

DESIGN AND IMPLEMENTATION OF NOISE GENERATOR

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ABSTRACT

The objective of this paper was to give an insight into the design and implementation of noise generator as well as to generate noise that can serve a useful purpose in the statistical data. Eliminating or minimizing the effect of noise in electronic circuits or communication systems is the problem of all designers. The generation of noise and the study of its characteristics overcome the problem of designers in electrical engineering.

I. INTRODUCTION

The concept of noise plays crucial role in the statistical analysis of data. "Noise" is a term used to signify extraneous signals which do not convey any useful information for the problem at hand, and which can only be described by their statistical properties". Noise can be defined as an electrical signal which has no pattern and the sources are unpredictable in values (Gupta, 1977). Noise sources are unpredictable in the sense that instantaneous waveforms can't be predicted over any significant interval of time. One can however, describe noise sources in statistical terms, such as probabilities, mean-square values and correlation functions. Noise in electric devices consist of random fluctuations of environmental noise in small electrical conductors while in electronics noise is an unwanted signal characteristic of all electronic circuit depending on the circuit the noise put out by electronic devices can vary greatly. This noise comes from many different electronics effects. Noise itself can be another signal which can be characterized by its frequency spectrum, its mechanism responsible of its generation (Johnson, 1971)

The approach in this work was to filter out the unwanted signal using the low pass filter. Each of the units of this design is implemented to perform its function as; the power supply is to provide a stable regulated desired dc voltage to all units while either the 555 timer or the crystal oscillator is to clock the pseudo random noise generator sequence as shown in Figure 1.

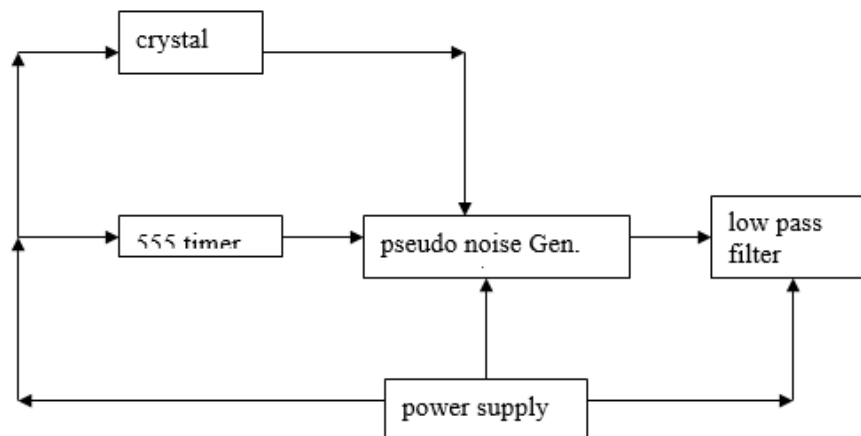


Figure 1: Block diagram of the noise generator.

In any telecommunication system, whether using line or radio links, there is unwanted electrical energy present as well as that of the wanted information signal. This unwanted electrical energy is called noise. The various type of noise includes;

Resistor Noise: The random movement of atoms gives rise to an unwanted electrical voltage which is called resistor noise, circuit noise, Johnson noise or thermal noise. This unwanted signal spread over a wide range of frequencies, and the noise present in a given bandwidth required for a particular information signal is very important.

Shot noise: This is the name given to noise generated in active devices (energy sources), such as valves and transistors, by random varying velocity of electron movement under the influence of externally applied potentials or voltage at appropriate terminals or electrodes.

Fluctuation noise: This can be natural (electric thunderstorms, etc) or man made (coronation systems, electrical apparatus, etc.) and again spread over a wide range of frequencies, such noise can be picked up by active devices and conductors forming transmission lines.

Static Noise or white noise: This is the name given to noise encountered in the free-space transmission paths of radio links, and is due mainly to ionosphere storms causing fluctuation of the earth's magnetic field. This form of noise is affected by the rotation of the sun (27.3-day cycle) and by the sunspot activity that prevails.

Cosmic or Galactic Noise: This type of noise is also most troublesome to radio links, and is mainly due to nuclear disturbances in all the galaxies of the universe.

Flicker noise or 1/f: A large number of physical phenomenon, such as mobility fluctuations, electromagnetic radiations, and quantum noise (Yugvessin, 1991), exhibit a noise power that varies inversely with frequency. The 1/f noise is important from 1kHz to 1MHz.

