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Design of Energy Efficient Embedded Ceiling Fan

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ABSTRACT

Ceiling fans are commonly used in our home, office, schools and almost everywhere. It is the simplest and most inexpensive means to keep our self cool in hot and humid weather. Most commonly single phase induction motors are used for making ceiling which consumes 70W to 100W. As the energy crisis is knocking the doors, soon or the other we need to save all possible power combination of harvesting and saving can only meet highly growing energy demand. This Paper proposes a BLDC ceiling fan in place of induction based which consumes less than 30W of power and gives the similar airspeed. A Smartphone application is developed and can be used to control fan speed. This fan is implemented using permanent magnet, brushless dc motor, ARM based STM32 ARM Cortex Microcontroller, H bridge driver and Bluetooth module.

Keywords

Energy Efficient, BLDC, H-Bridge, PWM, ARM Cortex Microcontroller, Hall Sensor, Bluetooth.

1. INTRODUCTION

A ceiling fan is a mechanical fan mounted on the ceiling of a room or space, usually electrically powered, suspended from the ceiling of a room, which uses hub-mounted rotating blades to circulate air. Ceiling fans typically rotate more slowly than other types of circulating fans, such as electric desk fans. They cool people effectively by introducing slow movement into the otherwise still, hot air of a room. Fans never actually cool air, unlike air-conditioning equipment, In fact, heat the air due to the waste heat from the motor and friction, but use significantly less power (cooling air is thermodynamically expensive). Conversely, a ceiling fan can also be used to reduce the stratification of warm air in a room by forcing it down to affect both occupants' sensations and thermostat readings, thereby improving climate control energy efficiency.

A look back to history Punkah-type ceiling fans date back to 500 BC and are native to India. Unlike modern rotary fans, these punkah fans move air by moving to and from and were operated manually by a cord. The first rotary ceiling fans appeared in the early 1860s and 1870s in the United States. At that time, they were not powered by any form of electric motor. Instead, a stream of running water was used, in conjunction with a turbine, to drive a system of belts which would turn the blades of two-blade fan units. The electrically powered ceiling fan was invented in 1882 by Philip Diehl. He had engineered the electric motor used in the first electrically powered Singer sewing machines, and in 1882 he adapted that motor for use in a ceiling-mounted fan. Each fan had its own self-contained motor unit, with no need for belt drive.

Electric ceiling fans became very popular in other countries, particularly those with hot climates, such as India and the Middle East, where a lack of infrastructure and/or financial resources made energy-hungry and complex Freon-based air conditioning equipment impractical. In 1973, Texas entrepreneur H. W. (Hub) Markwardt began importing highly efficient ceiling fans to the United States that were manufactured in India by Crompton Greaves, Ltd. Crompton Greaves had been manufacturing ceiling fans since 1937 through a joint venture formed by Greaves Cotton of India and Crompton Parkinson of England and had perfected the world's most energy efficient ceiling fans thanks to its patented 20 pole induction motor with a highly efficient heat-dissipating cast aluminum rotor. These Indian manufactured ceiling fans caught on slowly at first, but Markwardt's Encon Industries branded ceiling fans (which stood for Energy Conservation) eventually found great success during the energy crisis of the late 1970s and early 1980s, since they consumed far less energy (under 70 watts of electricity) than the antiquated shaded pole motors used in most other American made fans. The fans became very effective energy-saving appliances for residential and commercial use by supplementing expensive air conditioning with a cooling wind-chill effect.

Fans used for comfort create a wind chill by increasing the heat transfer coefficient but do not lower temperatures directly. Currently ceiling fans are available in different designs and sizes with induction motors or fraction kilowatt motor.

2. SYSTEM DESIGN

The System consists of a stator and rotor mechanism, controller, wireless connectivity module, H Bridge Driver, position and speed sensors as given in Figure1.

