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MICROCONTROLLER-BASED FOR SYSTEM IDENTIFICATION TOOLS USING LEAST SQUARE METHOD FOR RC CIRCUITS

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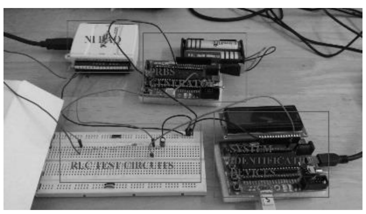
Graphical abstract



Abstract

System identification is one of the method to construct a plant mathematical model from experimental data. This method has been widely applied in the automatic control, aviation, spaceflight medicine, society economics and other fields more. With the rapid growth of the science and technology, the system identification technique has increasingly grown in various applications. Since most of the system identification devices are off-line base, this means that the system identification can only be done after collecting the data and process through a computer devices. This paper will show how to process system identification method with real-time system. This method required a microcontroller as the medium to perform. That's why the system identification method will be programmed into a microcontroller, based on Least Square Method. Later, the system will be tested on a RC circuit to see the effect of the signal and the mathematical model obtained. The data will undergo the system identification toolbox for process using ARX and ARMAX model. On the other hand, the data will also be collected using the microcontroller created for analysis purpose. To ensure the validity of the model some verification methods are performed. Results show that the Least Square Method using Microcontroller base has the capability to work as a system identification tools.

Keywords: System Identification, Least Square Method, RC circuits

Abstrak

Sistem Identifikasi adalah salah satu kaedah untuk membina model matematik tumbuhan daripada data eksperimen. Dengan pertumbuhan pesat dalam sains dan teknologi, teknik pengenalpastian sistem semakin berkembang dalam pelbagai aplikasi. Kertas kerja ini akan menunjukkan bagaimana untuk memproses kaedah Sistem Identifikasi dalam masa nyata. Kaedah ini memerlukan mikropengawal sebagai alat perlaksanaan. Dengan menggunakan Kaedah Least Squares, sistem yang telah disediakan akan diuji dengan litar RC. Dengan demikian, model yang diperoleh akan dibanding dengan model matematik. Data yang telah dikumpul juga akan dibanding dengan process model ARX dan ARMAX. Semua data yang telah dikumpul akan dibanding untuk tujuan mengenapasti ketepatannya dan eksperimen ini telah menunjukkan bahawa Kaedah Least Square yang telah menggunakan micropengawal mempunyai keupayaan bagi mengenalpasti model sistem tersebut.

Kata kunci : Sistem Identifikasi, *Least Square Method*, Litar RC

1.0 INTRODUCTION

System identification is one of the method which uses the input and the output data of the system to build a mathematical modeling of the system [1]. This method is widely used in the field of production and life. Modeling is one of the important aspect to view in for a system.The traditional identification method is normally using first principle of Newton Law and other method to model their system. Due to the complexcity of the modern system and even their unclear internal mechanisms, system identification method has established to play an important role in the process to obtain the mathematical model [2].

There are several methods which can be used in system identification to construct the mathematical model. For example, least square method, gardient correction method maximum like hood method is part of the method which can be found in this field. Recently, some modern methods which are more advantage also could be found being used such as neural network, fuzzy logic and other more. All the methods that have been explored consist of advantage and disadvantage of its usage, however it is up to the researcher or user to choose the method which they prefer and suit their research.

Nowadays, there are many companies providing the platform for system identification method to construct the mathematical modeling. Labview and Matlab are commonly used. System identification method is normally applied after a few set of data collection. The system identification process will be done offline using a computer after the data was collected. Sometime, online base system is much more preferable due to the result that it can be generated instainly. To create an online system identification device, microcontroller is more often being used due to its flexibility and compactness to carry around. By creating this device, a mathematical model of any system can be easily and quickly identified on the spot. By doing so, the modeling can be obtained and analysis can be done faster than the offline base method.

This paper would explain about the needs of the pseudorandom binary sequence generator (PRBS Generator) at the earlier part on how and why we need to create a PRBS generator. Then, it will follow by the system identification method used and the system created. At the discussion part, the paper would compare the system identification generated by the toolbox and the microcontroller using a basic RC circuit. Step response graph can be obtained. By using the root mean square method, the result obtained from the 2 difference methods would be verified. Figure 1 shown the flow chart of the project.

