CONVERSION OF A DC MOTOR FOR SERVO APPLICATIONS

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ABSTRACT

Nowadays servo motors have become a part and a parcel for industrial operations, as all most all the manufacturing lines in industry have been automated in order to achieve higher production and to compete in the market. Servo motors are used in data encoders as motors with ranges in excess of 1MW for winding machines used in mines. There are lots of places where the servo motors are used. In robotic applications servo motors are used to move the robotic part to a relevant position by means of controllers. In market there are servo motors with various rating both as DC and AC servo motors.

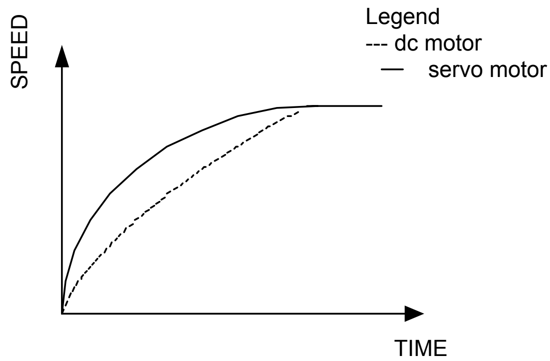
Servo motors have a special property that is starting and stopping immediately as soon as the power is ON or OFF. This property leads to use the servo motors for above mentioned applications and different position controls. The main cause behind the special properties associated with the servo motor is the low inertia of its rotor. The low inertia is achieved by fabricating the rotor with a special material which is of less weight but capable of producing the necessary magnetic flux. The main drawback of this material is its high cost which makes servo motors very expensive.

Therefore servo motors available in the market are very expensive. Due to this reason small scale industries will have to spend a big capital to achieve their relevant task which needs to use servo motors. So it is important to have motors which can be used for servo applications with lesser cost. The project described here will give such a method to use conventional dc motors for servo applications with very low cost. Firms who are using the proposed motor have to spend only about 1/10th of the cost of servo motors available in the market. For this purpose we need to use a permanent magnet DC motor with an electronic drive circuit part in order to control the motion of the motor.

INTRODUCTION

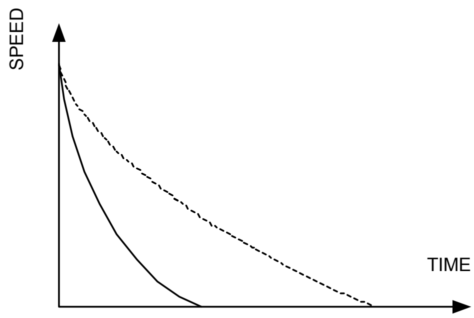
The dc motors used for general-purpose applications inherently posses higher inertia due to its heavy rotors. Due to this reason conventional dc motors take more time to come into steady state when started. And also at the braking they will show some delay in coming to the rest position. These facts make these motors unsuitable for servo applications as it is.

The following fig. 01 and fig. 02 show the difference between dc motor and dc servo motor speed characteristics.



Starting characteristics

Fig. 01



Braking Characteristics

Fig. 02

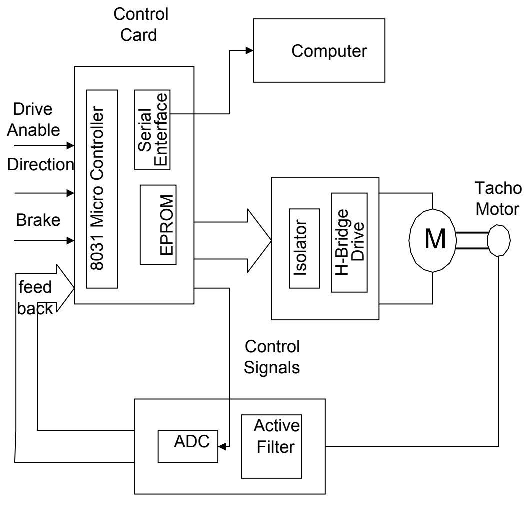
It is clearly seen from above curves that starting time constant as well as the braking time constant of a conventional dc motor is much higher than those of a dc servo motor. These differences in time constants, makes it impossible to use a conventional dc motor for applications where a dc servo motor is used. The recommended action for making it possible to use a conventional dc motor for applications where dc servo motors are used is to derive a technique to make two time constants approximately same by some means.

