming microcontroller and the speed of motor is handled by a remote.

Keywords: BLDC motor, Pulse width modulation, Remote-control, Infrared sensor, Hall effect sensor.

I. INTRODUCTION

Electric motors are the backbone of industrial drives. The DC motors are highly controllable but the cost of DC operation is more than AC motors. One of such component is commutator and brush. The maintenance of them is avoided in Brush Less DC (BLDC) motor [1] and this makes it popular. Its use extends from home appliances, automotive, aerospace to many industrial equipment and instrumentation for various applications. It is not only of ten thousand hour long life due to electronic commutated, but also highly efficient due to no copper loss in rotor, quiet operation, better speed range and higher torque to weight ratio as compared to others [2]. The precise control is achieved by Pulse Width Modulation (PWM) [3].

BLDC motor control can be with sensor and without sensor [3-6]. To control the rotor, present position is measured by the sensors. Then the next control action is determined by PWM or control of DC bus voltage. The stator winding are energized on alignment of rotor poles with them. Hall sensors are more used for position measurement [4] than older ones such as optical encoder [6] and potentiometer type sensors [4] for it is reliable in vibration, dusty and humid work environment where

BLDC motor is suitably used. The proximity of rotor poles is signalled by it as high for north and low for south pole. Speed is derived from the sensed position. Accuracy of position sensing ensures fast and stable control. The position control is achieved by current control and speed by an outer loop in cascade [5]. A variety of sensor-less techniques for BLDC motors are analyzed for speed control of brushless drive with PWM control [3,5]. Fuzzy and Fuzzy PID controllers [6,7] have been tested in BLDC speed control to perform better than conventional PI and MRAS controllers in Matlab simulation environment. But it is observed that, there is speed oscillation about the required one. Experimentally the control have been tested by some researchers in various digital signal processor (DSP) [3], [8-10] and observed the speed waveform in Oscilloscope or computer connected to the controller. Some control methods have been implemented in microcontrollers in hardware [10-12], which with a LCD display satisfy a complete product design. Infrared remote and receiver [11] with control in ATMEGA 16 microcontroller has been done by Agung et al., with the speed displayed in LCD, but the sensor was a photo diode for the position measurement and speed was controlled for a low speed drive. Further advancement in control and display has been done by remote control [13] by radio frequency.

The above literature don't show an application of Hall sensors with remote control and LCD display in one package which can make a complete product best suiting application of BLDC in dusty/limited access environment. This paper deals with sensed control method to run the BLDC motor remotely at exact entered speed. This is achieved by using the microcontroller programming [14]. The speed is viewed in a LCD display. In section 2 the control strategy with the help of block diagram is explained. Section 3 has hardware implementation connection of each part and results; with conclusion and suggestions for future work in next section.

II. BLOCK DIAGRAM

The control blocks as per fig. 1 are detailed as below.

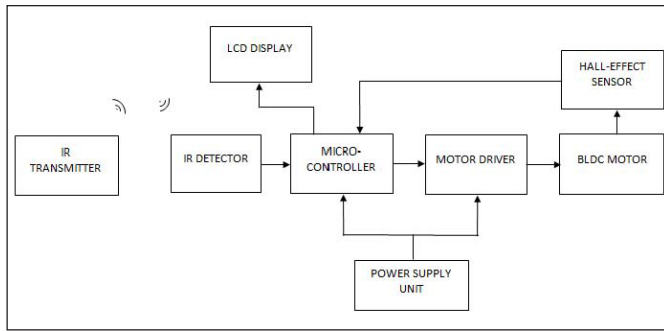


Fig. 1: Block Diagram of Remote Control of BLDC Motor

A. BLDC Motor

BLDC motor can be termed as a permanent magnet synchronous motor with a trapezoidal Back EMF waveform. The stator of a BLDC motor consists of stacked steel laminations with windings placed in the axial slots in the inner periphery. BLDC motor has permanent magnets in the rotor made up of rare earth alloys such as Samarium Cobalt (SmCo), Neodymium (Nd), Ferrite and Boron (NdFeB) [2]. Most BLDC motors have three stator windings formed of many coils connected in star. The windings are distributed to form an even number of poles. In BLDC motors the magnetic field produced by the stator and that of the rotor revolve at equal frequency. Its working principle is that, whenever a current carrying conductor is placed in a magnetic field it experiences a force. Due to an equal reaction force, the magnet on the rotor will move.

