PWM Controlled PMDC Motor Drive using microcontroller for Treadmills

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Abstract

Motion control plays a vital role in industrial automation. Manufacturing plant in industries like chemical, pharmaceutical, plastic and textile, all require motion control. And it may be a flat belt application, flow-control application or mixing of substances. Different types of motors—AC, PMDC, servo or stepper—are used depending upon the application. Of these, PMDC motors are widely used because controlling of a PMDC motor is somewhat easier than other kinds of motors. The treadmills are the walking machines used for exercise. This is a big application where a PMDC motor plays an important role in its operation .These machines are operated using PMDC motors. In this paper, Implementation of the PIC 16F877A microcontroller for speed control of PMDC motor fed by a MOSFET has been investigated. The MOSFET is driven by high frequency PWM signal. Controlling the PWM duty cycle is equivalent to controlling the motor terminal voltage, which in turn directly adjusts the motor speed.

Introduction:

The use of power electronics for the control of electric machines offers not only better performance caused by precise control and fast response, but also maintenance, and ease of implementation. In parallel with the advance in power electronic there have been great advances in microcontroller-based control systems due to the microcontroller flexibility and versatility. This is because all the control algorithms are implemented in the software. [1]
Adjustable speed drives may be operated over a wide range by controlling armature or field excitation. Speeds below rated by armature voltage control and above rated using field excitation variation, development of various solid stale switching devices in the form of diodes, transistor and thyristor along with various analog/digital chips used in firing/controlling circuits, have made dc drives more accessible for control in innumerable areas of applications [2].
Speed Control of a small capacity drives with low voltage supply is easy. These types of drives have limitations on their operation for applications where high torque is required. The design of a high capacity variable speed drives is difficult due to thermal run away of power MOSFET if used as a switching device. The snubber circuit play important role to protect the Power

MOSFET from high temperature loss. As the frequency of switching the device goes on increasing, the dv/dt & di/dt takes place across the MOSFET terminals. This makes the thermal breakdown of power MOSFET.

The Laszlo Balogh [6] has demonstrated a systematic approach to design high performance gate drive circuits for high speed switching applications.

Paper consists of an overview of MOSFET technology and switching operation, design procedure for ground referenced and high side gate drive circuits in more details. By controlling the gate charge for MOSFET during torn OFF protects the MOSFET from ringing & overshoot caused by dv/dt. John E. Makaran [3] has suggested the relationship between V_{GS} &V_{DS} to provide the two stage control of gate charge removal during MOSFET turn OFF. PMDC motor gives the best speed regulation using PI controller, as compared to other controllers, literature[4] shows the response of PI,PD &PID controller when it is connected to PMDC drive. Fuzzy logic controller using PIC 16F877A can be used for speed control of any motor only by changing control algorithm & by changing program without changing hardware[5].

The objective of this paper is to explore the approach of designing a microcontroller based closed loop controller. The interface circuit and the software are all designed to achieve a better performance. The system is designed with a temperature control system to protect the motor from overheating.

HARDWARE DESIGN

The hardware control system includes the dc shunt motor, power circuit, MOSFET driver circuit 16F877A PIC controller, speed sensor (shaft, encoder), and temperature sensor.

a. BLOCK DIAGRAM

The 16F877A microcontroller implements the control algorithm by conditioning the speed and current signals and performs the speed regulation according to speed reference fed through the keypad. The software includes a routine to read the temperature of motor and sends emergency shutdown signal to protect the dc motor from over heating

