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Energy Efficient Ceiling Fan using BLDC Motor

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***Abstract* - A brushless DC (BLDC) motor is a synchronous electric Motor powered by direct current (DC) electricity having an electronics commutation system, rather than a mechanical commutator and brushes. In BLDC motors, current to torque and voltage to rpm have linear relationship. This linearity provides an excellent opportunity to use the BLDC motor in conventional ceiling fans. This project is aims at the practical implementation of BLDC motor as a ceiling fan and also introduced different types of speed control method for BLDC fan. This fan is implemented with three different modes of operations-manual mode, auto mode, remote control mode. We can select the mode by using a mode selector switch. In each mode speed is controlled by different methods. When it is manual mode speed can be controlled by a potentiometer. If it is auto mode the speed is automatically changed depending on the room temperature, LM35 temperature sensor is used to sense the room temperature in auto mode. If remote control mode is selected the speed can be adjusted by using a remote controller. RF module-transmitter and receiver are used for remote control operation.**

I. INTRODUCTION

Electric power generation is limited in India due to various factors such as the environment and availability of raw materials (fossil fuels etc.).It is clear that residential sector is the one where maximum energy conservation is possible while the other sectors are so commercialized that there is no incentive to propose and sustain any major conservation of energy through other alternate energy efficient appliances in these sectors. So the focus of the project is on the residential sector and more specially on ceiling fans which sells more than 30 million units per year with an installed base of more than 250 million units in India. Further when the residential consumption was analyzed, it was found that the total consumption of power by ceiling fans amount to 6% which is more than that of the TV + Fridge combined. This project describes a method of using Brushless DC Motor to reduce the power consumption of the ceiling fans by more than 50% without sacrificing on the performance or any other features.

A brushless DC (BLDC) motor is a synchronous electric Motor powered by direct-current (DC) electricity and having an electronic commutation system, rather than a mechanical commutator and brushes. In BLDC motors, current to torque and voltage to rpm have linear relationships. This linearity provides an excellent opportunity to use the BLDC motor in the conventional ceiling fans. This paper presents practical implementation of such BLDC motor for ceiling fan application along with the actual power measurements in comparison with conventional ceiling fans. Complete electronics and the associated advantages and disadvantages of this BLDC ceiling fans are also presented.

II. WORKING AND SIMULATION

The most prominent characteristic feature of a BLDC motor is its speed controllability through various ranges. The speed control is possible through different methods. The implemented working model has two sections - Mode selection and working of motor.

A. Mode Selection

Three different modes of control are possible to control the speed of the fan, they are-manual mode, auto mode and remote control mode, which is controlled by a switch. The operator has a good choice of selection accordingly. Each mode has its own advantages. Regardless of the mode of operation, speed is controlled by adjusting the pulse width from micro controller (ATmega16) to ESC (Electronic Speed Controller). ESC controls the speed of BLDC motor which in turn depends on the output from micro controller. In each mode of operation, pulse width is controlled by micro controller.

1)Manual Mode

In manual mode of operation, the speed is controlled by adjusting the potentiometer where it adjusts the pulse width from the micro controller. The pulse width is controlled by controlling the reference voltage through the potentiometer. By controlling the pulse width the speed of motor can be controlled.

2) Auto Mode

In auto mode, temperature sensor LM35 is used. It senses the room temperature and accordingly the output voltage from LM35 is changed which in turn changes the input to the micro controller. We already discussed that the speed is controlled by adjusting the pulse from micro controller so

here change in room temperature change the output voltage of LM35 which will change the pulse width from microcontroller. The microcontroller is programmed in such a manner to sense these changes and vary the speed accordingly.

3) Remote control Mode

In remote control mode, working speed is controlled by a remote controller where a RF module is used for wireless control. The remote controller has two switches for speed control- up and down switches. If up switch is pressed the RF module transmitter send a data serially to microcontroller through RF receiver. Microcontroller is programmed in such a way that if a high value comes continuously the width of wave will increase and the width of wave will be decreased when low value comes.

B. Working of BLDC motor

A BLDC motor, with sensor less control is implemented here. The typical trapezoidal back-EMF waveforms and corresponding driving voltages of a 3-phase BLDC motor is shown in Figure 1. In every commutation step, one phase winding is connected to positive supply voltage, other is connected to negative supply voltage and one kept floating. The back-EMF in the floating phase will result in zero crossing whenever it crosses the average of the other two phase voltages. The zero crossings are marked as ZC in Figure 1.

