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Design and Validation of a Specified Length PRBS Generator

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***Abstract**: The Pseudo Random Binary Sequence (PRBS) plays a significant role in modern-day technology. It is a binary number with a random sequence. The binary pattern is usually generated by a distinct pulse pattern generator known as the PRBS which has a vast area of application such as system identification, fibre optic testing, correlation, telecommunication, encryption, spectroscopy of flight time, and conversion of analogue to information among others. Hence, this work aims to design a PRBS generator with a maximum length of N = 18 with SR7 XOR SR18 feedback and also, determine the autocorrelation function. Moreso, a second-order un-damped LC black box circuit was designed. The Arduino Mega microcontroller was utilised as the intermediary between the host PC and the hardware. The hardware was implemented using a capacitor and inductor which was connected to the oscilloscope and multimetre which were used to measure, observe and validate the system response. The model was designed in Matlab Simulink and was validated in real-time.*

***Keyword**: Design, Validation, Specified Length, Pseudorandom Binary Sequence, Signal Processing, FPGA Implementation, Communication Systems, Electronic Circuits.*

Introduction

Work on PRBS has been in existence since the 1960s. They have specified signal lengths and can equally be produced using the shift register circuitry. However, there is a need to precisely connect the circuitry to suitable feedback to attain a useful sequence. A maximum-length PRBS signal has a correlation function that resembles a white noise. Work by [1] shows an enhanced parameter estimation in electrochemical batteries using a simplified monopolar current pulse excitation strategy, identifying Randles' model equivalent circuit values for state-of-charge and state-of-health algorithms while [2] works on the deterministic and repeating after N elements. Implemented using VHDL programming language, it produces a predefined sequence of 1's and 0's with the same probability. The output cycles are between 0 and 65535. The development of PRBS was achieved in [3] by addressing non-uniform distribution issues. It passes statistical tests and performs encryption effectively, subsequently [4] establishing a test signal generator using three shift registers with feedback connections, enabling a longer length sequence for better data pattern detection and subsequently, [5] generates a random, uniform sequence with maximum cycle length and high linear complexity. Experiments verify the sequence's robustness and efficiency, proving superior cryptographic properties compared to existing ones. Therefore this work aims to design an $N = 2^n - 1 = 262144$ employing the SR7 XOR SR18 feedback with a second-order un-damped LC black box circuit as well as determining the autocorrelation function. Figure 1 illustrates the general configuration of the 18-stage shift register with feedback in Simulink.

