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Efficient System Identification Methodologies for a Direct Current (DC) Motor Academic prototype

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Abstract: For the aim of efficient direct current (DC) motor control, accurate model estimation is required to be derived. However, the DC motor model is estimated and derived via the system identification procedure and the objective of current paper is to illustrate two different methodologies for the mentioned procedure. First methodology is the linear one in which the DC motor is proposed to work in a linear (stable) range and it gives better data fit than the second methodology through which we implement a PRBS (Pseudo Random Binary Sequence) test on the DC motor. Indeed, even though the PRBS methodology gives less data fit, it is more suitable for matching the real time working conditions under control algorithms implementation on the DC motor due to the load disturbance rejection and other working requirements.

Keywords: Direct Current (DC) Motor, System Identification, Pulse Width Modulation (PWM), PRBS (Pseudo Random Binary Sequence) Test.

1 Introduction

Digital current regulation of the motor drives enables the feasibility of developing universal motor drives using software control technique and implementing the work on embedded systems [1]. Those drives receive the signals from a designed controller for a specific control task and accordingly give appropriate output signals to the actuator in the control process [2]. The latency requirements at computational stages should be given significant importance to insure proper and trusted control algorithm implementation via a specified hardware target. Those requirements are greatly depended on the processor working frequency while performing the control algorithm program cycling and the operator should ensure a complete program scale on each cycle before every controller necessary action to satisfy the desired output. This goal can be achieved by suitably selecting the sampling time period in such a manner to allow the smooth and accurate controller algorithm implementation using specified hardware boards. However, the designed controller is highly depended on the actuator model and when the actuator is a DC motor; this model is referred to it as the plant transfer function. Industrial applications, laboratory experiments and many areas of research are some of the DC motors benefits using their simplicity, low cost and efficiency [3-7]. Nowadays, the DC motors continue to be used in the industry because of their static and dynamic performance [8]. Indeed, the procedure of deriving the plant transfer function is known as system identification process and it is very necessary stage before designing the required controller [9]. The derived transfer function determines the appropriate controller's parameters [10]. After obtaining the DC motor model i.e. deriving its accurate transfer function, traditional and modern control algorithms are optimally implemented and satisfying results are guaranteed [11, 12]. Taking the importance of the transfer function for proper controller design into consideration, current paper objective is to illustrate the system identification methodologies for the DC motor academic prototype. This paper is organized as following: the required resources for performing the system identification procedure are illustrated in section two, the linear methodology is explained in section three, the PRBS

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(Pseudo Random Binary Sequence) methodology is illustrated in section four, and, finally the paper is concluded in section five.

2 System Identification Required Recourses

In order to perform system identification we must use statistical methods and build mathematical models of the systems from measured data. Performing the system identification also includes the optimal design of the system to be worked with various experiments for generating informative data for matching such models as well as matching the model approximation. In this work the required resources to perform the system identification procedure contain two parts i.e. hardware and software. For the hardware part we use the Benix DC motor trainer prototype which used for academic purposes, Arduino Mega kit and driving circuit for the DC motor. For the software we use MATLAB SIMULINK. However, the Benix DC motor kit is a trainer kit. It is a standalone kit used for speed control tutorial and educational purposes. This prototype includes the following units: DC motor, power supply unit, buffer and power amplifier unit, optical encoder unit and frequency to voltage control unit. The DC motor is manufactured by Pranshu Electricals and has the following specification: the maximum speed is 1500 rpm, the maximum input Voltage is 10 Vd , and the maximum input current is 0.9 Amp. The power supply unit provides up to 12 Vdc and 1 Amp current. The objective of the Buffer and power amplifier unit is to receive and adjust external signals when the voltage signal from the source is not powerful to drive a load, a power amplification unit accepts a voltage signal from the source and adjusts its power in proper value in terms of current which can drive the load. The optical encoder unit is made up of slotted disk mounted on back of the motor axis with Infrared light source and detector. It provides 12 pulses per full rotation. The frequency to voltage control unit is used for speed measurement. Pulses from optical encoder are fed to the frequency to voltage (F _ to _ V) converter for measurement of speed in terms of DC voltage values. The range is from 0 to 2 volt DC for 0 to 1500 Rpm. Figure 1 shows the DC motor prototype.