In driving a DC motor for servo operation fundamentally deals with servo amplifiers, which uses transistors in the linear region. But particular is a high-energy consumption method. Because of that pulse width modulation scheme which drives MOSFETs in the switching mode is used as a energy saving strategy.

The complete hardware of the system consists of three parts. All these three parts will contribute similarly for the final results. They are.

1. Control circuit
2. Driving circuit
3. Feedback circuit

The following Fig. 03 shows how these sections are interconnected in the servo amplifier. To verify the improvement of motor speed characteristics, feedback samples are interfaced via RS232 interface to a PC.



Block Diagram of the Controller

Fig. 03

DRIVING MODULE

As mentioned above PWM scheme is used as the driving principle, it is essential to drive the motor through a driving circuit. In our system we have used H-bridge driving circuit with four power MOSFETs.

Concept behind the driving circuit:

The driving circuit of our system consists of four MOSFETs and four opto-couplers as isolators. The motor is driven at high power while the controlling is done at low power. Above mentioned parts are isolated using four opto-couplers. Also these opto-couplers take care of the proper biasing of the FETs at relevant stages. The biasing of the transistors is very important for proper operation of the motor, as the switching of FETs will wholly depend on the biasing of them. Also opto-couplers will provide noise immunity.

Selection of the MOSFETs

In driving circuit our main concerns are higher switching speed, high current handling capability and low resistance while switched on. Normally power MOSFETs are faster in switching also and when they are ON they provide a low resistance acting as a short circuit but conventional bipolar transistors offer a high ON resistance eating away most of the voltage provided by the motor supply. Therefore we select MOSFETs for our switch mode bridge. Also for braking operation the bridge transistors should be capable of reverse current handling. In this point significant difference now becomes apparent between the MOSFETs smart power transistors and the conventional bipolar configurations. Since active MOSFET transistors have their built in body diode, they can be reverse conductive while Bipolar transistors cannot have this property.

Also the MOSFEts we have selected have a current rating of about 45A, therefore they can handle high current even when the motor is loaded and during switching. There are integrated circuits with the same bridge configuration, but the reason why we did not select them for our system is the inability of handling much high current by them. Therefore we decided to use discrete components and build up the bridge which will enable us to select suitable MOSFETs as we went. We have used IRFZ46N MOSFET for our purpose.

Theory of the driving circuit:

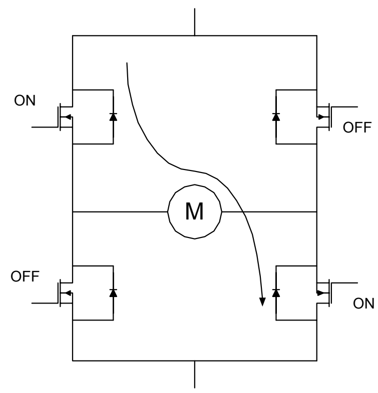
The operation of the motor can be divided into three parts, namely

- Starting operation
- Steady state operation
- Braking operation

The theory of the driving circuit will defer for these three operations, as the controlling signals are different from one another. Following sub sections describe each of them separately.