II Application of Noise Generator

1. Noise generators can serve a useful purpose; a common example of this is in random number generation.
2. Noise generators are used in probabilities games
3. Noise generators are used in sampling of data
4. Noise generators and sources are used to produce noise outputs for testing radio frequency (RF) equipment.
5. Noise generators are used to test and align many types of transmitters and receivers.
6. They measure frequency, tuneable within certain frequency bands, and are used in a variety of test application.
7. Noise sources are used to provide known good signals
8. Some application of noise generator and sources include: encryption, dithering, jamming or gumming simulation and base signal simulation (Piece, 1956)
9. Noise sources are also used for calibration reference.

III. Implementation

Power Unit

Power supply circuit is built using filters, rectifiers, and then voltage regulators. Starting with an A.c. voltage. A steady dc voltage is obtained by rectifying the ac voltage, then filtering to a dc level and finally, regulating to obtain a desired fixed dc voltage. The regulator is usually obtained from an IC voltage regular unit, which takes a dc voltage and provides a somewhat lower dc voltage which remains the same even if the input dc voltage varies or the output load connected to the voltage changes.

DC Voltage Regulation

The ac voltage typically 220-250v rms, is connected to a transformer which steps that ac voltage down to the level for the desired dc output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simply capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation.

A regulator circuit can use this dc input to provide a dc voltage that not only has much less ripple voltage but also remains the same dc value if the input dc voltage varies some what or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of a number of popular voltage regulator IC units.

The IC's regulators that are used in the power unit of this work are 7805, 7812 and 7912.

The overall circuit diagram of the power unit of the system is shown in Figure 2.

Specification for the diodes

Max. V_r	=	1.1v	forward voltage drop
I_r average	=	1.0 A	average forward current
Max V_0	=	50v	reverse voltage drop
Max I_0	=	10 μ A	reverse current

Positive voltage regulators in 7800 series

IC part	output voltage (v)	minimum V_i (v)
7805	+5	7.3
7812	+12	14.6

Table 1: Specification sheet data for voltage regulator ICs. $\mu F7812C$ Electrical characteristics.

Parameters	Min	Type	Max	Units
$\%_p$ Voltage	11.5	12	12.5	V
$\%_p$ regulation		3	120	mv
Ripple rejection	55	11		dB
$\%_p$ regulation		4	100	mv
$\%_p$ resistance		0.018		Ω
Drop out voltage		2.0		V
Short circuit $\%_p$ current		3.5		mA
Peak $\%_p$ current		2.2		A

The output of the 7812 when measured with a rms meter was found to be 12.07v and that of the 7912 was -11.97v. 7805 regulator given exactly 5v dc.

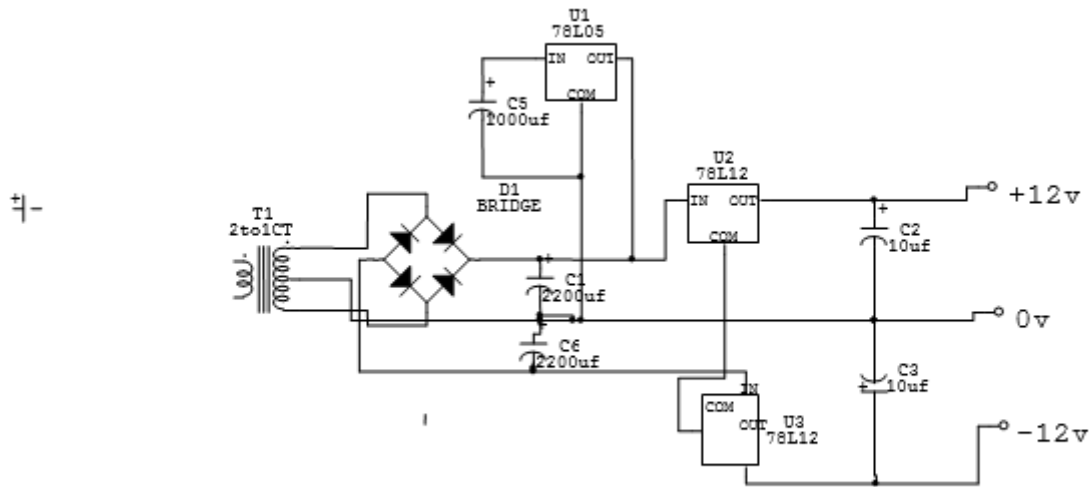


Figure 2: Power unit.