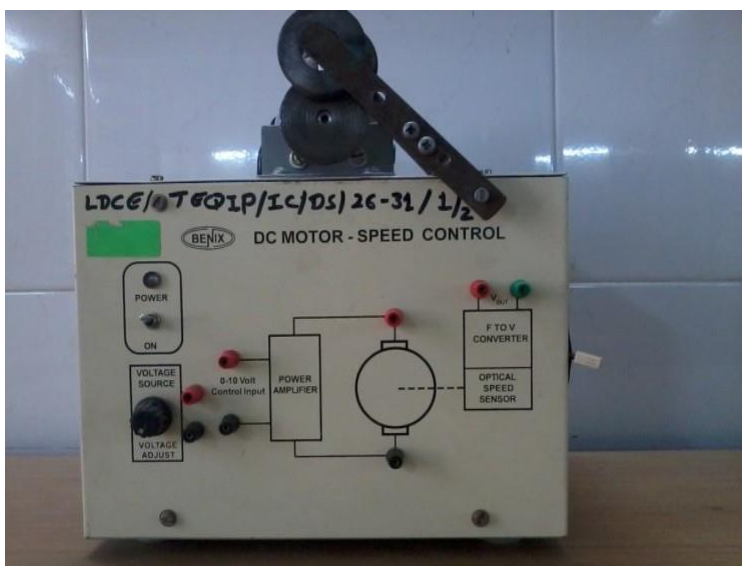

Figure 1: DC motor academic prototype

Due to its suitability, Arduino Mega 2560 Kit is used for the DC motor interfacing with the software i.e. Matlab Simulink and its support package for Arduino board. Actually, this kit has a microcontroller of ATmega 2560 type, an operating voltage equals to 5 V, digital I/O Pins number 54 (of which 15 pins provide pulse width modulation (PWM) output), analog input of 16 pins, a DC current per I/O pin of 40

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mA, a flash Memory of 256 KB of which 8 KB used by boot loader, an SRAM of 8KB, and an EEPROM of 4 KB. The interfacing process is performed via the Driving circuit. This circuit receives the PWM output signals from the Arduino Pins and accordingly provides the voltage to the DC motor armature. Here are two efficient methods to perform system identification for the DC motor in order to get its transfer function.

3 Linear Methodology

In this methodology, we assume that the DC motor will work in the linear rang of its voltage/current-speed curve. With the help of the Matlab Simulink model, shown in figure 2, in which we use Arduino kit to provide the input to the DC motor and to measure the output from it, we give the input voltage from 3 to 8 volt (linear range) and measure both the output voltage and speed as shown in table 1. Then we calculate the ratio between the input voltage and the output speed, and we compute the average value so we get 0.006 as a result. We use the above result as gain in the Matlab Simulink model shown in figure 3; this gain enables us to give the input of the DC motor in terms of speed as shown.