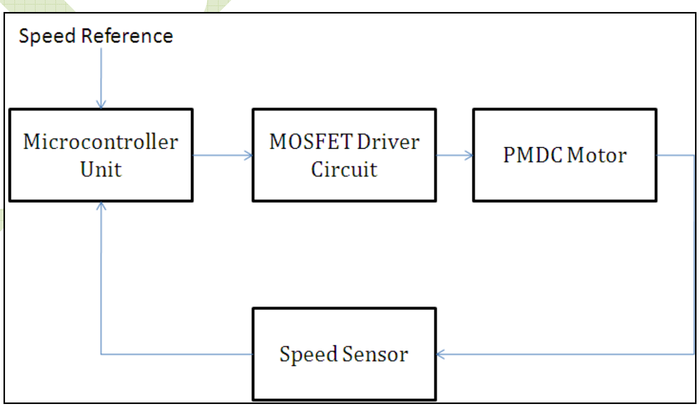

Fig 1 block diagram

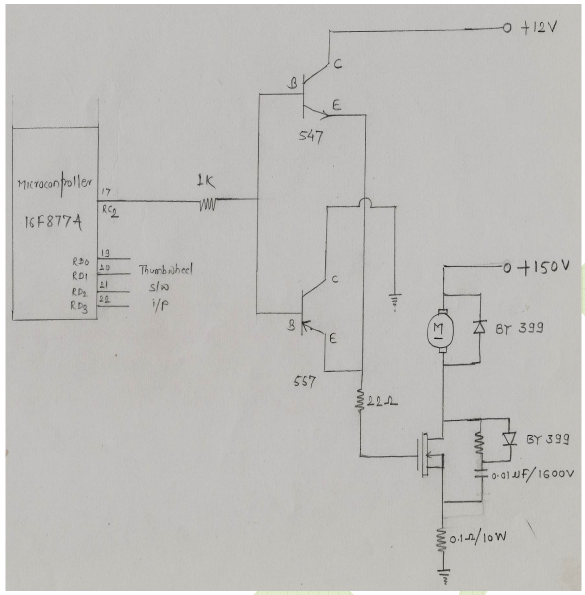

Fig 2 Circuit outline

b. DESIGN OF SNUBBER CIRCUIT

When a power device is abruptly turned OFF, the trapped energy in the stray inductance is dissipated in the switching device causing a voltage overshoot across the device. The magnitude of this transient voltage is proportional to the amount of stray inductance and the rate of fall or turn-off current. The situation is at its worst for fast switching MOSFET modules. These devices switch at a high magnitude of currents in a short duration of time, giving rise to potentially destructive voltage transients. The di/dt produced in the MOSFET could easily be a few thousand A/us. Proper attention needs to be paid to protect these devices from destruction. It is determined that the snubbers offer optimized protection against voltage transients during the normal turn-on and turn-off switching. Usage of such protection circuits allows faster & safer operation by operating the device within the boundaries of the rated Safe Operating Area.

c. RCD SNUBBER CIRCUIT-

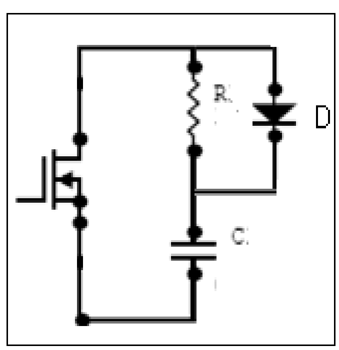

Fig 3 snubber circuit

The charge discharge snubber as shown in above figure can be used to minimize turn off dissipation in MOSFET. During MOSFET turn on the snubber capacitor is fully discharged and during turn off it is fully charged. This circuit reduces the rate of rise of voltage across MOSFET at turn off and gives softer switching and thereby reducing the losses in MOSFET.

d. SPEED MONITERING SYSTEM

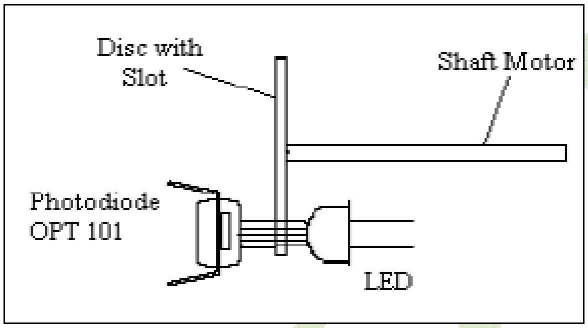

Fig 4 speed sensing

In the system, an optical encoder will be used to measure the DC motor speed. The fundamental reason for the superiority of this system is that the optical encoder used as the velocity sensor, is capable of much better performance than the generator type of tachometer (by using back EMF)When the optical disc is properly mounted on the motor shaft, it generates a frequency directly proportional to motor speed. Changes in gap, temperature, and magnet strength simply have no effect on the output of the optical tachometer. By contrast, an analog tachometer is directly affected by all the problems listed above.