Calculation for 7805 regulator

$$V_r(\text{peak}) = \sqrt{3}V_r(\text{rms}) = \frac{\sqrt{3} \times 2.4I_{dc}}{C} = \frac{\sqrt{3} \times 2.4 \times 400}{250} = 6.65\text{v} \quad (1)$$

$$V_{dc} = V_m - V_r(\text{peak}) = 15 - 6.65 = 8.35\text{v}$$

Since the input swings around this dc level, the minimum input voltage can drop to as low as;

$$V_i(\text{low}) = V_{dc} - V_r(\text{peak}) = 15 - 6.65 = 8.35\text{v} \quad (2)$$

Since the voltage is greater than the minimum required for the IC regulator then

$V_i = 7.3\text{v}$ from the specification table.

The IC can provide a regulated voltage to the load.

Determine the maximum value of load current at which regulation is maintained for the circuit above;

To maintain $V_i(\text{min}) \geq 7.3\text{v}$

$$V_r(\text{peak}) \leq V_m - V_i(\text{min}) = 15 - 7.3 = 7.7\text{v} \quad (3)$$

$$\text{So that } V_r(\text{rms}) = \frac{V_r(\text{peak})}{\sqrt{3}} = \frac{7.7}{1.73} = 4.4\text{V}$$

The value of load current is then

$$I_{dc} = \frac{V_r(\text{rms})C}{2.4} = \frac{4.4 \times 250}{2.4} = 458\text{mA} \quad (4)$$

Any current above this value is too large for the circuit to maintain the regulator output at +5V

Pseudo Random Sequences Generator

The SN74LS164 is a high speed 8-bit serial in parallel out shift register. Serial data is entered through a 2-input AND gate synchronous with the LOW to HIGH transition of the clock. The device features an asynchronous masters reset which clears the register setting all output LOW independent of the clocks. It utilizes the schottky divide damped process to achieve high speeds and is fully compatible with all semiconductor TTL products (Ragazzini and Chang, 1962).

Typical shift frequency of 35 MHz

Asynchronous master reset

Gated serial data input

Fully synchronous data transfers

Input damp divides unit High speed

Effects

ESD> 3500 Volts

Table 2: SN74LS164 Specification

SYMBOL	PARAMETER	MIN	TYPE	MAX	UNIT
Vcc	Supply Ambient	4.75	5.0	5.25	V
TA	Operating Range Output Current-High	0	25	70	⁰ C
IOH				-0.4	mA
IOL	Output Current –Low			8.0	mA

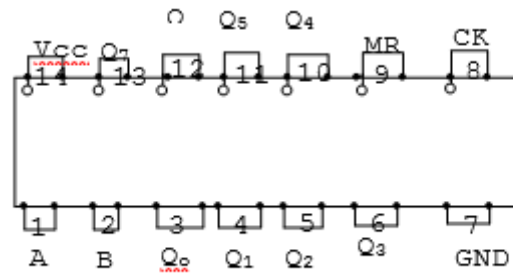


Figure 3: Connection Diagram DIP (Top View).

Pin Names

- A,B - Data inputs
 CK - Clock (Active High Going Edge) input
 MR - Master Reset (Active Low) Input
 Q₀-Q₇ - Output
 LOADING

Table 3: Loading specification.

PIN	HIGH	LOW
AB	0.5 UL	0.25 UL
CK	0.5 UL	0.25 UL
MR	0.5 UL	0.25 UL
Q ₀ -Q ₇	10 UL	5 UL

Note

TTL Unit Load (U.L)

= 40uA High /1.6mA LOW

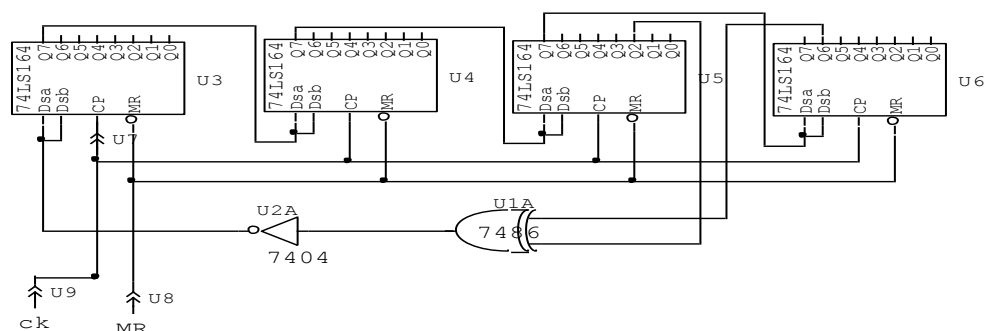


Figure 4: Pseudo random sequence generator circuit.