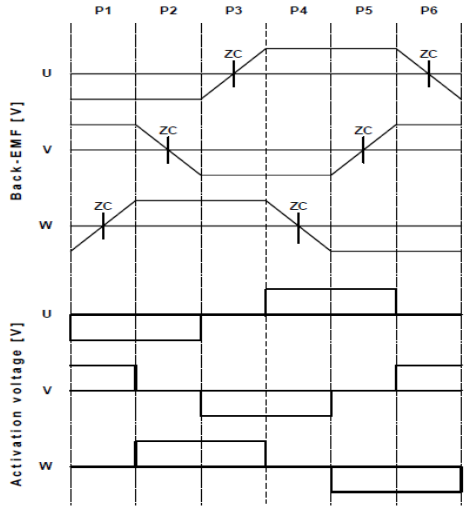

Figure 1: Waveform

The zero crossing occurs right in the middle of two consecutive commutations. At constant speed or at low variations of speed, the time period from one commutation to zero-crossing and the time period from zero-crossing to the next commutation are equal. This is the basic idea used in this implementation of sensor less commutation control. The floating phase, where the zero crossing must be detected, changes for every commutation step. There requires an ADC channel for each phase winding to detect the zero crossings.
ESC is a power-controller device which switches the supply to the windings of BLDC motor according to the back EMF produced.

III. BLOCK DIAGRAM

The aim of this project is to develop an energy-efficient fan using BLDC motor, with different modes of speed control. This model comprises of motoring part, micro controller part and controlling part. Figure 2 shows the block diagram of the implemented system.

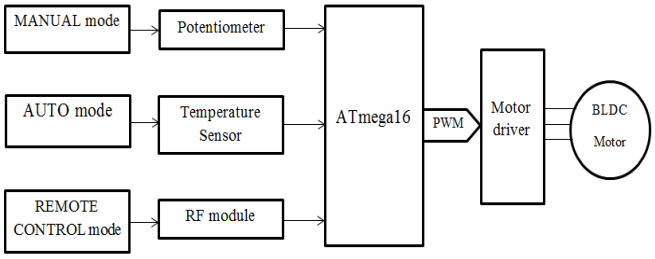

Figure 2: Functional block diagram

Motoring part includes a motor driver and a BLDC motor (12V,12 pole,35000rpm).The speed of the motor is controlled by an ESC(Electronic Speed Controller) .The speed of the motor varies according to the variation in the pulse width of the microcontroller.Atmega16 micro controller is programmed for generating pulses which is further varied with the input control signal.

The controlling part has three sections vis-a-vis potentiometer, an LM35 temperature control and a RF module, among which any of the modes can be selected according to the requirement of user.

The model is implemented with three modes of working-manual mode, automatic mode and remote control mode. In manual mode, speed can be controlled by adjusting a potentiometer. In auto mode, speed is automatically controlled according to the room temperature with the help of a temperature sensor where the sensor senses the room temperature and compares it with the reference temperature. Speed is varied according to the difference between the two temperatures-reference and room temperatures. In remote control mode operation, speed can be adjusted by using a remote controller control with RF control.

IV. CIRCUIT DIAGRAM

The circuit of this model mainly comprises of two sections - a transmitter part and a receiver part.

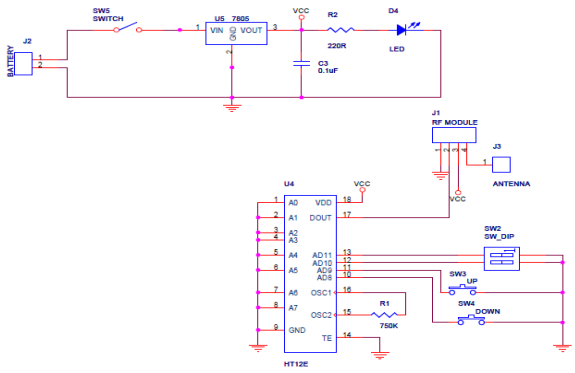

Figure 3: Transmitter part of RF module

The transmitter part has a RF module to transmit data serially to receiver, HT12E encoder and a mode selection switch to select different modes, up-down control switch for

remote control mode and a regulator IC for supplying 5 volt from a 9-volt battery.5V supply is required for the RF transmitter and corresponding antenna. Figure 3 shows the transmitter part circuit.