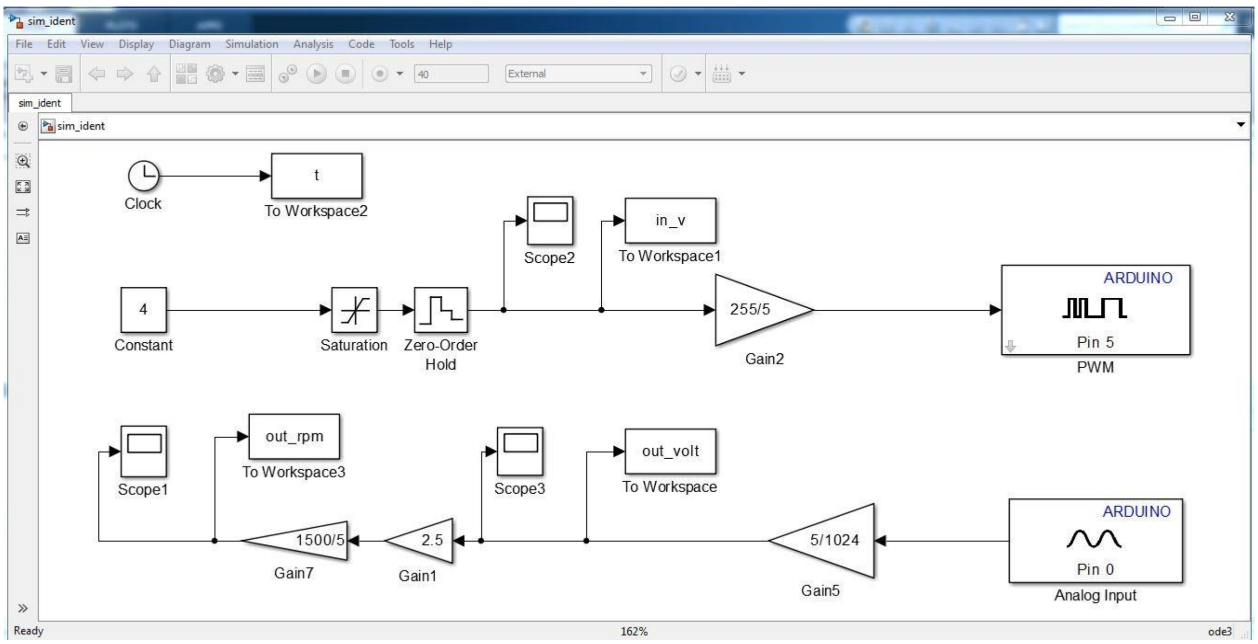

Figure 2: Matlab Simulink model for DC motor interface.

Table 1: DC motor I/O Data

Input voltage (DC volt)	Output voltage (DC volt)	Output speed (RPM)
3	0.43	328
4	0.89	670
5	1.21	908
6	1.38	1040
7	1.5	1133
8	1.6	1207

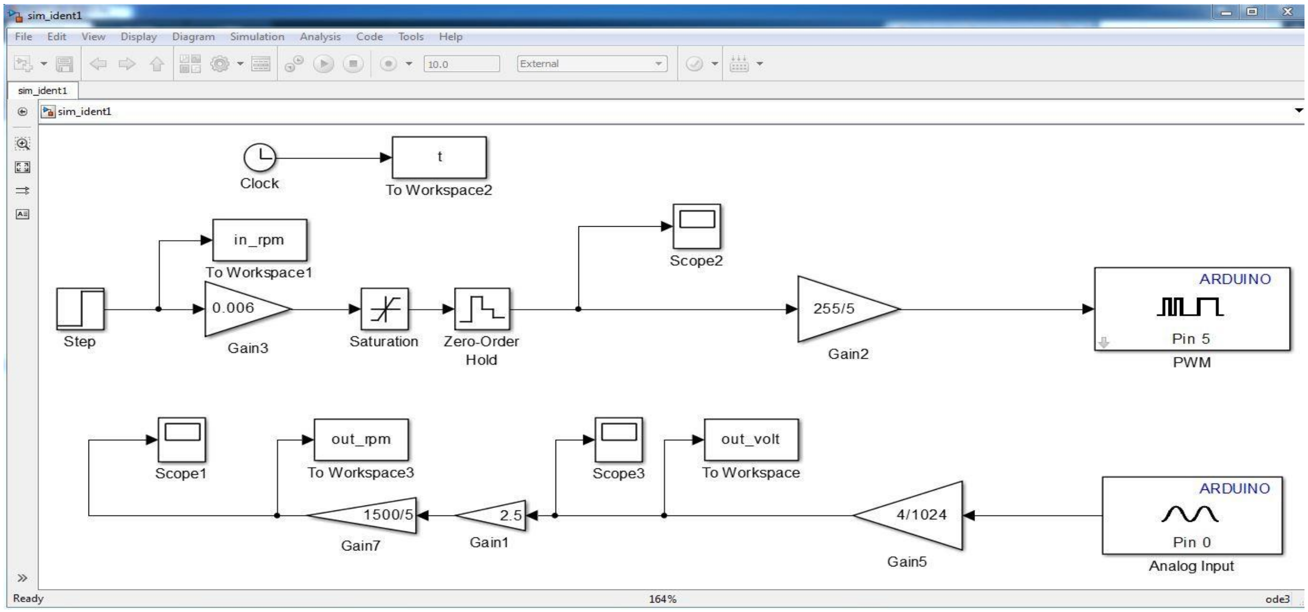

Figure 3: Matlab Simulink model for performing linear system identification.