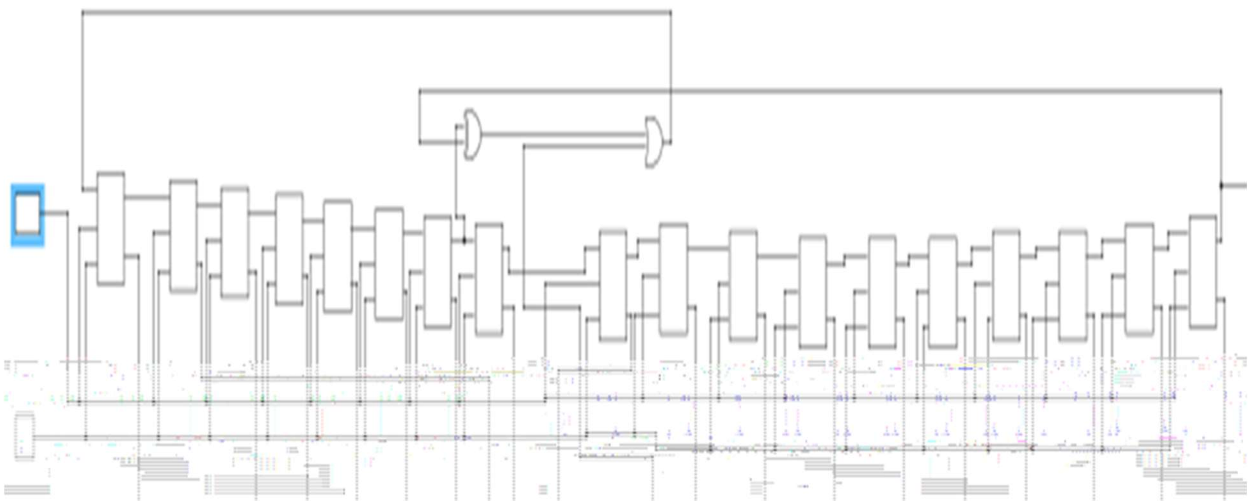


Fig 1. Shows the General Configuration of the 18-Stage Shift Register PRBS Generator with Feedback of XOR of SR7 and SR18.

Method

The PRBS model was designed and implemented with 18 D flip-flops. The system identification toolbox was employed to ascertain the system's best fit and equally determine the model data and the mathematical model. The system input and output signal were observed and the system best fit was found to be 100% which shows the precision of the design, Consequently, the resultant output waveform illustrated the model design requirement which was matched equally with the experimental result. Furthermore, the hardware is conducted using the capacitor and inductor. Figure 2 illustrates the step-by-step system flow.

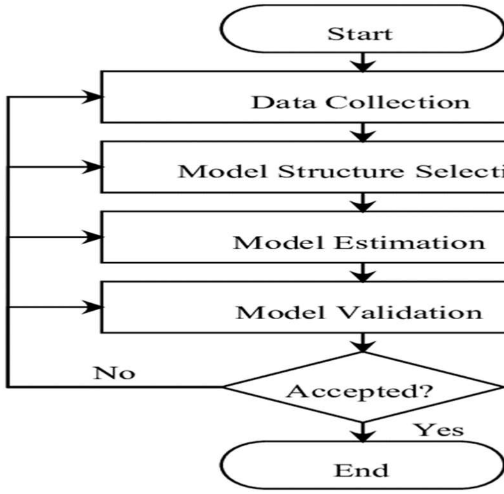
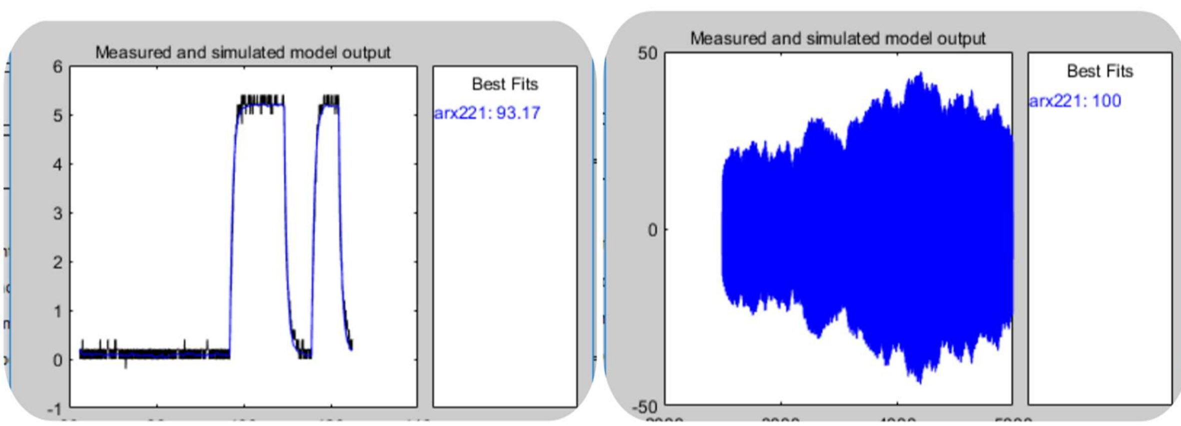