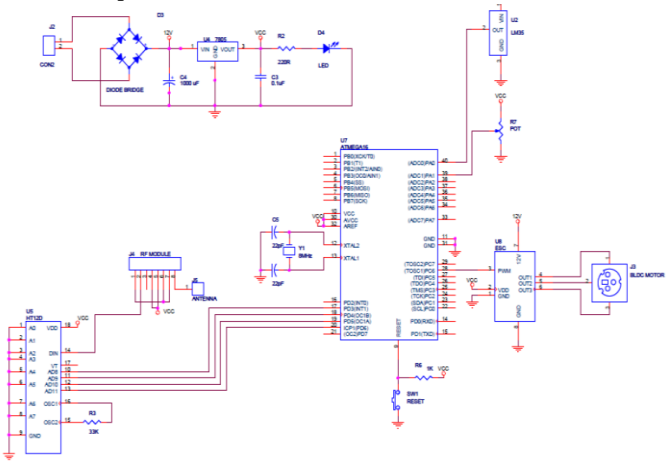

Figure 4: Receiver part of RF module

The receiver part has a RF module receiver, a HT12D decoder and ATMEGA-16 micro controller, a temperature sensor (LM35), a potentiometer, an ESC switch, a BLDC motor, a 5V regulator IC and a reset switch.

The corresponding data lines from RF receiver are connected to the decoder where decoder decodes the serial data received. The decoded data is connected to port D of the micro controller and output pins of temperature sensor as well as the potentiometer are connected to the first two pins of port A. The input to ESC driver is taken from pin-7 of port C.BLDC motor is connected to the output of ESC.A 5V regulator IC is connected to the decoder, RF receiver, micro controller, potentiometer and LM-35 sensor. Also, the ESC Driver is connected with a 12V supply. Figure 4 shows the receiver part circuit.

V. HARDWARE

A. *BLDC motor*

Brushless DC electric motors (BLDC motors/BL motors) also known as, electronically-commutated motors (ECMs/ EC motors) are synchronous motors which are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor (AC/alternating current, does not imply a sinusoidal waveform but rather a bi-directional current with no restriction on waveform); additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed).

A typical brushless motor has a stationary armature and rotating permanent magnet which eliminates the problems associated with connecting current to the moving armature. An electronic controller replaces the brush/commutator assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solid state circuit rather than the brush commutator system.

Compared with induction motor, BLDC motor is efficient, compact and easy to control. BLDC motor has at torque to speed characteristics whereas it is non-linear for induction motor. BLDC motor has high out power per frame size so smaller size can be achieved for a given output power. But for induction motor it is moderate. BLDC motor has low rotor inertia so it has better dynamic characteristics compared to induction motor. BLDC motor has rated starting current so no special starter circuit is required. For BLDC motor, a controller is always required. But for induction motor it is required only for variable speed requirements. In induction motor, the rotor runs at a lower frequency than stator by slip frequency and slip increases with load on the motor whereas no slip is experienced between stator and rotor frequencies in BLDC motors.

It is crucial to know how much torque a BLDC motor can output at different speeds. Typically, a user has selected a certain speed range and can then understand the torque capabilities of a motor. This speed and torque relationship is linear.

It is important to understand the relationship between how much torque the motor provides and how much current is required by the motor. More torque naturally requires more current. It is also a linear relationship.

1) *Propellers*

The enhanced efficiency is greatest in the no-load and low-load region of the motor's performance curve. Under high mechanical loads, brushless motors and high- quality brushed motors are comparable in efficiency. Brushless type DC motors are preferred in a rear of maintenance-free operation, high speeds, and operation where sparking is hazardous (i.e. explosive environments), or could affect electronically sensitive equipment.