Now we use the input speed data and the output speed data for system identification with the help of System Identification Tool in Matlab using sampling time $Ts = 0.01sec$, then we get the transfer function given in equation 1 with fitting value equals to 97.4% as it is shown in figure 4:

$$G_s = \frac{0.4618\, s + 6.857e - 6}{s^2 + 0.2942\, s + 3.636e - 6} \tag{1}$$

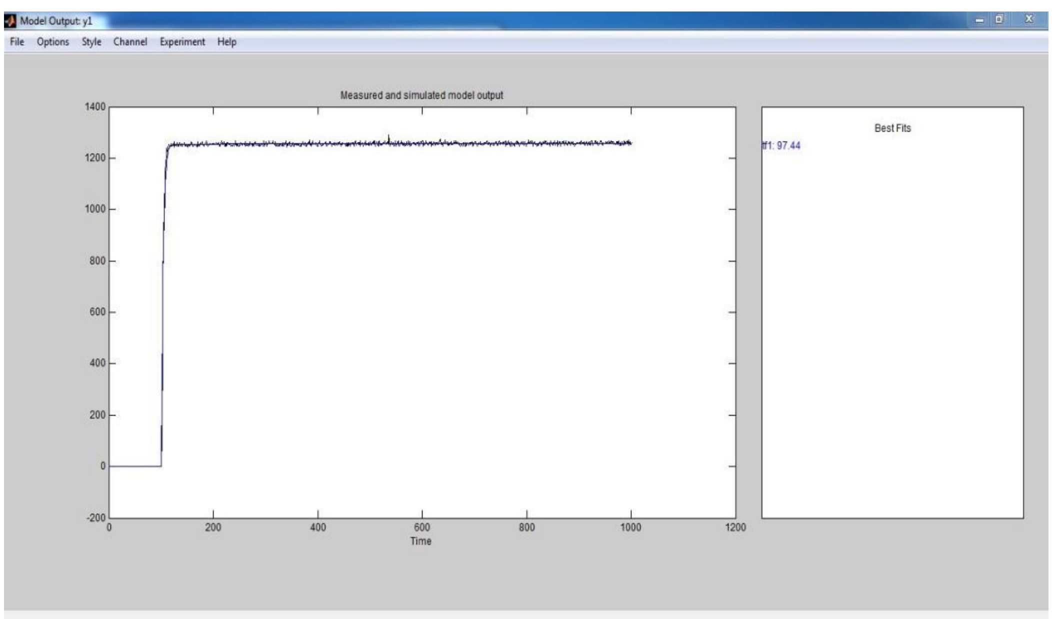

Figure 4: Estimated model output for the linear methodology.

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4 PRBS (Pseudo Random Binary Sequence) Methodology

In this methodology the PRBS (Pseudo Random Binary Sequence) test is used. During the experiment different setup configuration of input signals has been provided to the actuator to get best outfit. In this method, we expect different working conditions of the DC motor in the reality and not only the linear range is considered. Here PRBS input signal (shown in Fig 5) is sent to trainer kit via Arduino board using PWM output fed to motor using power amplifier. The feedback signal obtained with the help of Analog input pin.