Fig 2. Flowchart

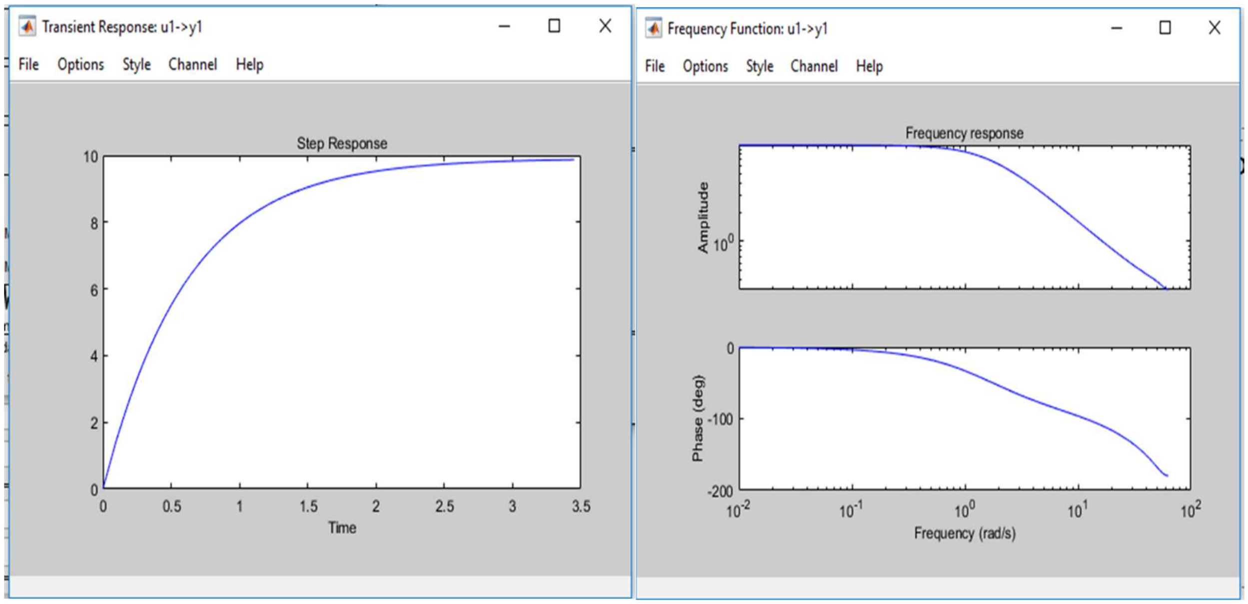
Simulation Result

The resultant output was carefully observed both in terms of waveform and numerical values. Figure 3 describes the performance fitness of the system both in simulation and experiment, where the best fit was observed to be 100% during simulation with a stable system, consequently, real-time results indicate 93.17% with equally a stable system While Figure 4 shows the transient and frequency response. This was attained after capturing the simulation data which was uploaded to the system identification toolbox for system prediction. Figure 5 identifies the noise spectrum and poles and zeros mapping.