B. *Electronic Speed Controller for BLDC*

ESC is a device for controlling speed of BLDC motor. It has mainly six leads-three leads connected to BLDC motor, two for 12V supply for ESC and one for input pulse to ESC from microcontroller. Instead of single MOSFET, pair of MOSFETs are connected in parallel, six such pairs are provided to carry more current and along with a microcontroller. Microcontroller is programmed for speed control of BLDC which in turn depends on the input to the ESC driver.

C. *Temperature sensor LM35*

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of 14C at room temperature and 34C over a full 55 to +150C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35s low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially

easy. It can be used with single power supplies, or with plus and minus supplies.

D. ATmega16 microcontroller

The ATmega16 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATMEGA32 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

ATmega16 has a high performance characteristic with low-power consumption. AVR 8-bit Microcontroller has a advanced RISC Architecture with 131 Powerful Instructions of which mostly have Single-clock Cycle Executions. There are about 32 x 8 General Purpose Working Registers with fully Static Operation. It is embedded with non-volatile programs and data memories. It has a 32K Bytes of In System Self Programmable Flash Endurance with 10,000 Write/Erase Cycles. It also has special feature like Optional Boot Code Section with Independent Lock Bits.

Atmega16 has also have the property of In-System Programming by On-chip Boot Program with true Read-While-Write Operation. It has 1024 Bytes of EEPROM Endurance with 100,000 Write/Erase Cycles. It is more attractive with its 2K Byte Internal SRAM and Programming Lock for Software Security.

E. RF module

The RF module comprises of a receiver, a transmitter, an encoder and a decoder.

1) RF Transmitter

The RF Transmitter is ideal for remote control applications where low cost and longer range is required. The transmitter operates from a 1.5V to 12V supply, making it ideal for battery-powered applications. The transmitter employs a SAW stabilized oscillator, ensuring accurate frequency control for best range performance. Output power and harmonic emissions are easy to control. The manufacturing friendly SMT style package and low cost make the RF module make it suitable for high volume applications. The transmitter used is of low cost and of smaller size. It has a frequency range around 433.92 MHz. It is designed with ASK modulation and is able to transmit up to 100 meters around.

2) RF receiver

The RF Receiver used is ideal for short-range remote control applications where cost is a primary concern. The receiver module requires no external RF components except for the antenna. It generates virtually no emissions. The super regenerative design exhibits exceptional sensitivity at a very low cost. A SAW filter can be added to the antenna input to improve selectivity for applications that require robust performance. The friendly SIP style package and low-cost make it suitable for high volume applications. The receiver used is of low cost since as no external parts are required. The receiver frequency is around 433 MHz with a typical sensitivity at 105 Dbm. The supply current is 2.3 mA with an operating voltage of 5V.

3) RF Decoder HT12D

The 212 decoders are a series of CMOS LSIs for remote control system applications. They are paired with Holteks 212 series of encoders (refer to the encoder/decoder cross reference table). For proper operation, a pair of encoder/decoder with the same number of addresses and data format should be chosen. The decoders receive serial addresses and data from a programmed 212 series of encoders that are transmitted by a carrier using an RF or an IR transmission medium. They compare the serial input data three times continuously with their local addresses. If no error or unmatched codes are found, the input data codes are decoded and then transferred to the output pins. The VT pin also goes high to indicate a valid transmission. The 212 series of decoders are capable of decoding information's that consist of N bits of address and 12 N bits of data. Of this series, the HT12D is arranged to provide 8 address bits and 4 data bits, and HT12F is used to decode 12 bits of address information.

It has an operating voltage of 2.4V-12V with a low standby current. It is capable of decoding 12 bits of information with binary address setting. Received codes are always checked 3 times together with the Address/Data number combination. It has a valid transmission indicator and an easy interface with an RF or an infrared transmission medium with minimal external components.

4) RF Encoder HT12E

The 212 encoders are a series of CMOS LSIs for remote control system applications. They are capable of encoding information which consists of N address bits and 12N data bits. Each address/ data input can be set to one of the two logic states. The programmed addresses/data are transmitted together with the header bits via an RF or an infrared transmission medium upon receipt of a trigger signal. The capability to select a TE trigger on the HT12E or a DATA trigger on the HT12A further enhances the application flexibility of the 2^12 series of encoders. The HT12A additionally provides a 38 kHz carrier for infra-red systems.