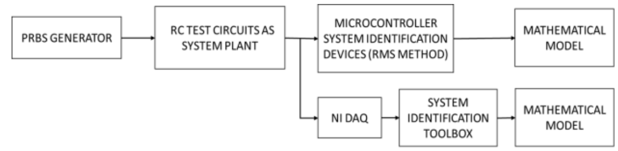


Figure 1 Flow chart of the project

2.0 PSEUDORANDOM BINARY SEQUENCE SIGNAL

Pseudorandom binary sequence signal is a very common signal which is used in the field of signal processing as a noise input [3]. To obtain the input and the output data for analysis in system identification, the input must be a random test signal pattern signal. Since PRBS signal is used to generate random signal, it is normally used as the input signal to test the system due to its randomness to excite its dynamics characteristic. By doing so, a plant could be excited in various forms in term of its dynamics.

2.1 Linear Feedback Shift Register

PRBS signal is using the linear feedback shift register to generate its signal pattern. By using this method, there are 2 factors which determine the difference of the signal generated which depend on the user needs. One of it is the maximal length sequence which define the size of the length for the sequence to be repeated. The maximal length sequence can be determined by Equation 1 and the second one if the feedback gate modulo tapping [4].

$$\mathrm{N} = 2^m - 1 \qquad (1)$$

Table 1 shown the configuration for the PRBS signal for both of the factors mentioned which m is the length of the bits used and Nis the sequence which the signal will repeat after N length bits the feedback shows that the bits which can be tapped to produce the PRBS signal. Mistake in tapping will result in cyclic sequence has the length less than the maximum length.

Table 1 Feedback configuration of linear feedback shift register

No	m	$N=2^m-1$	Feedback
1	2	3	2-1
2	3	7	3-2
3	4	15	4-3
4	5	31	5-3/5-4-3-2/5-4-3-1
5	6	63	6-5/6-5-4-1/6-5-3-2
6	7	127	7-6/7-4/7-6-5-4/…

2.2 Microcontroller Base PRBS Generator

PRBS Generator is an expensive device. To obtain cheaper solution, microcontroller is employed to create a PRBS generator. The project uses PIC microcontroller due to the PIC support up to 16 bits and easily obtain in the market. Using the C language and the LFSR method which was discussed at section A. The PIC created is able to operate at 20 Mb/s or up to 80 Mb/s clock speed. The maximal length sequence is up to 15 bits with 0 to 5 V designable output. The devices also support pattern trigger to initialize the starting of the system signal. The most important part of the device is portable and low cost in term of its prices compare to the market price.

3.0 SYSTEM IDENTIFICATION USING RECURSIVE LEAST SQUARE METHOD

System identification is a process of formatting a mathematical model using measureable data. The data is obtained by comparing the input and the output signal [5]. System identification is also categorized as the black box types modeling method which means that the user does not know anything about the plant system to construct the mathematical modeling. There are various types of estimation that can be done using system identification like autoregressive exogenous (ARX) and also Autoregressive–moving-average model with exogenous inputs model (ARMAX model). But in this paper, the method used is only based on the ARX method using recursive least square method for the estimator [6], [7].

3.1 Recursive Least Square Method (RLSM)

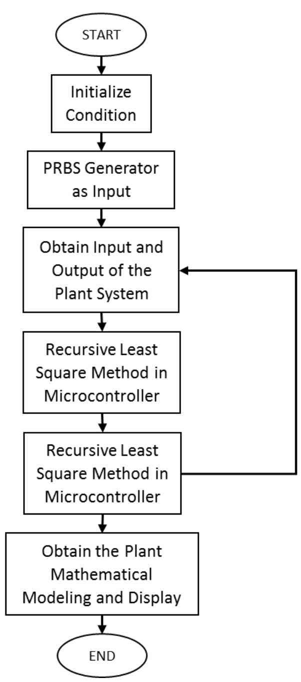


Figure 2 System flow chart

The recursive least square method is the method that will be programmed into the microcontroller as a system identification estimator in this project. The model method utilizes the error between the outputs of the plant to estimate the model as a basic update mechanism. It will determine the best-fit curve line from the given outputs data. By using this method, it will allow the user to save lot of computation time in the process. Equation 2, 3 and 4, show the basic equation on how the RLSM work.