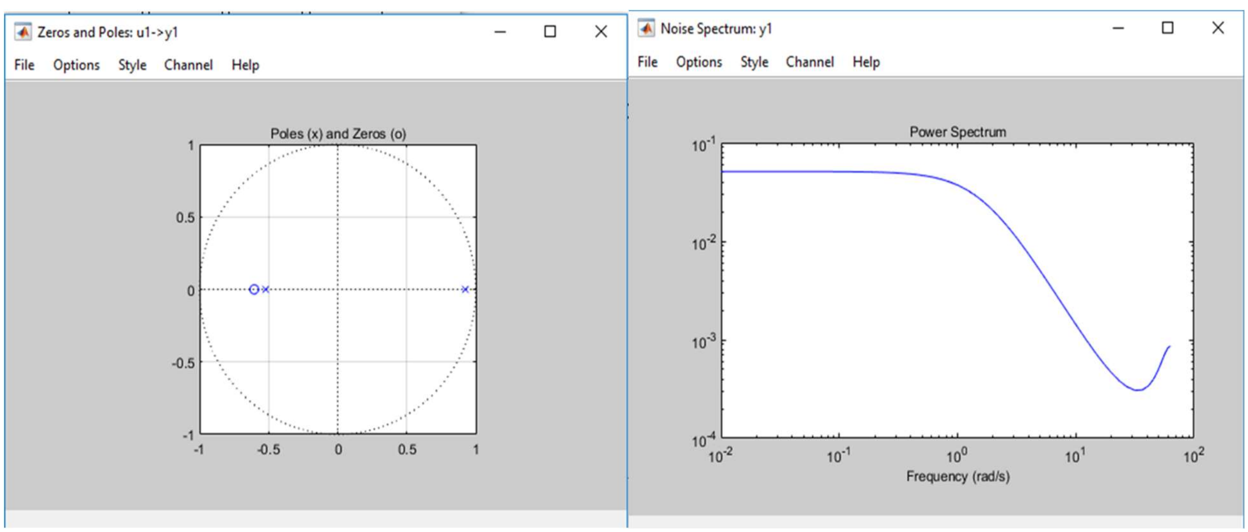
(a) Experiment Result (b) Simulation Result

Fig 3: (a) Experiment Result with 93.17% Best Fit and Stable while (b) Simulation Result with 100% Best Fit and equally Stable.



(a) (b)

Fig 4. (a) Transient Response of u1 against y1 and (b) Frequency Response of u1 against y1.



(a) (b)

Fig 5. (a) Plot of Poles and Zeros Mapping of u1 against y1 and (b) Noise Spectrum of y1.

Figure 6 describes the simulated clock signal. The clock signals are critical in estimating the response frequency for proper commutation, these generated signals can minimize the estimated time which is preferred to the usual sine stream signal input.