The operating voltage is about 2.4V-12V with low power demand and has high noise immunity. It is designed with CMOS technology.HT12A has a 38 kHz carrier for infrared transmission medium with a minimum transmission word.

VI. SOFTWARE

A. OrCAD

With the advent of powerful computing system and interactive software, several stages in the design and development of an electronic circuit has undergone automation .The software and this hardware tool, which enables this automation, is called EDA tools. This tool helps us in such a way that we can draw that circuit ; list the functioning of the circuit in response to the best input in assimilation software after successful simulating the circuit.

Industry-proven OrCAD solutions are available as standalone products or in comprehensive suites. Unlike other PCB design tools, OrCAD PCB design suites provide a feature-rich, fully scalable solution that can be expanded and

upgraded as PCB challenges and the level of design sophistication grows.The placing and routing software does the PCB artwork in the project the design automation tool used in OrCAD, which includes.

B. MikroC

MikroC is a powerful, feature rich development tool for PIC microcontrollers. It is designed to provide the programmer with the easiest possible solution for developing applications for embedded systems, without compromising performance or control.

PIC and C fit together well: PIC is the most popular 8-bit chip in the world, used in a wide variety of applications, and C, prized for its efficiency, is the natural choice for developing embedded systems. MikroC provides a successful match featuring highly advanced IDE, ANSI compliant compiler, broad set of hardware libraries, comprehensive documentation, and plenty of ready-to-run examples.

C. *Proteus*

The Proteus Design Suite is wholly unique in offering the ability to co-simulate both high and low-level microcontroller code in the context of a mixed-mode SPICE circuit simulation. With this Virtual System Modeling facility, you can transform your product design cycle, reaping huge rewards in terms of reduced time to market and lower costs of development. Proteus Virtual System Modeling (VSM) combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co-simulation of complete micro-controller based designs. For the first time ever, it is possible to develop and test such designs before a physical prototype is constructed. This is possible because you can interact with the design using on screen indicators such as LED and LCD displays and actuators such as switches and buttons. Here instead of HT12E transmitter we were connected a LED to the corresponding pin. If the LED is ON, it indicates that the micro-controller is transmitting a signal.

VII. CONCLUSIONS

BLDC motor based ceiling fan solution will provide an insight into the present status as well as into various challenges faced in deriving the solution along with some of the basic fundamentals of the DC, BLDC and AC motors in general. This project provides an overview of the various building blocks of the solution and identifies the right technology-approach to be adopted for energy utilization. Energy crisis is one of the major problems that we are facing today. We can save energy by using energy efficient appliances. Energy efficient fan is such a measure which has greater role in reducing the power consumption and hence we have a BLDC fan. It is highly compatible, highly efficient, less noisy, reliable, longer life-time and have a linear torque – speed characteristics. All these features together contribute to energy saving up to 40-50 %.

The fan designed in this project has three modes of operations-manual mode, automatic mode and remote control mode through which speed of the BLDC motor can be varied. This fan is energy efficient because speed can be varied according to user's convenience in different methods. The speed can be varied by varying the duty cycle of waveform and duty cycle can be varied in three different methods-manual control, automatic control, remote control.

BLDC motors are often more efficient in converting electrical energy into mechanical energy than brushed DC or AC motors, which have high electrical and frictional losses.

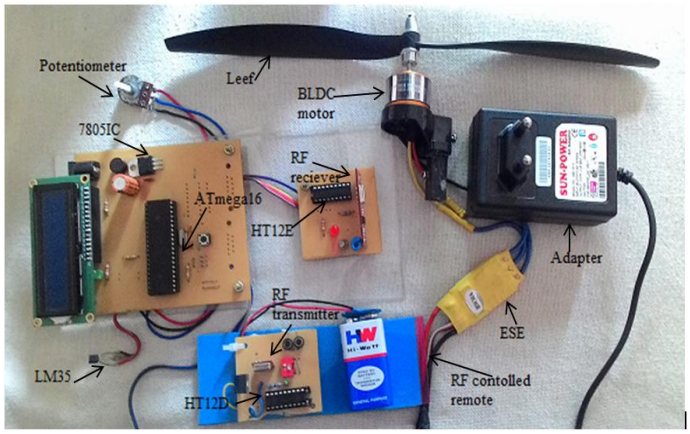

Figure 4: Hardware Implementation

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