The encoder in the market is very expensive. In order to reduce the cost of the project, an optical encoder is built. Fig. 4 shows the schematic of the optical encoder in action respectively.

The speed accuracy over fractions of a revolution depends on the quality of the optical encoder. The DC motor has an optical disc (made by cardboard) mounted on its shaft. The disc has N radial lines on its surface. In this project, we will make single slot on the disc. An LED (light emitting diode) as transmitter is put at one side of the disc and a photodiode, as receiver is fixed on the other side of the disc. Chip OPT 101 is selected as photo diode.

e. TEMPERATURE CONTROL SYSTEM

Due to continue operation of treadmills the motor winding temperature gets increases. The increase in motor temperature short circuits the motor conductors. The short circuit reflects into the possibility of burning of motor. In this project temperature protection of motor is provided. IC LM 35 is used as a temperature sensor. This sensor is kept near to the motor winding. Any increase in temperature above the set value gives the signal to the relay circuit, which instantly stops the motor hence motor is protected from burning.

SOFTWARE DESIGN

The microcontroller acts like the brain of the DC motor speed control system. The microcontroller chip that has been selected for the purpose of controlling the speed of DC motor is PIC16F877A manufactured by Microchip. This chip is selected based on several reasons:

a. Its size is small and equipped with sufficient output ports without having to use a decoder or multiplexer.
b. Its portability and low current consumption
c. It has PWM inside the chip itself which allow us to vary the duty cycle of DC motor drive.
d. It is a very simple but powerful microcontroller. Users would only need to learn 35 single word instructions in order to program the chip.
e. It can be programmed and reprogrammed easily (up to 10,000,000 cycles) using the universal programmer in robotics

Microcontroller will receive the desired speed from user through thumbwheel switch. The actual speed will be compared with the desired speed and the correction will be done by microcontroller to always maintain the DC motor speed at the desired speed.

SPEED CONTROL PROGRAM FLOW

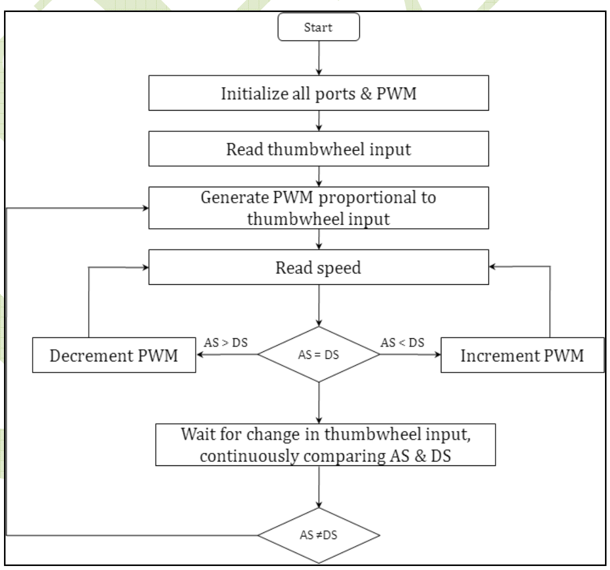

Fig 5 speed control program flow

CONCLUSION

The above PID speed control implementation through PIC 16F877A microcontroller for a Permanent Magnet DC motor for treadmill reduces the voltage fluctuations. A smooth control is achieved over the jerky load of treadmill. The PID control improves the response time of the overall system.

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