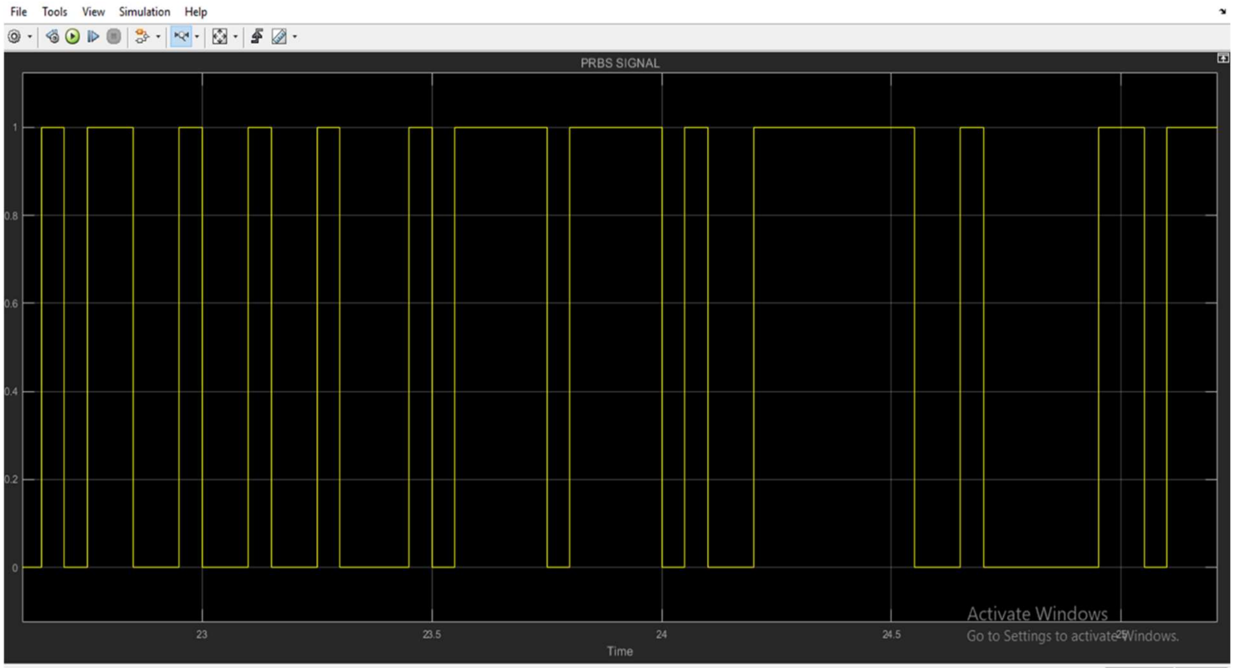


Fig 6: Clock Signal.

Figure 7 shows the PRBS signals which are periodic and have a deterministic white noise such as characteristics which shift between two ideal values. Here, the signal is fundamentally periodic having a determined period of 2^n-1, taken n as the PRBS order.

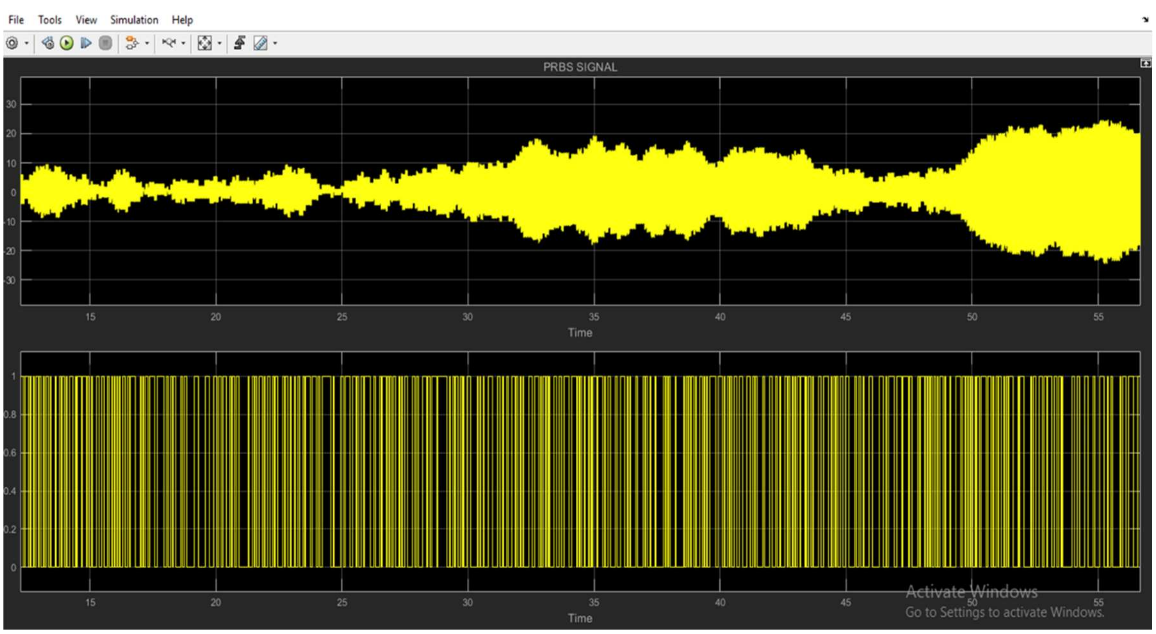


Fig 7. PRBS Signal.

Table 1 describes the truth table register. Here, the designated bits contain a position in the shift register which has some functions where the outcome is sent back to the input bit signal. These shifts register feedback has some specified signal in the chain of the register which includes an XOR tap to produce a signal back to the register. The feedback is needed by the system for stability and to avoid errors.