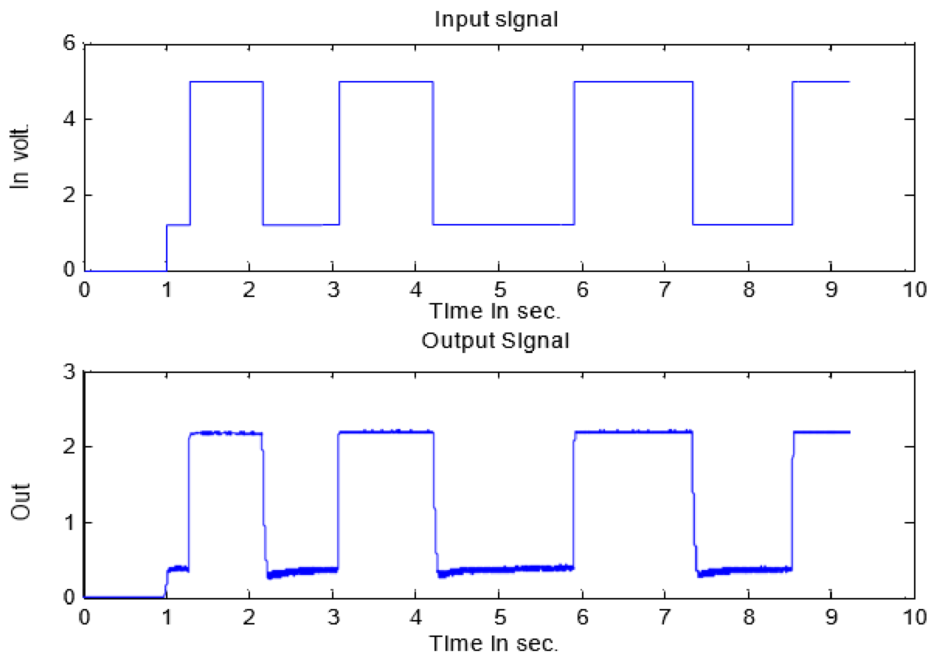

Figure 5: PRBS signals.

With the help of Matlab System Identification toolbox and the Input/output PRBS signals the transfer function given in equation 2 is obtained, data was taken at sampling time=0.01 sec:

$$G_s = \frac{29.19s + 13.36}{s^2 + 62.35\, s + 32.94} \tag{2}$$

However, the estimated transfer function fits to the data by 91.29%, as it is shown in figure 6. In fact, the estimated transfer functions of the DC motors do not represent the exact model whereas the real time test represents the real behavior of the actuators and hence such different results between simulation and real time tests are obtained. For example, if another method of system identification is used or even if another set of the given random signals through the PRBS test are applied on the same actuator, then this will result in a different estimated mathematical model.

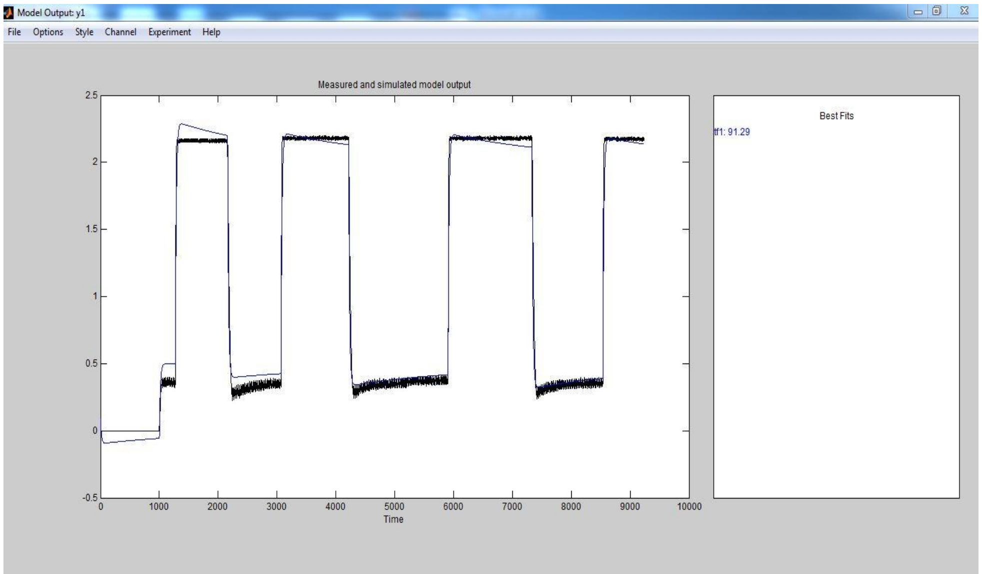

Figure 6: Estimated model output for the PRBS methodology.

5 Conclusion

The performed work in current paper enables the researchers/students to find general methodology that teaches them how to deal with low cost and readily made available component i.e. Arduino board and Matlab Simulink after installing this board's supporting package so that the interfacing process of the DC motor with the software via Arduino Mega becomes easier. The system identification procedure established using two methodologies i.e. linear method and the PRBS test. However, the obtained estimated models of the DC motor academic prototype have 97.4% data fit for the linear method and 91.29% data fit for the PRBS test which makes the linear methodology more preferable if the control application doesn't include load implementation stages. It is important to mention that; most control applications related to the DC motor have disturbances to be rejected and hence the PRBS test estimated model is to be selected for the controller design purposes. The optimal controller design of the utilized DC motor is the next necessary step and considered as the future scope of current work.

Conflicts of Interest Statement

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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