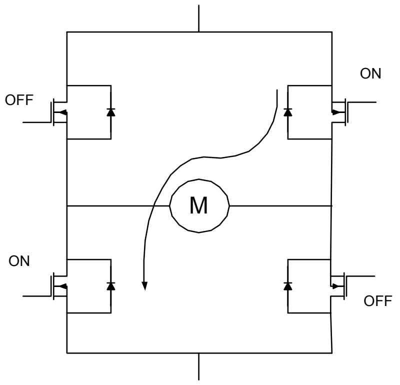
Starting operation

The starting of the motor can be done by switching on two FETs, which are at diagonal of the bridge. Our objective is to start the motor as soon as the motor is given the drive enable signal externally. Therefore we have written the algorithm to apply 3V above the rated voltage 12V, that is 15V allowing a high initial voltage across the motor. This higher voltage is applied to the motor until it comes to its steady speed. The steady speed is detected by the feedback values which are fed through the feedback circuit. The following figures show the switching on and off of relevant FETs for forward and reverse operation with drive enable signal.



Forward operation

The application of the higher voltage is removed when motor comes to the steady state level. Within this time the relevant FETs are made fully ON to handle high current and to apply the rated voltage at the motor terminals. Since the H-bridge is powered with a 15V dc supply, whenever two diagonal FETs are ON they act as short circuit and make the applied voltage to 15V at the motor. Therefore it’s important to switch the FETs properly.



Reverse Operation

Fig. 04

Steady state operation:

It is not safe to operate the motor above the rated voltage. Therefore it is better to operate the motor at a reduced voltage. For this purpose the switching property of the FETs are used. After motor gets its maximum speed the applied voltage to the motor is reduced to 12V in order to take care the safe operation of the motor. Applying a pulse with 80% duty cycle as the switching voltage to the relevant transistors does the application of the effective voltage of 12V.

This PWM method will take care to apply a reduced voltage to the motor terminals.

Braking Operation:

Braking of the motor is done by short circuiting the motor terminals. For this purpose the switching property of the FET is used. As the MOSFETs act as short circuited at switch mode the motor terminals are considered to be short circuited when the relevant FETs are ON. The lower pair of FETs of the H-bridge and the upper pair of FETs of the H-bridge are alternatively switched on for a time period of 5ms. Due to the back EMF across the motor, a current will flow in short circuited loop in the reverse direction until the back EMF is reduced to zero enforcing dynamic braking technique.

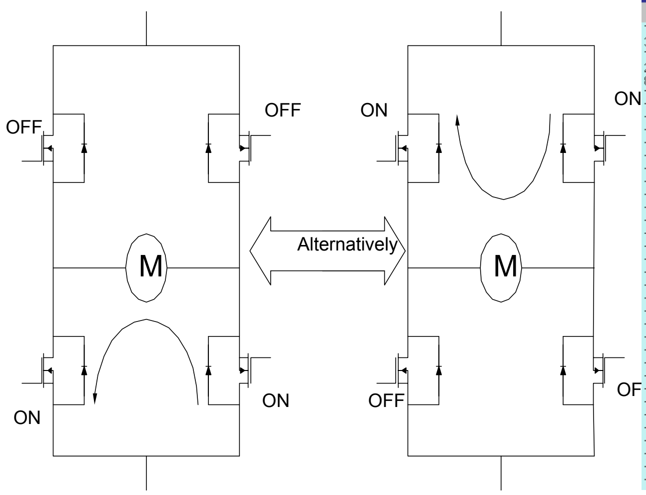


Fig. 05

FEED BACK MODULE

Since the PWM scheme is to be used at the steady state operation of the motor, it is necessary to check the speed of the motor at relevant intervals. Feedback speed is taken from the feedback module and

It is given to the microcontroller for comparison.

Concept behind the Feed Back Circuit

Analog approach

A cassette motor coupled to the conventional DC motor is used as a transducer. Cassette motor's induced EMF voltage varies in accordance with the speed of the DC motor.

Low pass filter filters out the noise components in induced voltage. Analog to digital converter converts the speed samples to digital domain.

Digital approach

We found that feed back signals coming from DC motor contains much noise as switching on and switching off taking place. Because of that a optical feedback system was introduced and due to the synchronization difficulties it wasn't work properly.

Since we are using the both timers in 8031 microcontroller in making the PWM waveform it was difficult to use a timer to count the number of digits that comes from the optical encoder.