The permanent magnet rotor of BLDC motor imparts low inertia. So the speed control time reduces with faster acceleration and deceleration. Its linear speed/torque characteristics makes speed regulation predictable. Servicing is reduced due to brushless feature which suits in limited access areas in medical instruments. The silent operation and reduced Electromagnetic Interference (EMI) in low-voltage rating are best suited for battery operated handy medical instruments. BLDC motors are used for robotics, automotive and small actuating applications at 48 V or lower; whereas, for industry automation it is 100 V or higher. High performance BLDC motors are also used in electric vehicles [3].

B. Remote

When a button on the remote handset is pushed on infra red (IR) light signal is transmitted from the light emitting diode (LED) placed at the front beak. The 940-nm wavelength IR light is received by the IR sensor on the device.

For multi-channel remote control, modulating the carrier with signals of different frequency at remote and demodulating at the receiver with frequency filter is used to separate the particular signals.

C. IR Detector

Since infrared (IR) remote control uses light, it needs line of sight to operate the destination device. Infrared receiver has limited operating angle that depends on the optical characteristics of the photo-transistor at the device end. The received signal is then converted to electric signals and used by the microcontroller.

D. Microcontroller

The microcontroller is a miniature computer on one chip designed for specific machine control, which is programmable. ATMEGA328 microcontroller, is the processor for the arduino dumilanove board. It has 28 pins [14] as shown in Fig. 2. The device operates between 1.8-5.5 volts.

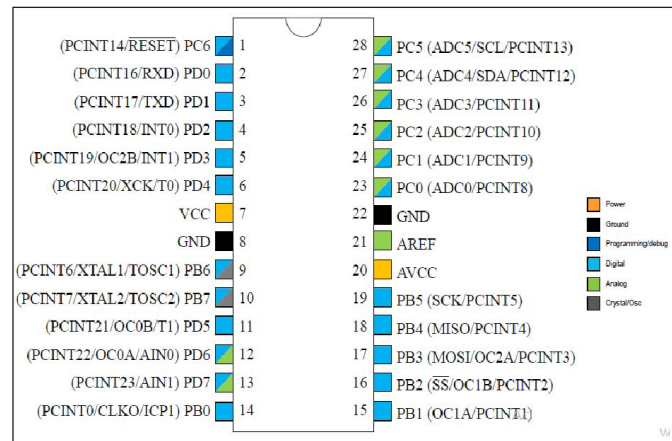


Fig. 2: Pin Diagram of ATMEGA328 [14]

It has 6 analog inputs pins PC0 to PC5 and 12 digital input pins PD1 to PD11 which act as an digital input ports for PWM in discrete form. Input power is connected at VCC and GND pins. Pins PB6 and PB7, connect a crystal oscillator for generation of clock signal. PC6 pin resets the chip.

The program is written by using Arduino software tool, Arduino IDE 1.6.9. By the USB port on the board connected to the computer, the program is uploaded to Arduino for its application.

E. Motor Driver

A motor driver is an H-Bridge current amplifier. It takes a low current control signal and then converts it into a higher-current signal to drive a motor [15]. An H-Bridge can input current of either polarity. It is controlled by Pulse Width Modulation (PWM) [3].

F. Hall Effect Sensor

When a current carrying conductor is placed in a magnetic field, the field applies a transverse force that tends to push the electrons towards one wall of the conductor [4]. A build-up

of charge that balances this magnetic field produces potential difference between the walls of the conductor. This is termed as the Hall effect. The most commonly used sensors are hall sensors and optical encoders [6].

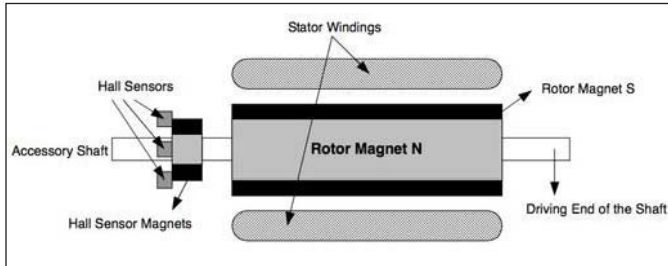


Fig. 3: Longitudinal Section of BLDC Motor

As seen from Fig. 3 rotor of the BLDC motor has alternate north (N) and south (S) poles. Three Hall sensors are placed in the stator very precisely to ensure correct detection of rotor position. Hall sensor magnets are placed on the rotor, besides the main rotor magnets. They impart the same effect as the main magnets. They are placed at 60 or 120 phase shift to one another.