$$\mathbf{X(N)}=\boldsymbol{X_0}(\mathbf{N-1})+\boldsymbol{k}(\mathbf{N})(b-\boldsymbol{X_0}(\mathbf{N-1})*\boldsymbol{a^T}) \quad (2)$$

$$\boldsymbol{k}(\mathbf{N})=\frac{1}{1+\boldsymbol{a^T}\boldsymbol{P_0}(\mathbf{N-1})\boldsymbol{a}}\times\boldsymbol{P_0}(\mathbf{N-1})\boldsymbol{a} \quad (3)$$

$$\boldsymbol{P}(\mathbf{N})=[\boldsymbol{I}-\boldsymbol{k}(\mathbf{N})\boldsymbol{a^T}]\boldsymbol{P_{0(N-1)}} \quad (4)$$

3.2 System Identification based Microcontroller

Figure 2 shows the flow chart of how the system identification using the recursive least square method is being run in a microcontroller.

3.3 Experiment Setup

The experiment setup contains of a few parts: system identification microcontroller, PRBS Generator microcontroller, RC system Circuits, and also NI-DAQ. Figure 3 shows the system identification platform for the whole system.

The input stimulus signal is being generated by a PRBS generator which created by a microcontroller and the signal is sent into the RC circuits. In the meantime, the signal also being collected by the NI-DAQ and System Identification Devices. To initialize the same starting point, a trigger pulse will be sent from the PRBS generator to both the devices. The data obtained from the NI-DAQ will be processed in the Matlab system identification toolbox. On the other and, the system identification devices created will directly display the transfer function for the system.

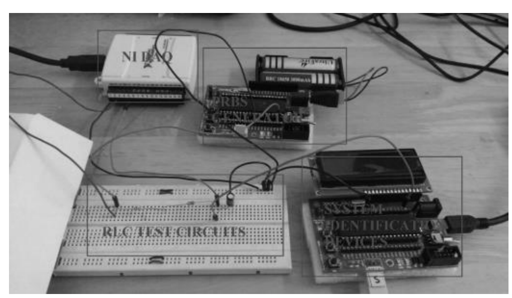


Figure 3 System identification microcontroller platform

3.4 Model Validation

The validation of the model obtained will be compared using a verification method called root mean square error. The method will try to show the difference of both result using the calculation for the graph from Equation 5.

$$RMS\ Error = \frac{\sqrt{(X_1 - X_2)^2}}{n} \qquad (5)$$

The reason RMS Error is chosen because it is easier to interpret statistically and its unit of display is the same as the quality plotted in the vertical axis. This criterion allows to compromise small parameters variation of system and minimize of resulting error of the system [8]. In this case, finding out reliability of the experiment result can be determined.

4.0 RESULTS AND DISCUSSION

Input and output data are being processed in the RC circuit to obtain a set of data. The data sampling time is determined by the set input which initialize to test on the system response time. The sampling rate used in the system is 1000 Hz which means 1000 data will be collected in 1 second time and a 20 second sampling time will be used in the process.

4.1 Model for RC Circuits

RC circuit is an electric circuit which created by resistor and capacitors which is driven by voltage. The system used in this test is first order RC circuit. Since, the project is generally going to test on the newly develop system identification system on the hardware, the simplest RC circuit will be used in this test. Figure 4 shows how the circuit of the RC circuit look like and the component value.

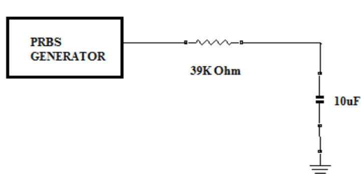


Figure 4 RC circuit

4.2 PRBS Signal Generated and the Response System

Each system response differently when a step input is being injected into a system input. A PRBS signal is like multiply difference of step input is being injected into the system. Figure 5 shows how the system reacts when the PRBS signal is being injected into the RC circuits system. The dotted line in the figure shows the system response according to the input signal.