One week before the submission of the project we are keep on trying a new feedback system which converts frequency to the voltage.

Our main objective of introducing a good feedback system is to provide a good control system to the motor and to have a sound graphical output to a PC via RS232 interface

The following figures show the speed characteristic that was taken from the serial interface of the drive circuit. This program to the PC was written using Microsoft Visual Basic language.

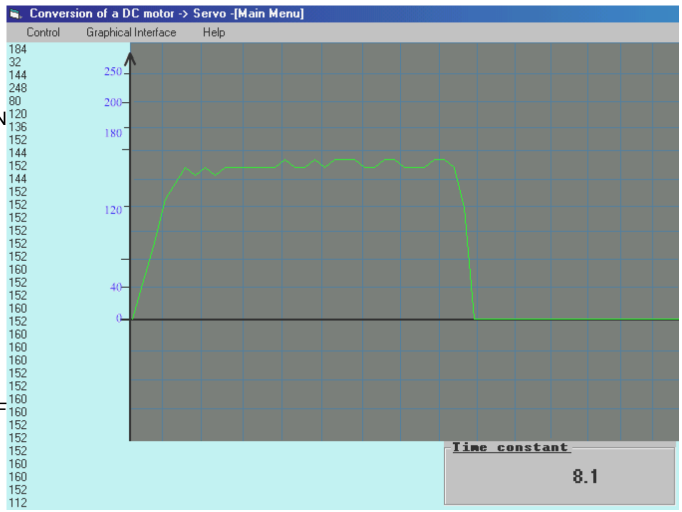


Fig. 06

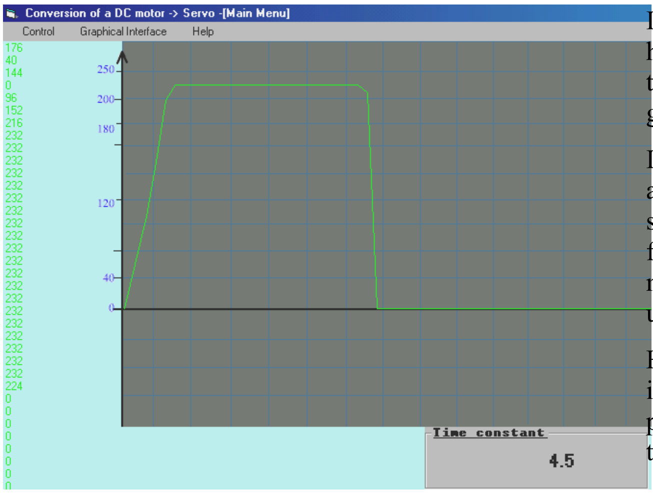


Fig. 07

- Fig. 06 shows the speed characteristics when the motor runs at 12V without using the PWM scheme.
- Fig. 07 shows the speed variation when the motor runs at 15V with PWM scheme.

According to the above figures it shows that the improvement of the speed characteristics of the permanent magnet DC motor when using the drive circuit with Pulse width modulation technique, where the starting time constant has improved from 8.1 units to 4.5 units.

CONCLUSION

Main objective of the project was to built a drive circuit or a servo amplifier which convert the traditional permanent magnet DC motor for servo operation. For drive circuit IGBTs could be used instead of MOSFETs but due to the high cost of IGBTs we depend on MOSFETs.

It would be better if we made the feedback circuit to have direct digital signal to the microcontroller rather than converting analog signals to digital which makes a grater amount of noise.

It was also not possible due to the lack of timers available in the 8031 microcontroller and due to the synchronization of microcontroller clock with the speed feedback signals. All the above errors could me minimized a microcontroller in the AT 89*** series was used.

How ever when the overall project results are concern it is proved that the servo amplifier which was made provide better starting and stopping time constants for the permanent magnet DC motor.

ACKNOWLEDGEMENT

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We would like to thank all of them together with other personals who helped us to complete our project SUCCESSFULLY.

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