Closed loop Control of A DC Motor using expEYES with Python

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Abstract

Ever since the inception of industrial automation, the speed control of a motor is of utmost importance. Though DC motors were developed in 19th century itself, a primary reason for its present importance is its variable speed characteristics. Since the speed of the DC motor is linearly related to applied voltage [5], it is very easy to control the speed for variable speed application in comparison to induction motor (IM). Due to its ease of controllability, DC motors are used in many industrial applications requiring variable speed and load characteristics. The speed control of DC motor is very crucial in applications where precision is of the essence. A DC motor can develop full torque throughout its operating range from zero to base speed [5]. This makes it very suitable for its use in constant torque applications like conveyors, elevators etc. Hence these applications can be stopped even when fully loaded and will require full torque to get them moving again. A generic speed control system consists of a signal processing unit and a power processing unit [1]. The objective of this paper is to investigate open source controllers which can be used be used to control a DC motor without compromising on the performance. Here, an open source platform known as expEyes Junior (developed under PHOENIX project by IUAC, New Delhi) and Python (version 2.7, spyder IDE) as a software interpreter are evaluated for closed loop speed control of a DC motor. This paper banks upon the ease of programming using Python and flexibility of its hardware counterpart (expEyes Junior) to generate a high frequency variable PWM which is used to control the DC motor. Owing to the simplicity of the algorithm, the convergence of error is very accurate but the response of the system is to be improved for real time applications.

I. INTRODUCTION

The motor speed is dependent upon the terminal voltage [5]. Therefore by controlling the terminal voltage of the DC motor, we can effectively control the speed of the machine. We are using a solid state chopper which converts fixed DC supply into pulses of varying duty cycle. By varying the duty cycle, the average voltage to the armature, or the terminal voltage of the DC motor varies. Equations 1, 2, 3 and 4 govern the speed-voltage relation. Equation 5 depicts the effect of duty cycle on the terminal voltage.

$$E = K_e \phi \omega_m \tag{1}$$

$$V = E + I_a R_a \tag{2}$$

$$T = K_e \phi I_a \tag{3}$$

From the above equations,

$$\omega_m = \frac{V}{K_e \phi} - \frac{R_a I_a}{K_e \phi} \tag{4}$$

$$V_t = \delta(V_{in}) \tag{5}$$

where ϕ is the flux per pole in webers, I_a is armature current in amperes, V is the armature voltage in volts, ω_m is the angular speed in rad/sec and T is the torque in Nm. K_e is the motor constant. V_t is the variable terminal voltage and V_{in} is the constant DC supply voltage. δ is the duty cycle of the chopper.

II. EXPEYES JUNIOR

expEYES Junior is meant to be a tool for learning by exploration, suitable for young engineers and scientists. The design is optimized to be simple, flexible, rugged and low cost. Because of low cost, it enables students to perform experiments both in laboratories and beyond. Hardware design is open source and royalty-free. The software is released under GNU General Public License. The following are the salient features of expEYES Junior [2]:

- Built-in Signal Generator and CRO
- USB Powered
- 12 bit Analog to Digital Converter
- Open Source Hardware and Free Software
- Uses Python programming language

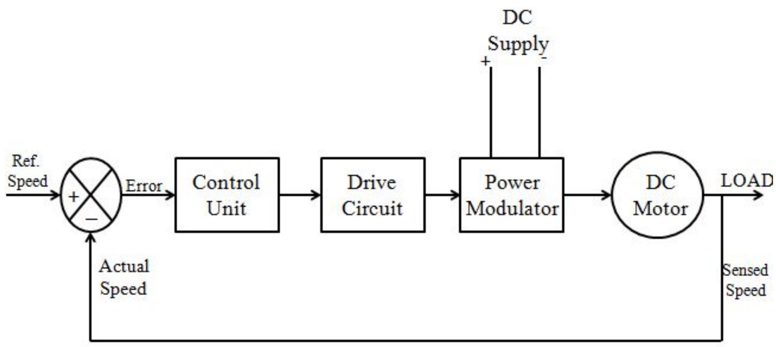

Fig. 1. Schematic Block Diagram

- Compact, 8.6 x 5.8 x 1.6 cm, 60 gm
- Low Cost about $ 33.0
- Measure/control voltages with 12 bit resolution
- Generate/Capture waveforms and analyse them mathematically
- Everything controlled from simple Python programs