G. Liquid Crystal Display (LCD)

LCD display module with Green black light built-in HD44780 standard with 2X16-characters display is powered from 5V DC [12] to display the angular speed.

H. Power Supply Unit

A DC Power Supply Unit (PSU) takes power from the AC supply and keeps the output voltage constant in an event of AC supply or load current variation.

III. IMPLEMENTATION IN HARDWARE

A. Materials Requirement

Hardware Requirements

- BLDC motor fan: 12V, 0.36 A
- Motor driver circuit L298:25W, +5V to 46 V

- IR receiver/ Detector:2.7V to 5.5V
- Serial LCD display: green, 2X16
- Magnetic Hall sensor
- Arduino Duemilanove
- TV remote
- Power supply
- Bread board
- Connecting wires

Software Requirements

- Arduino IDE 1.6.9

The Arduino Duemilanove is an 8 bit microcontroller board. It is the centre of the hardware set up. It is featured with 14 digital input/output pins, 6 analog inputs, a 16 MHz oscillator, 32 kb Flash memory, a USB connection, a power jack, an ICSP header, and a reset button. It is powered by 12V AC-to-DC adapter or battery [14]. Out of 14 I/O pins, 0 and 1 are used for USB programming, debugging, and communication. Pin 13 connected to a resistor and LED is used for testing, diagnostics, and other forms of blinking. When Hall effect sensor detects a signal, LED lights, otherwise it lights out. Six of the digital pins 3, 5, 6, 9, 10, and 11 can output PWM signal. Six additional Analog pins A0 to A5 are connected to the microcontroller's analog to digital converter (ADC). Each I/O pin works on a range of 0 to +5 V DC with 0 to +2V is off and above +3V is on.

B. Implementation Methodology

a. Motor Driver Circuit Connection to BLDC fan and Arduino

Here L298N H-bridge Dual Motor Controller is used. It has 14 pins as shown in fig.4(a). The L298 can drive inductive loads such as relays, solenoids, DC motors [9]. The BLDC motor is connected to pin 1 and 2. The positive power supply is given to pin 4 and GND to pin 5. Pin 3 is open as 5V is output from pin 6 on the module. This can feed power to Arduino's 5V pin and Arduino GND is connected to pin 5 on this module.

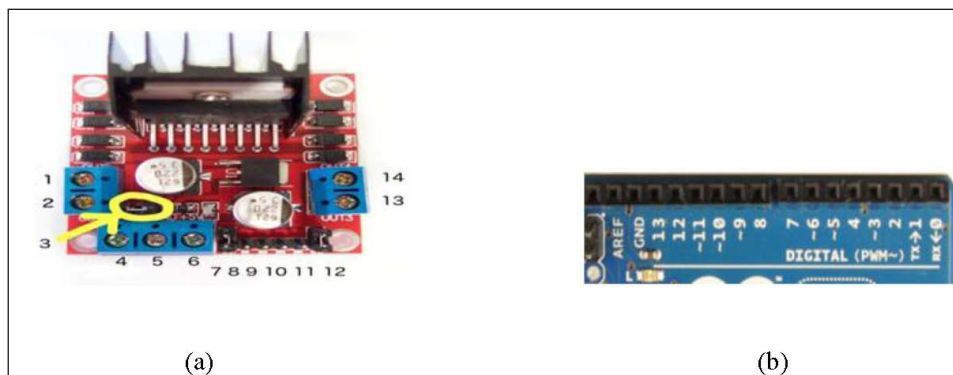


Fig. 4: (a) Motor Driver (L298N H-bridge) (b) Arduino PWM Pins

Out of six digital output pins on Arduino Dumilanove board (fig.4(b)), two will be used for PWM purpose. PWM pins are denoted by the tilde (“~”) next to the pin number. The Arduino

digital output pins 3 and 5 are connected to the driver module at IN1 and IN2 which are the pin no 8 and 9 respectively of the driver.