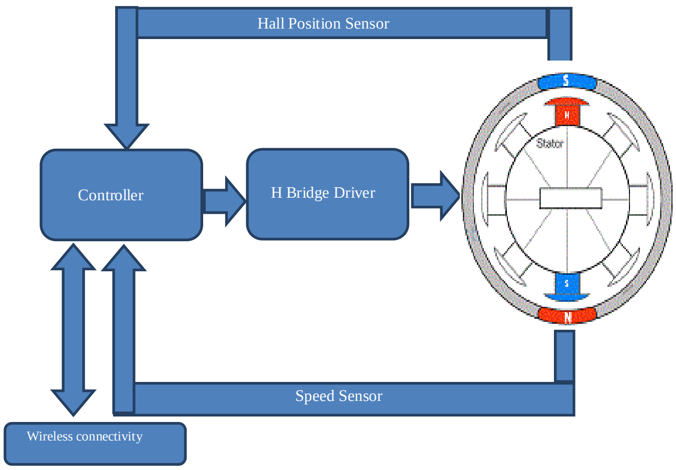

Figure 1: Block diagram for Embedded Ceiling Fan

2.1 Motor basics

The rotor is a permanent magnet. When stator induces a magnetic pole repulsion or attraction happen, this depends on pole induced and thereby making a tangential movement. When this happens with all available poles, the rotator forces builds up and triggers its rotation. This permanent magnet rotor is attached to the fans casing, to which wings are attached providing the required air delivery. Coils wound on a core head makes up the stator. The number of windings and number of poles are depended on the required rpm and applied max voltage. By this, basic laws of magnetic poles are induced in the coil and when the direction of current changes, opposite pole will be induced.

2.2 Working Principle

The Rotor is a moving component of an electromagnetic system, with circular shaped permanent magnet. The magnetic rings are reinforced by steel plate to strength it to carry the load. This steel case is molded to fans outer body whose leaves are attached to give airflow.

The stator is the stationary part of a rotary system with an electromagnet made from a coil of wire that acts as a magnet when an electric current passes through it but stops being a magnet when the current stops. The pole induced can also be controlled by controlling the direction of current flow. The current entering point is induced as the South Pole and leaving as North Pole. However, unlike a permanent magnet that needs no power, an electromagnet requires a continuous supply of current to maintain the magnetic field.

Poles winding are made such that they form a series of 3-1-1-1-3-1-1-1. First three winding in done serially and then the next three are done parallel and this series is repeated again. So a total of twelve poles are there. This is done like this because 10 magnetic rotor poles and 12 magnetic stator poles never lock on to each other. If the lock on happens fan will get a freeze in place of rotation. Figure 2 shows the formation of magnetic field with a coil of wire.

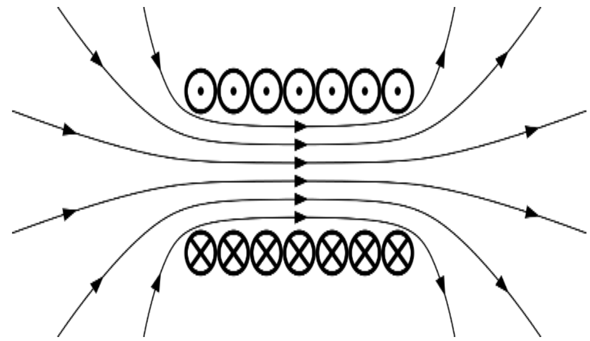

Figure 2: Magnetic field produced by a solenoid (coil of wire)

An H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards or backwards. Most DC-to-AC converters (power inverters), the DC-to-DC push–pull converter, most motor controllers, and many other kinds of power electronics use H bridges. In particular, a bipolar stepper motor is almost invariably driven by a motor controller containing two H bridges.

3. DESIGN AND IMPLEMENTATION

3.1 Hardware Implementation

To make the fans motor rotate we need to induce opposite poles in stator coil with respect to permanent magnet. For this we use a HALL Effect Sensor to sense the magnetic field. When the current enters conductor south poles is induced and when it leaves a north pole is induced. So by altering the direction of current flow we can create a repulsive force that rotates the fan. H-bridge was designed to alter the direction of current in accordance with given input from the ARM Cortex STM32F103C8T6 Microcontroller. Figure 3 shows the implementation of H bridge driver using power transistors.