Table 1. The Truth Table of PRBs

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	SR1	SR2	SR3	SR4	SR5	SR6	SR7	SR8	SR9	SR10	SR11	SR12	SR13	SR14	SR15	SR16	SR17	SR18	XOR
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
3	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
4	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
5	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
6	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
7	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
8	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0
9	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1

Hardware Setup

The Experimental setup contains the host PC, LC connection, Arduino Mega and the oscilloscope. The hardware terminals were investigated to ensure accuracy. Figure 8 shows the black box circuit in which the transfer function is expressed in equation (1) while Figure 9 shows the interconnection between the LC terminal and the Arduino.

$$\text{T.F} = \frac{1/_{LC}}{S^2 + 1/_{LC}} \qquad (1)$$

Taken the value of L= 100mH and C= 30uF.

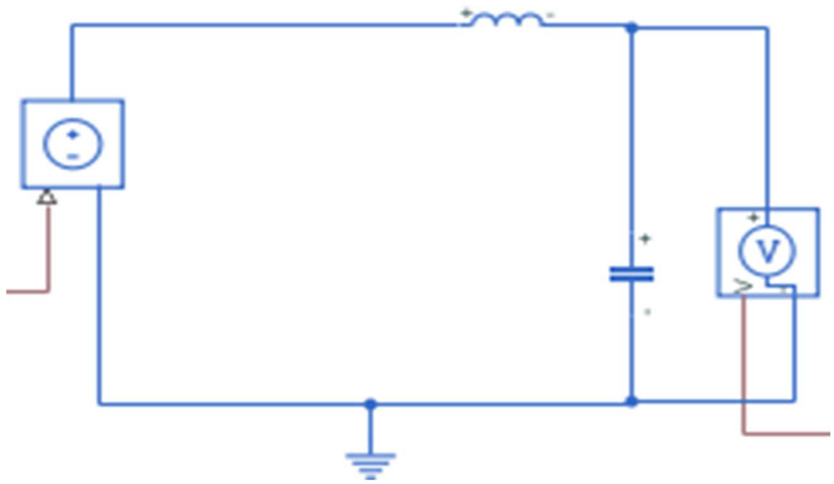


Fig 8. black box circuit

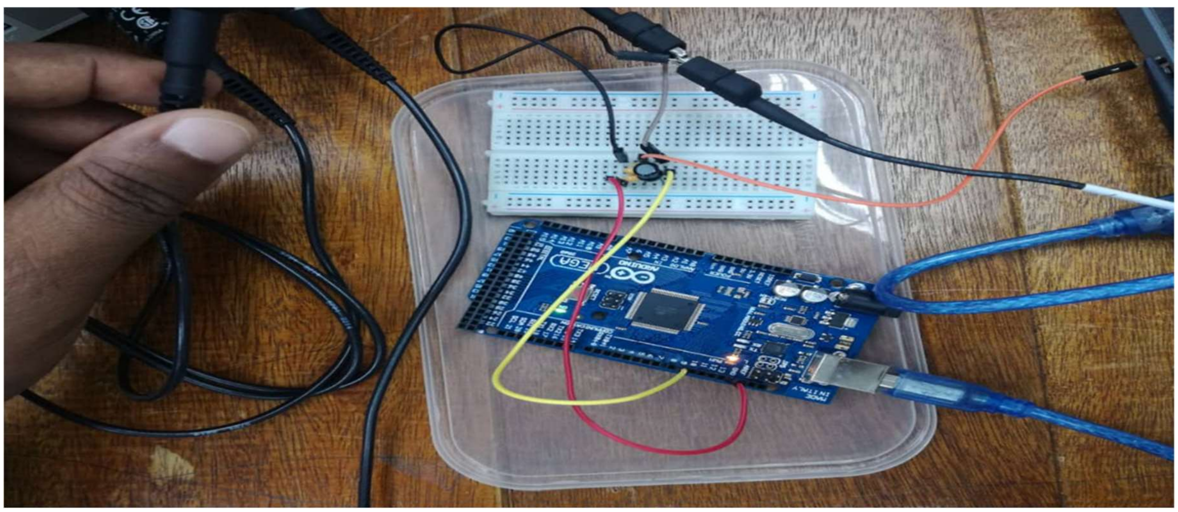


Fig 9. Picture Showing the LC Connection.