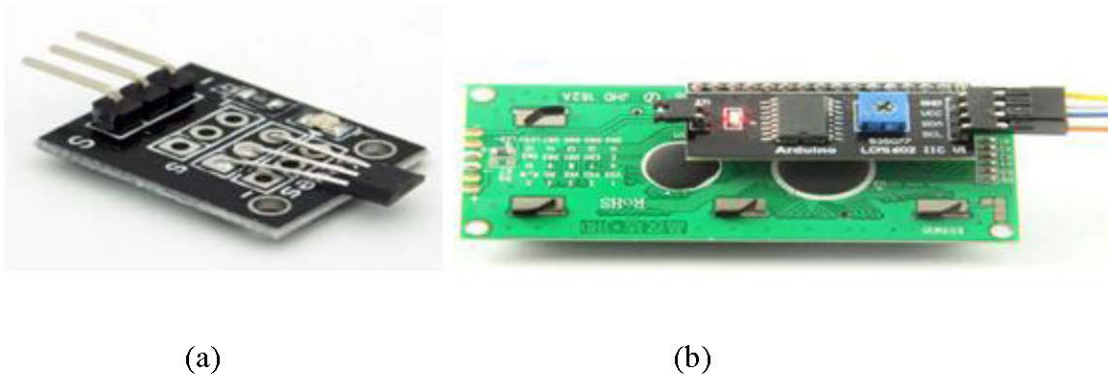


Fig. 5: (a) Hall Effect Sensor (b) Serial LCD Display Unit (Back side)

b. Magnetic Hall sensor connection and working

Pin S seen from fig.5(a) of magnetic hall sensor is connected to arduino analog pin A0. Pin GND is connected to Arduino GND pin and then middle pin +5V connected to the arduino +5V. When the rotor crosses the magnetic hall sensor it detects the magnet and when input to the programmed Arduino ATmega 328 microcontroller, the interfaced LCD finally shows the computed speed.

c. Serial LCD display unit

Serial LCD connects to the Arduino by one pair of wires. There are four pins on the UART labeled GND, Vcc, SDA and SCL as in fig.5(b). The GND pin is connected to the Arduino GND pin and the Vcc pin to arduino 5V or VCC pin then SDA and SCL pin to Arduino analog pin A4 and A5 pin respectively.

d. IR Receiver and Remote

In IR receiver there are 3 pin named Vout, GND, V_{CC} which connect to Arduino board as :Vout - pin 11, GND-GND, V_{CC} -V_{CC}. Remote is used for transmitting the required signal and the IR receiver receives the signal according to that speed is controlled.

Arduino IDE written sketch is uploaded to the ATMEGA328 microcontroller from computer by USB cable connection on the

Arduino duemilanove board. By one part of coding the serial LCD displays to show the result 'VSSUT_BURLA', 'FAN SPEED'. By another part of code by using PWM techniques the speed of the BLDC motor is controlled.

e. PWM Technique

PWM signal is a constant frequency square wave, where the time the signal is on (the duty cycle) can be varied between 0 and 100%. In PWM [4], the voltage output fed to the motor is controlled by adjusting the width of the gating pulse of the electronic switch at a high frequency as per duty cycle. Duty cycle is the fraction of on time to the period. If the duty cycle is more, the output is more. Duty cycle of 100% is on for whole period as depicted from fig.6. When a switch is off there is no conduction, and when it is on, there is nearly zero voltage drop. Power loss is negligible in both states.

Thus the motor is run at required speed by varying the duty cycle. PWM program in the microcontroller is run to adjust the duty cycle.

By Arduino's program PWM can be achieved by inputting in analog write (pin, duty Cycle), where duty cycle is a value from 0 to 255. Here the pin is one of the PWM pins (3, 5, 6, 9, 10, or 11). The analog write function provides a simple interface to the hardware. Here two PWM pins 3 and 5 are used. So, any speed can be adjusted by only changing the duty cycle which is the ratio of pulse width to time period.