The 555 Timer

The NE 555 IC chip was used. The circuit diagram is shown in Figure 5.

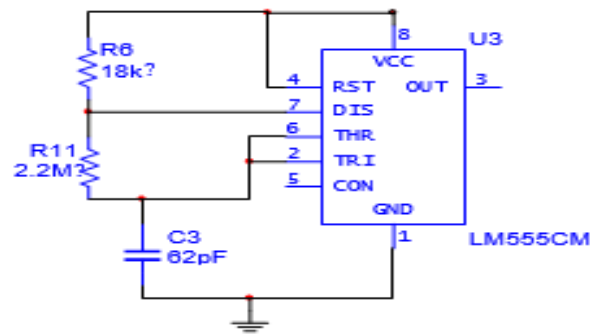


Figure 5: 555 circuit connection is a stable mode.

Mathematically,

$$\text{Where } t_H = t_{\text{High}} = T_{\text{low}}$$

$$t_H = 0.693 (R_A + R_B) C$$

$$t_L = 0.693 R_B C$$

$$\text{Period is } T = t_H + t_L = 0.693 (R_A + R_B) C$$

$$\text{The frequency} = \frac{1.44}{(R_A + R_B) C} \quad (5)$$

$$\text{Output driver duty cycle } \frac{t_H}{t_H + t_L} = \frac{t_H}{R_A + R_B} \quad (6)$$

$$\text{Output driver duty cycle} = \frac{R_B}{R_A + 2R_B} \quad (7)$$

$$\text{Output driver duty cycle } \frac{t_L}{t_H} = \frac{R_B}{R_A + 2R_B} \quad (8)$$

$$\text{The design frequency } F = 5\text{KHZ}$$

$$T = \frac{1}{F} = \frac{1}{5 \times 10^{-3}} = 0.2\text{ms}$$

$$\text{We have } T = 0.693 (R_A + 2R_B) C$$

$$\text{if } C = 62\text{pf}$$

$$\text{we have } T = 0.693 \times 10^{-3} \times 62 (R_A + 2R_B)$$

$$(R_A + 2R_B) = \frac{0.2 \times 10^{-3}}{0.693 \times 62 \times 10^{-9} \times 10^{-3}}$$

$$\text{If } R_A = 18\text{K}\Omega$$

$$2R_B = 4637$$

$$R_B = 2318.5\text{ K}\Omega$$

$$\begin{aligned}
 \text{Preferred Value } R_B &= 2.2 \text{ M}\Omega \\
 t_H &= 0.693 (18 + 2300) \times 10^3 \times 62 \times 10^{-12} \\
 t_H &= 0.000099595 = 99.6 \text{ms} \\
 t_L &= 0.693 R_B C = 0.693 \times 2.3 \times 10^3 \times 62 \times 10^{-12} \\
 t_L &= 0.000098821 = 98.8 \text{ms} \\
 t_L &= t_H
 \end{aligned}$$

$$\text{Duty cycle} = \frac{t_H}{t_H + t_L} = \frac{99.6}{99.6 + 98.8}$$

$$\text{Duty cycle} = 50\%$$

$$\text{Period } T = t_H + t_L = 0.000198416$$

$$T = 198.42 \text{ms}$$

$$F = \frac{1}{T} = 5039.8958 \text{Hz}$$

$$F = 5.04 \text{ KHz}$$

Low Pass Filter

The Vcc voltage (controlled voltage sources) circuit configuration is used. The filter has two poles and is Butterworth since maximum flatness of pass band is desired (Smale,1981)