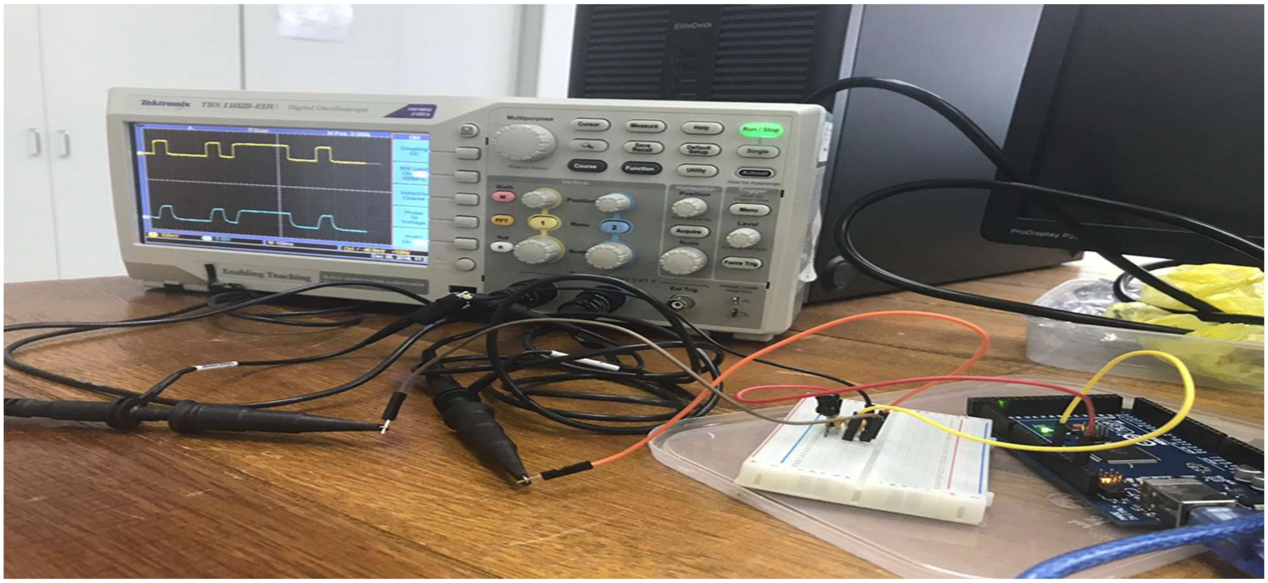


Fig 10. Shows the Hardware Setup.

Record Le	2.50E+03		0	0.02
Sample In	4.00E-04		0.0004	0.02
Trigger Po	0.00E+00		0.0008	0
			0.0012	0
			0.0016	0
			0.002	0
Source	CH1		0.0024	0
Vertical U	V		0.0028	0.02
Vertical Sc	5.00E-01		0.0032	0.02
Vertical O	1.02E+00		0.0036	0
Horizonta	s		0.004	0
Horizonta	1.00E-01		0.0044	0.02
Pt Fmt	Y		0.0048	0.02
Yzero	0.00E+00		0.0052	0
Probe Att	1.00E+00		0.0056	0.02
Model Nu	TBS1102B-EDU		0.006	0.02
Serial Nur	C011834		0.0064	0
Firmware	FV:v2.52		0.0068	0