A. Coding in Python

The expEYES uses Python for code development [2][3]. expEYES can run on any computer having a Python Interpreter and a Python module to access the Serial port. The USB interface is handled by the device driver program that presents the USB port as an RS232 port to the application programs. Python is an interpreted language with an easy to learn syntax and has very good libraries for graphics, networking, scientific computation etc. It is freely downloadable and available on almost all operating systems. Some of the libraries we made use of are math, expeyes.eyesj, scipy, numpy, pylab etc [7][8].

A brief algorithm describing the code for closed loop control is given below:

Step 1: Import necessary libraries.
Step 2: Initialize pwm value to an arbitrary value between 10 and 90, preferably 50.
Step 3: Read the reference speed.
Step 4: Get the frequency of the pulse obtained from the opto-interrupter based speed sensing circuit.
Step 5: Convert sensed frequency into angular speed in RPM.
Step 6: Find error between reference speed and sensed speed.
Step 7: If previously set pwm is greater than 90, set pwm as 90. Similarly if previously set pwm, is less than 10, set pwm as 10.
Step 8: If error found in step 6 is positive, increment pwm, else decrement pwm.
Step 9: Goto step 4.

III. Implementation

The schematic block diagram of this experiment is as shown in Fig. 1 [5]. The aim of this experiment is to keep rotational speed of the dc motor at a constant value as defined by the user (also known as reference speed), even when there are variations in load torque and supply voltage. Actual speed of the motor is sensed through an optical sensor which is mounted on the motor platform. Actual speed signal is processed through a low-pass filter so as to filter out unwanted high frequency components. The difference between reference and actual speeds is calculated using a summer to obtain speed error. A controller will process this error, so as to minimize the difference between reference and actual speeds. Controller output will set the gain of the dc-dc converter, which in turn alters input voltage to dc motor according to the gain set by the controller.

As an example, let us say that the reference speed is more than the actual speed. Then the speed error is positive and controller will increase the gain of the dc-dc converter. Since gain of the converter has increased, applied voltage to the motor is increased which will increase actual speed of the motor, thus minimizing the error. The controller will behave exactly opposite to what has been explained above, if the speed error is negative.

expEYES has been used to implement the following blocks / activity:

1) Definition of reference speed
2) Summer implementation
3) Controller and
4) Conversion of analog speed feedback signal into digital