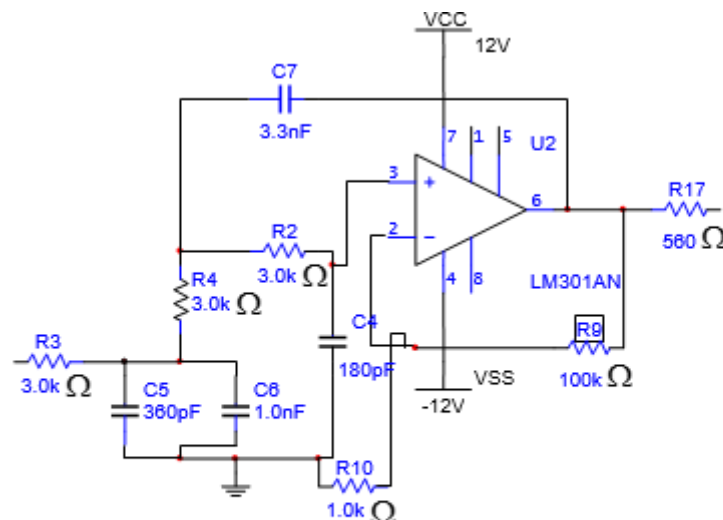


Figure 6: Second order low pass filter.

The expression of the transfer function of the low pass filter From node 1, we have

$$\frac{V_i - V_p}{R} = (V_o - V_p)SC + (V_p - V_A) \quad (9)$$

$$\frac{V_i}{R} = V_oSC - V_pSC + \frac{2V_p - V_A}{R}$$

$$V_i = V_oSC + V_p \left(\frac{2}{R} - SC \right) - \frac{V_A}{R}$$

$$V_i = V_oSCR + V_p \left(\frac{2}{R} - SCR \right) - V_A \quad (10)$$

We have $\frac{V_p - V_A}{R} = V_A SC$

From Node 2

$$V_A = \frac{V_o R_1}{R_1 + R_2} (SCR + 1) \quad (11)$$

$$V_i(s) = V_o SCR + \frac{V_o R_1}{R_1 + R_2} (SCR + 1)(2 - SCR) \frac{V_o R_1}{R_1 + R_2}$$

$$V_i = V_o \frac{[SCR(R_1 + R_2) + (R_1 S^2 C^2 R^2 + R_1 SCR + R_1)]}{R_1 + R_2}$$

$$\frac{V_i(s)}{V_o(s)} = \frac{R_1 + R_2 V_o(s)}{R_1 S^2 C^2 R^2 + SCR(R_1 + R_2) + R_1}$$

$$\frac{V_o}{V_i} = \frac{\frac{R_1 + R_2}{R_1} \times \frac{1}{C^2 R^2}}{C^2 + \frac{S(2R_1 + R_2)}{RC} + \frac{1}{R^2 C^2}}$$

Let $\frac{R_1 + R_2}{R_1} = A$

$$2R_1 + R_2 = K$$

$$\frac{1}{RC} = W$$

$$\frac{V_o(s)}{V_i(s)} = \frac{AW^2}{S^2 + KWS + W^2} \quad (12)$$

The overall transfer functions of a second-order (2 poles) low pass filter.

We have $\frac{1}{RC} = W = 2\pi FC$ where FC is the cut off frequency of the

Filter. The cut-off frequency is $= \frac{1}{RC} = 2\pi \times 50 \times 10^3$

If $R = 10K\Omega$

$$C = \frac{1}{2\pi \times 50 \times 10^3}$$

$$C = 3.18 \text{ nf}$$

Let $R_1 = R = 10K\Omega$

For the $V=V_c$ table the gain of a 2 pole filter is 1.586

If $R_1 = R = 10K\Omega$ we have

$$\frac{R_1 + R_2}{R_1} = \frac{R + R_2}{R} = 1$$

$$R_2 = (1.586 - 1) R$$

$$R_2 = 5.86K\Omega$$

Or voltage gain below the cut off frequency

$$\begin{aligned} A_v &= \frac{1 + R_G}{R_F} = \frac{R + R_2}{R} \\ &= 1 + \frac{5.86 \times 10^3}{10 \times 10^3} \\ &= 1.586 \end{aligned} \tag{13}$$

$$\text{Cut off frequency } F_{OH} = \frac{1}{2\pi RC} = 50048.72 \text{ Hz} = 50 \text{ KHz}$$

IV. EXPERIMENTAL RESULTS

Noise Figure

The noise figure of an amplifier is defined as the ratio in decibels of the output of the amplifier to the output of a “noiseless” amplifier with same gain. Therefore, the noise figure can be expressed as;

$$NF = 10 \log \frac{V_n^2}{V_o^2} \tag{14}$$

Different readings were taken for different values of source resistances and the results are tabulated as shown in Table 5.