(a) Input

Record Le	2.50E+03		0	0.2
Sample In	4.00E-04		0.0004	0.4
Trigger Po	0.00E+00		0.0008	0.2
			0.0012	0.4
			0.0016	0.2
			0.002	0.2
Source	CH2		0.0024	0.2
Vertical U	V		0.0028	0
Vertical Sc	5.00E+00		0.0032	0.2
Vertical O	-6.60E+00		0.0036	0.2
Horizonta	s		0.004	0.2
Horizonta	1.00E-01		0.0044	0.2
Pt Fmt	Y		0.0048	0.4
Yzero	0.00E+00		0.0052	0.2
Probe Att	1.00E+01		0.0056	0.2
Model Nu	TBS1102B-EDU		0.006	0.4
Serial Nur	C011834		0.0064	0.2
Firmware	FV:v2.52		0.0068	0.2

(b) Output

Fig 11. Shows the Input and Output Data Captured

The output from the oscilloscope Figure 12 describes the accuracy of the data captured, where channel 1 yellow indicates the input of the PRBS signal while channel 2 blue shows the output of the black box.

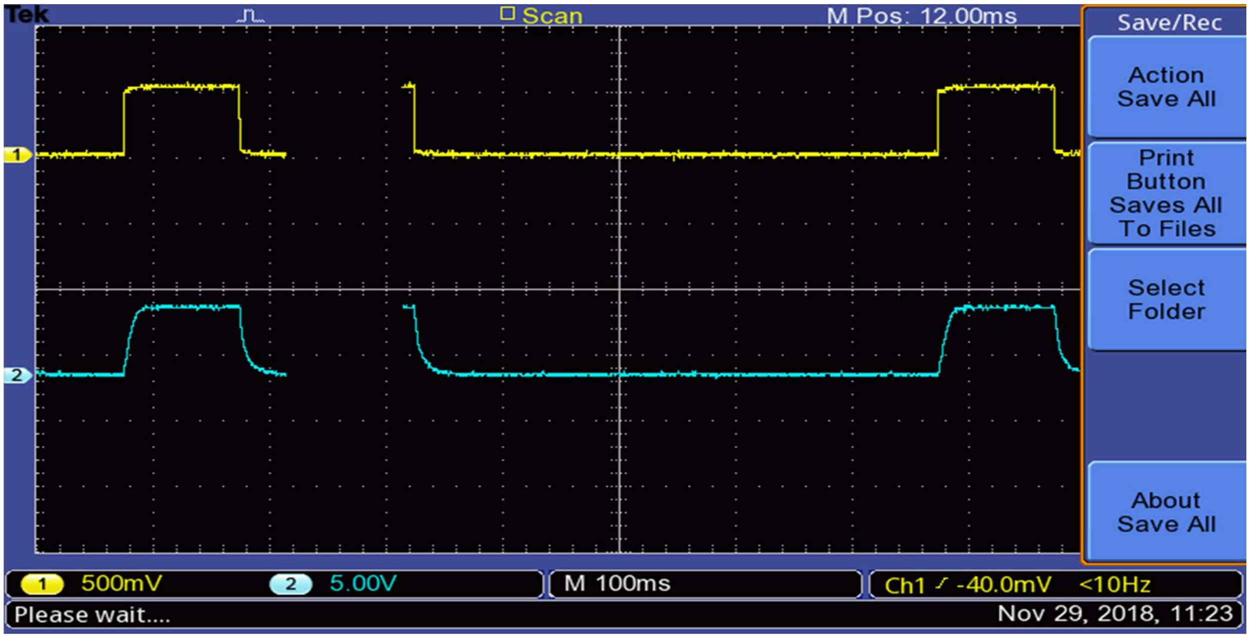


Fig 12. Experiment Result.

Conclusion

Conclusively, the generation of a PRBS with a maximum length of 262144bit was attained where the general configuration of 18 stage shift register PRBS generator has feedback of XOR of SR7 and SR18 equally, the output configuration of the system was through SR18. Waveforms were observed and compared equally for optimum efficiency. However. it was observed that the simulation result was more stable with a best fit of 100% compared to the experimental data with a best fit of 93.17% and stable. It is however worth saying that the experiment result validates the simulation result.

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