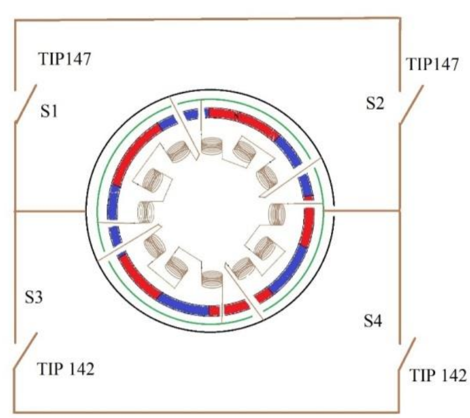

Figure 3: H bridge driver implementation

The switching of S1 and S2 were controlled using STM32F103C8T6 output with respect to feedback from hall sensor. Base drive with a simple BJT was deployed. S3's base drive was generated from S4's collector current and S4's base drive from S3's collector. This was to avoid shoot over even though dead time was created in controllers output. When S1 and S4 are turned on current flow happens in one direction and when S2 to S3 are turned on the current flows in opposite direction.

We have implemented fan speed control using PWM technique. As PWM width increases speed increases, so with respect to feed back from HALL EFFECT SENSOR we start and stop generation of PWM of which width is varied in accordance with our required speed. A remote based speed selection and feedback has been implemented using Bluetooth.

3.2 Software Implementation

We have used CUBEMX Tool for the Embedded Software development, along with KEIL MDK-5 CMSIS software package. Android Studio was used to develop the mobile application for fans speed control. CUBEMX Tool was used for basic configuration of RCC, SYS, Timer in PWM mode, UART, Interrupts of the ARM Cortex Microcontroller and the application code was developed using KEIL tool chain. CMSIS package empowered the code for PWM generation, PWM width control, UART communication and Interrupt service routine. ARMs ULINKpro-D was the debugger used to download/debug the compiled and build code to microcontroller. Figure 4 shows the test set-up of the system development.

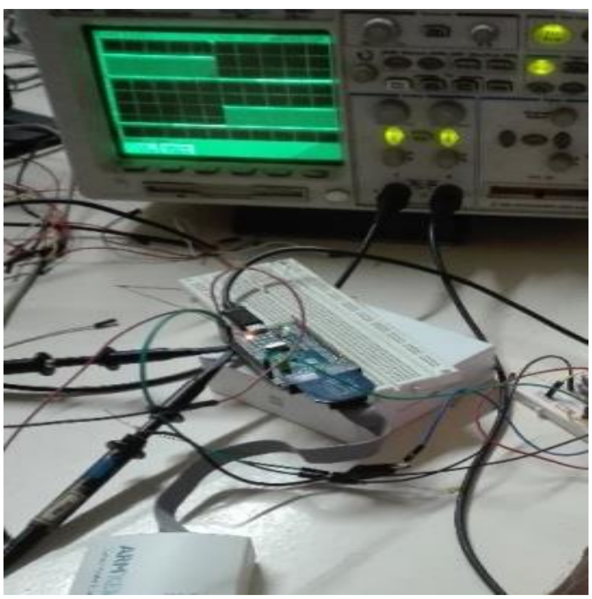

Figure 4: Test setup with ARM ULINKpro-D

The mobile application was developed using Andriod studio. The app is implemented with a rotary type switch which gives the current running speed and we can update the speed, of which data can be sent via phones inbuilt Bluetooth. Our Embedded Fan is integrated with Bluetooth connectivity module and is capable of handling instruction from the mobile application.

4. RESULTS

The prototype of a ceiling fan based on BLDC motor was successfully deployed with power consumption of 28 watts was observed. Speed control of the Fan can be done using a mobile app with 8 stages of speed. This prototype fan work in 28W when compared to the models with 70W. The snap shot of the final working model is shown in Figure 5.

Figure 5: Working model of Embedded Ceiling fan

5. CONCLUSION

We have successfully implemented the prototype of the Embedded Ceiling Fan. It has been tested for the various functionalities as required. More features can be added to the system to improve its capabilities like auto decrease of speed with respect to room temperature, auto-sleep after fixed time interval etc. As Bluetooth module is already integrated with the fan, it is possible to connect with Google assistant or Amazon Alexa very easily.

6. ACKNOWLEDGMENTS

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