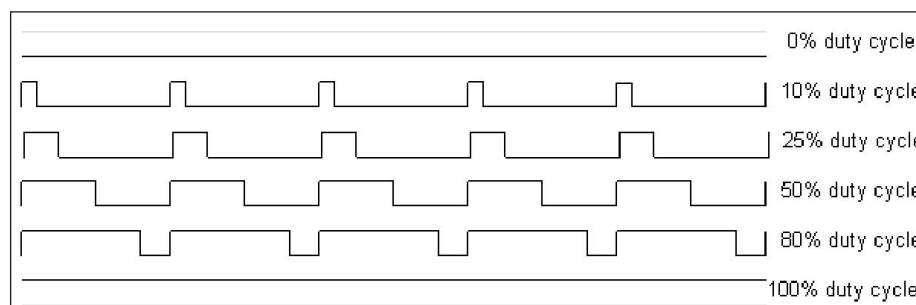


Fig. 6: PWM Pulse Representing Duty Cycle

f. Arduino firmware (Arduino IDE 1.6.9)

The sketch was compiled on Arduino IDE to control and display the measured speed of BLDC motor for different values of PWM duty cycle. A delay of 1000 ms was given between successive displays of parameter on LCD display. The baud rate was initialized to 9600. The inputs to the sketch were from the magnetic hall sensor, IR receiver, and motor driver circuit and after control and processing the output was displayed on the serial LCD.

The project is written in the form of a sketch in Arduino integrated development environment (IDE) [14] with the file extension.ino. After compiling the *avrdude* program converts the executable code into a hexadecimal coding that is loaded into the Arduino board by a loader program in the board's firmware.

C. Results

The wiring diagram and the final operational model is shown in fig.7 (a) and (b) respectively. Here in Table 1 different speed obtained by varying the PWM duty cycle is presented. Instead

of expressing the duty cycle in % it is expressed in terms of 8 bits which is coded in the microcontroller. Six speeds are shown for different pressing of digits from remote. Input 1 gives off state and input 6 gives maximum speed of 2100 RPM. From the above tabulation, it is clear that by varying the duty cycle different speed can be obtained for example at 50 duty cycle the speed was 412 RPM which is actually 20% and for 100 duty cycle speed was 826 RPM and for 150 duty cycle speed is 1238 RPM and so on. First, speed control was achieved and the same was displayed on the LCD screen.

Table 1. Different Speed According to Duty Cycle

Input from Remote	Duty Cycle	Speed (in RPM)
1	0	0
2	50	412
3	100	826
4	150	1238
5	200	1650
6	255	2100