The noise Figure measured for all the values of source resistance was approximately 3dB, this indicates that the amplifier is relatively noisy since the best noise figure for amplifier is about 0.2dB for a source resistance of around 10k (Horowitz and Hill 1987). However, this noise figure is acceptable since noise figure of amplifiers varies from about 0.2dB to 3dB for relatively good performance.

Table 4: Noise figure measurement.

Meter reading with noise generator disconnected $V_o(\text{mV})$	Meter reading with noise generator connected $V_n(\text{mV})$	$R_s(\text{k}\Omega)$	NF (dB)
4.20	6.32	0.1	3.05
4.18	6.25	0.5	3.01
4.16	6.24	1.0	3.00
4.14	6.20	5.0	2.99
4.12	6.18	10.0	2.98
4.11	6.17	50.0	2.97
4.10	6.10	100.0	2.90

Noise Temperature

Noise temperature is defined as the temperature to which the noise source resistance would have to be raised to produce the same available noise output power as the amplifier. The relationship between noise figure and noise temperature is given by.

$$NF = \left(1 + \frac{T}{T_o} \right) \quad (15)$$

Where T is the noise temperature

T_o is the ambient temperature

Thus from the figure the noise temperature can be calculated.

For $NF = 3.05$; $T_o = 300^\circ\text{K}$

$T = 306^\circ\text{K}$

For $NF = 2.9$

$T = 285^\circ\text{K}$

Table 5: Measurements of noise temperature as source resistance varies.

Source resistance (k Ω)	Noise temperature ($^{\circ}$ k)
0.1	306.0
0.5	300.0
1.0	296.6
5.0	297.0
10.0	296.0
50.0	294.0
100.0	285.0

The noise temperature calculated between 306 $^{\circ}$ k and 285 $^{\circ}$ k while the amplifier is operating at 300 $^{\circ}$ k from the amplifier IC specification. For good performance the noise temperature should be different from the operating temperature of the amplifier. The result obtained show that the source resistance is equal to 0.5 k Ω and the noise temperature was equal to the operating temperature of the amplifier.

Signal-to-Noise Ratio (SNR)

The signal to noise ratio defined as;

$$SNR = 10 \log \frac{V_s^2}{V_n^2} \text{ dB} \quad (16)$$

Where V_s is the signal amplitude

V_n is the noise amplitude

In terms of noise figure the signal to noise ratio can be expressed as;

$$SNR = -NF \text{ (dB)}$$

Table 6: Measurements of SNR as source resistance varies.

Source resistance (k Ω)	SNR (dB)
0.1	-3.05
0.5	-3.01
1.0	-3.00
5.0	-2.99
10.0	-2.98
50.0	-2.97
100.0	-2.90

The Noise Voltage V_n (RMS);

The rms noise voltage is expressed as;

$$V_n(\text{rms}) = a \left(\frac{2}{F_{\text{clock}}} \right)^{1/2} \text{ (v/Hz)} \quad (17)$$

Where a is the peak amplitude of the noise voltage.

The peak noise voltage measured from the scope for a frequency of 1MHz was 15 mV, therefore we have;

$$V_n(rms) = 15 \times 10^{-3} \times \left(\frac{2}{10}\right)^{1/2}$$

$$V_n(rms) = 20 \mu V$$

The noise voltage calculated was high compared to noise amplitude in electronics circuits. This show that the circuit designed in this work was a noise generator.

Noise Resistance

We have;

$$V_n(rms) = (4KTRB)^{1/2} \quad (18)$$

Where K is Boltzman constant equal to 1.38×10^{-23}

T is the absolute temperature

B is the bandwidth measurement

For our measurement

$$B = 48 \text{ KHz}$$

$$T = 300 \text{ }^0\text{K}$$

$$R = 557.3 \text{ K}\Omega$$

The wave forms of the noise generated was simulate for a frequency of 100 Hz.

Noise Bandwidth

The measurement of noise voltage versus frequency were recorded and tabulated in Table 7.

Table 9: Noise voltage for different frequencies.