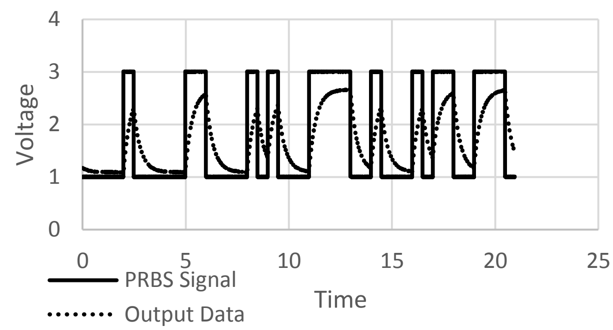


Figure 5 Data collected for system identification process using modulo 6 & 7

4.3 Model from System Identification Toolbox, MATLAB

Model of the data which obtained from the DAQ using 1000Hz sampling rate and 20 s sampling time is shown in Equation 6.

$$MLSID(z) = \frac{0.002397}{Z - 0.9974} \qquad (6)$$

4.4 Model from System Identification Devices, Microcontroller

Model of the data which generated by the microcontroller devices using 1000Hz sampling rate and 20 s sampling time is shown in Equation 7.

$$PIC(z) = \frac{0.002712}{Z - 0.99703} \qquad (7)$$

4.5 Step Response Comparison for the System

Figure 6 shows the step response for both Equation 6 and 7 which obtained from the system identification toolbox and also the microcontroller system identification devices. It is also shows the white box model which is obtained from the calculation itself. From figure 6, the graph shows that the real system is different from the calculation part by having the steady-state error. This happens due to the elimination of noise and disturbance in that calculation. The recursive least square method programmed and the system identification toolbox produced are almost the same.

4.6 Model Verification Results

Figure 7 shows the root mean square error by comparing the system identification toolbox and the model obtained from the microcontroller itself.

The graph shows that there are slightly differences between the two graphs. The rise time of recursive least square method in microcontroller is slightly faster compare to the system identification toolbox. But the differences become smaller by the time being. The reduction of the differences occurs is due to the steady-state error for both graph. A steady-state error exist between the systems since the model is produced from difference method and due to the first order characteristic of the system. The differences of the steady-state error are shown in the end of the graph. The steady state error occur in the system is due to the charging and discharging effect of the capacitor in the system.

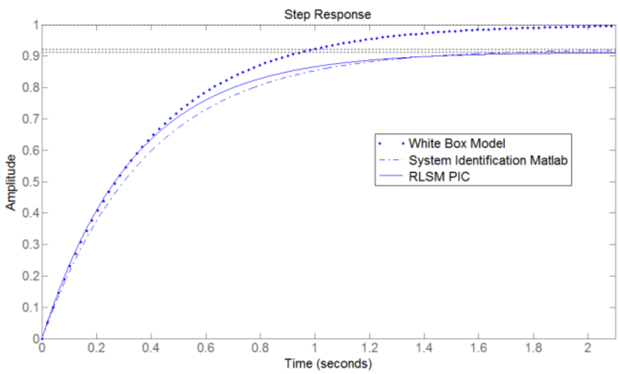


Figure 6 Step response for both system identification result

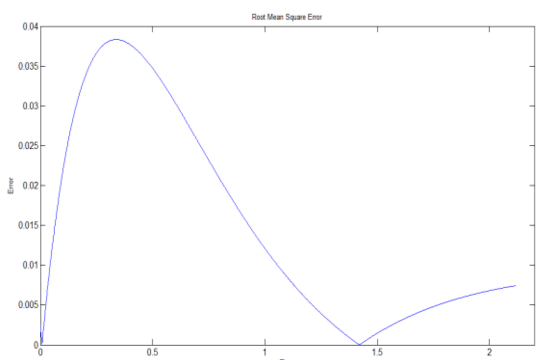


Figure 7 Root mean square error verification

5.0 CONCLUSION

In conclusion, there are various method to develop a mathematical modeling. System identification is one of a method used. This method doesn't require to have a prior knowledge of the system. Normally, System Identification Toolbox and Labview are being used in this method. In this project, a well programmed microcontroller will also perform an accurate method to obtain the mathematical modeling. This project has proven that the RLS Method System identification microcontroller can also well perform in obtaining the model from the RC circuit model used.

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