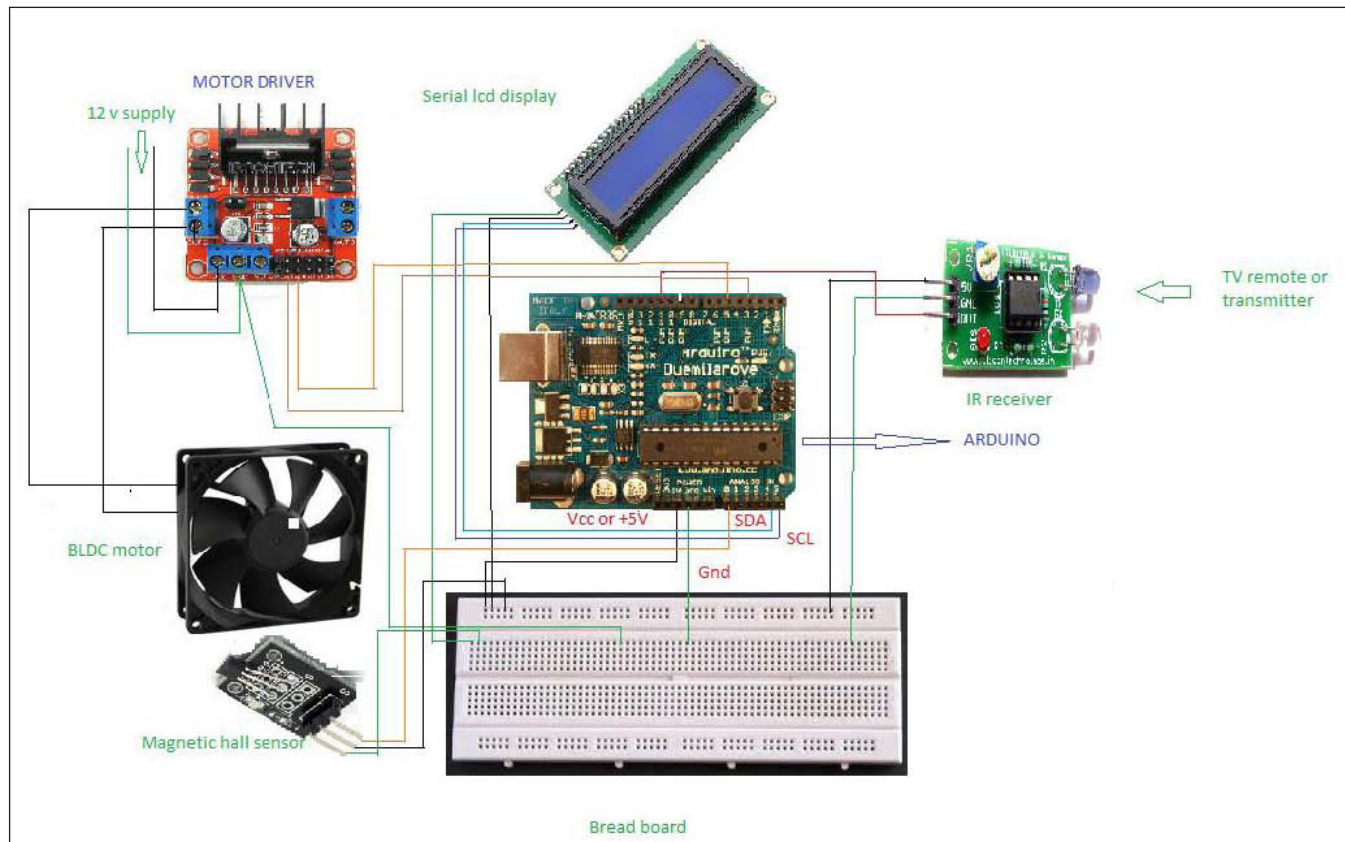


Fig 7(a): Connection Diagram

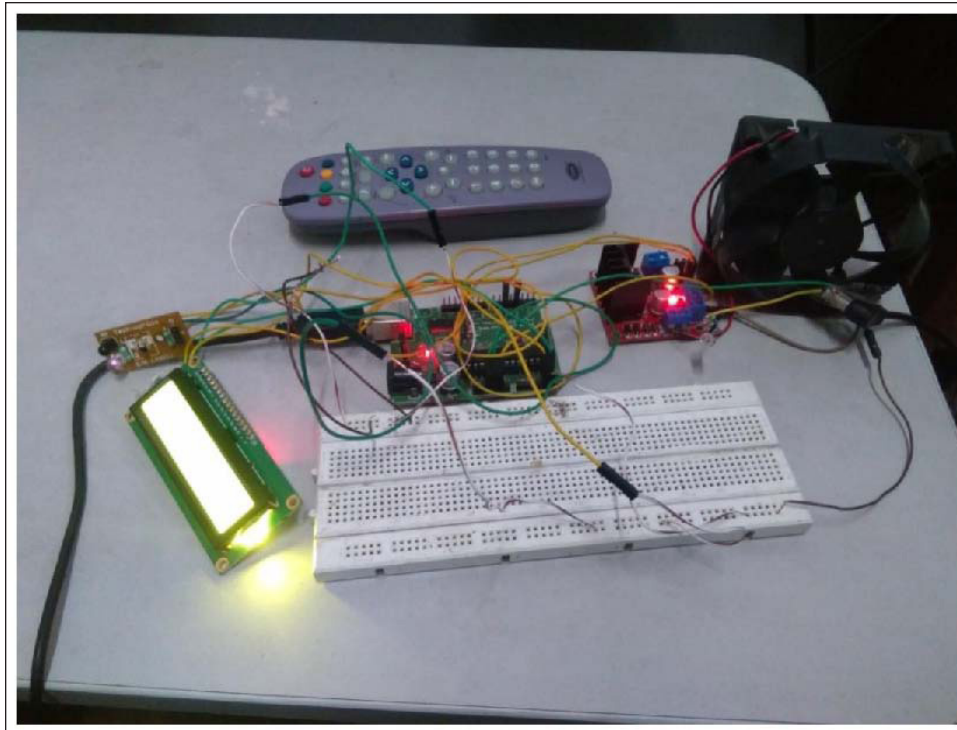


Fig. 7(b): Picture of the Operational Hardware Model

IV. CONCLUSION

The speed of BLDC motor was controlled successfully by the use of IR remote control method which was driven by motor driver circuit having a supply voltage of 12V supply through AC/DC adapter. The speed data was shown through serial LCD which is interfaced with the Arduino Duemilanove by programming and uploading certain code written on Arduino IDE. The Hall effect sensor best fits the BLDC to improve its reliability in speed sensing further. The whole system proved to be an automation system, reliable, accurate and also cost effective. Here in this system the motor speed can be varied for many intermediate values by varying PWM duty cycle in between 0-255 and the same can be measured and displayed. It means in small scale machines speed variation could be done instantly. This system can be successfully used in medical, industries and automotive appliances etc.