Fig. 2. Experimental setup

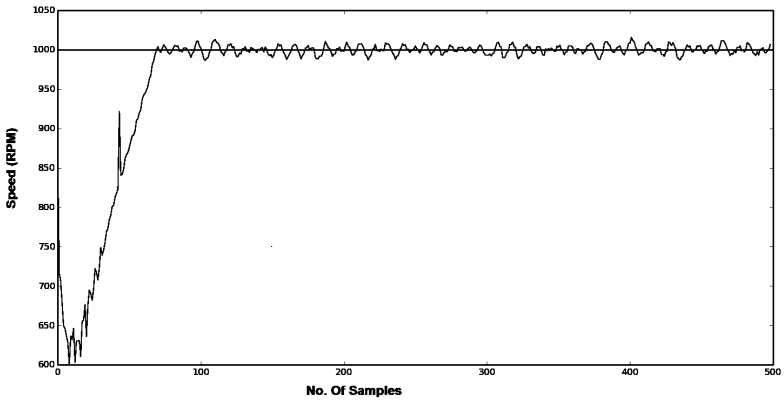

Fig. 3. Motor speed response with constant load torque

A. Experimental Results

Fig. 2 shows the experimental setup in the laboratory. All the components of schematic block diagram can be seen in this figure. As an example, the reference speed of the motor is set at 1000 rpm and the motor actual speed response is shown in Fig. 3. It can be seen from this figure that the speed of the motor increases initially towards the reference speed and then it becomes equal. Generally, speed of the motor decreases as the applied load torque is increased. But with the closed loop feedback control, it is expected to keep the speed constant in spite of the increase in load torque. Fig. 4 shows the effect of change in load torque on the speed of the motor. Speed of the motor drops momentarily when there is an increase in load torque, but later on, the motor speed will be at its reference/set speed as can be verified from this figure. Fig. 5 shows an increase in duty cycle of gate drive pulses when the reference speed of the motor is increased. Increase in duty cycle of gate drive pulses will in turn increase the average output voltage of the power converter which will cause an increase in speed.

While Python and expEYES has been successfully used for this experiment, the following are the limitations of the tool experienced when using it for motion control applications:

- Available ADC channels are limited
- Not possible to program timers according to application requirements
- When expEYES input and output ports are being accessed through programming, CRO plus feature is not available
- Cannot generate multiple (≥ 3) PWM waveforms
- As it uses Python interpreting language, it cannot be used for real-time/time-critical applications

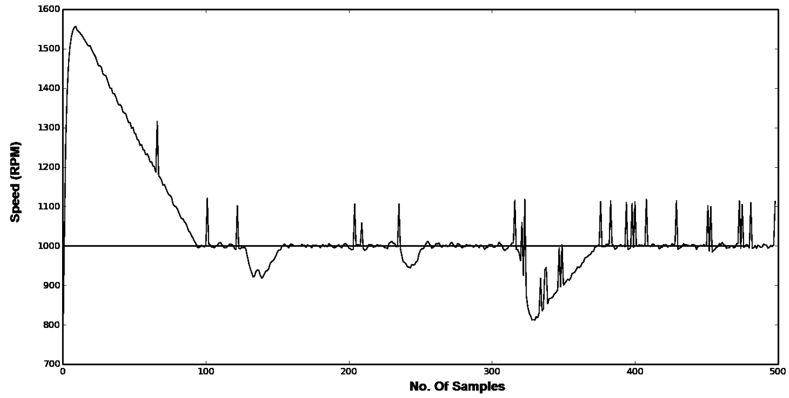

Fig. 4. Motor speed response for an increase in load torque

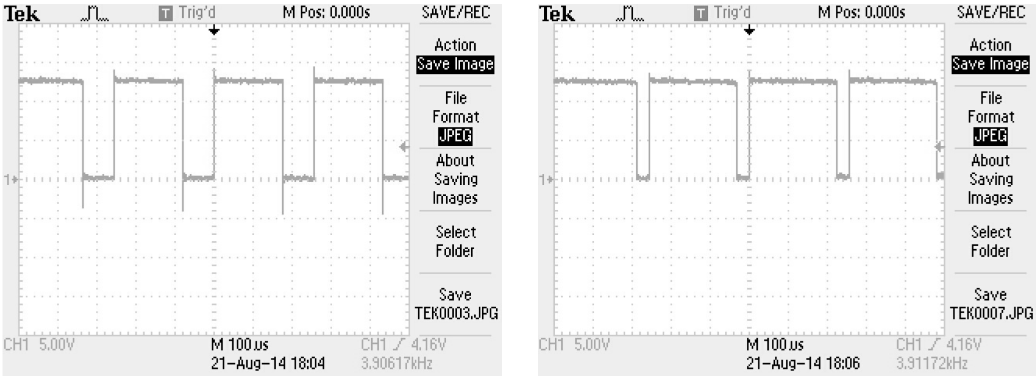

Fig. 5. Duty cycle variation when reference speed is increased

IV. Conclusion

This paper presented usefulness of Python for implementing a low cost closed loop control of a DC motor, using an open source platform expEYES. As seen in the results above, the hardware expEYES Junior is fairly successful in accomplishing the stated objective. Although the response time of the system can be improved, we conclude that as a first step to learn the basic implementation motion control, expEYES is a good platform to start from.

Acknowledgment

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