The existing system can be used in small scale application. But further in large scale industrial application BLDC speed control can be done by increasing remote control distance. Instead of remote control the speed of BLDC motor can be controlled by GSM module, ANDROID mobile etc. which could be more efficient, more accurate and also make control feasible from more distance.

REFERENCES

- [1] R. Gambhir, and A. K. Jha, "Brushless DC Motor: Construction and Applications," *International Journal of Engineering and Science*, vol. 2, no. 5, pp. 72-77, 2013.
- [2] D. C. Hanselman, "Brushless permanent magnet motor design," *The Writers' Collective*, University of Maine, Orno, USA, (2nded.), 2003.
- [3] Y. Liu, J. Zhao, M. Xia, and H. Luo, "Model reference adaptive control-based speed control of brushless DC motors with low-resolution Hall-effect sensors," *IEEE Transactions on Power Electronics*, vol. 29, no.3, pp. 1514-1522, 2014.
- [4] Y. Y. Lee, R. H. Wu, and S. T. Xu, "Applications of linear Hall-effect sensors on angular measurement," *In Proceedings of IEEE International Conference on Control Applications (CCA)*, pp. 479-482, September, 2011.
- [5] J. S. Rao, G. R. Kumar, and O. C. Sekhar, "Sensorless speed control of Brushless DC Motor using fuzzy controller," *In Proceedings of IEEE International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*, pp. 4082-4085, March, 2016.
- [6] W. Huazhang, "Design and implementation of brushless DC motor drive and control system," *Procedia Engineering*, vol. 29, pp. 2219-2224, 2012.
- [7] M. M. Kamal, L. Mathew, and S. Chatterji, "Speed control of brushless DC motor using intelligent controllers," *In Proceedings of IEEE Students Conference on Engineering and Systems (SCES)*, pp. 1-5, May, 2014.
- [8] G. Prasad, M. V. Reddy, P. V. N. Prasad, and G. Tulasi Ram Das, "Speed control of Brushless DC motor with DSP controller using MATLAB," *International Journal*

- of Engineering Research and Applications (IJERA)*, vol. 2, no. 3, pp. 2120-2125, 2012.
- [9] Q. Wu, and W. Tian, "Design of permanent magnet brushless DC motor control system based on dsPIC30F4012", *Procedia Engineering*, vol. 29, pp. 4223-4227, 2012.
- [10] H. C. Wu, M. Y. Wen, and C. C. Wong, "Speed control of BLDC motors using hall effect sensors based on DSP," *In Proceedings of IEEE International Conference on System Science and Engineering (ICSSE)*, pp. 1-4, July, 2016.
- [11] I. R. Agung, S. Huda, and I. A. Wijaya, "Speed control for DC motor with pulse width modulation (PWM) method using infrared remote control based on ATmega16 microcontroller," *In Proceedings of IEEE International Conference on Smart Green Technology in Electrical and Information Systems (ICSGTEIS)*, pp. 108-112, November 2014.
- [12] A. Tyagi, A. K. Maurya, S. S. Singh, Gaurav, P. Verma, and S. Bhambri, "Brushless DC motor speed control with rpm display," *International Journal of Engineering Science and Computing*, vol. 7, no. 3, pp. 6045-6047, March, 2017.
- [13] A. N. Nichat, S. K. Ali, Y. D. Solanke, and A. M. Dodke, "Wireless Speed and Direction Control of DC Motor by using Radio Frequency Technology," *International Journal of Engineering Trends and Technology (IJETT)*, vol. 20, no. 2, pp. 48-51, February, 2015.
- [14] ATMEL.AT mega 328, AT mega 238P, 2010. Available: <http://www.atmel.com/Images/doc2466.pdf>.
- [15] Texas Instruments L293, L293D Quadupler Half- H Drivers, 2017. Available: <http://www.datasheetcatalog.org/datasheet/texasinstruments/l293d.pdf2002..>