Noise voltage (mV)	Frequency (Hz)
4.10	100.0
4.20	1.0k
4.2	10.0k
4.17	100.0K
4.17	1.0M

Specification of noise generator

Noise bandwidth 48 kHz

Noise temperature 300°k
 Noise voltage peak 15mV

Input impedance

Output impedance 182.7kΩ

The graph of noise voltage (peak) was plotted

Bandwidth $BW = F_1 - F_2 = (148.7 - 100)$
 $= 48.7\text{kHz}$

APPENDIX A

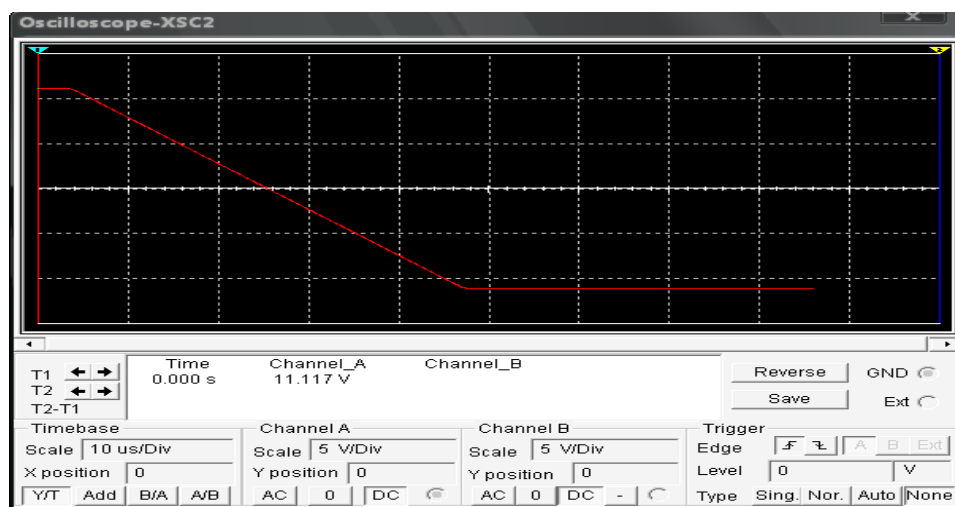


Figure 7: Output of the digital filter section.

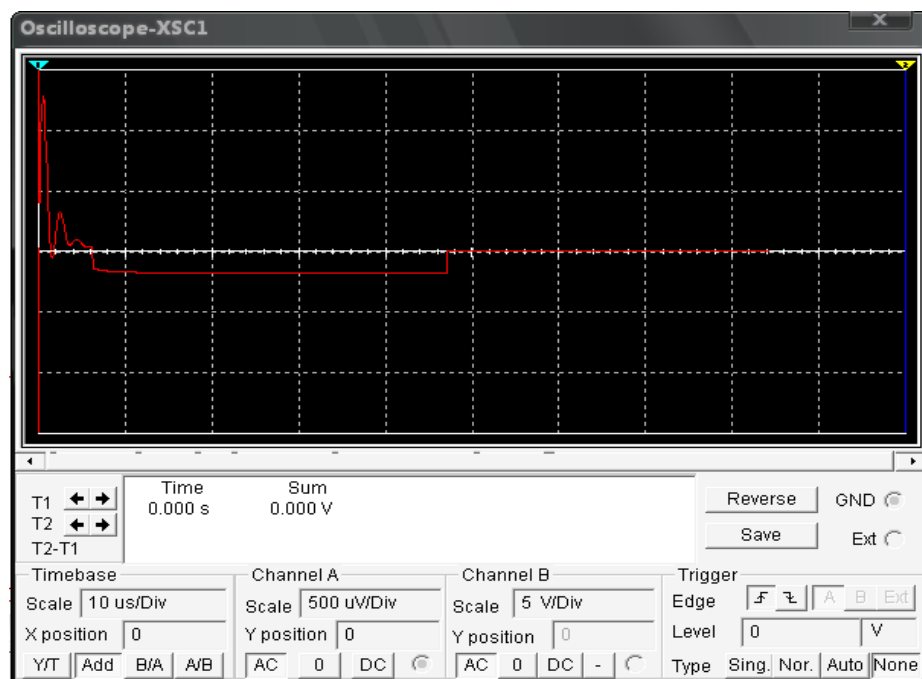


Figure 8: Output of the analog section of the circuit.

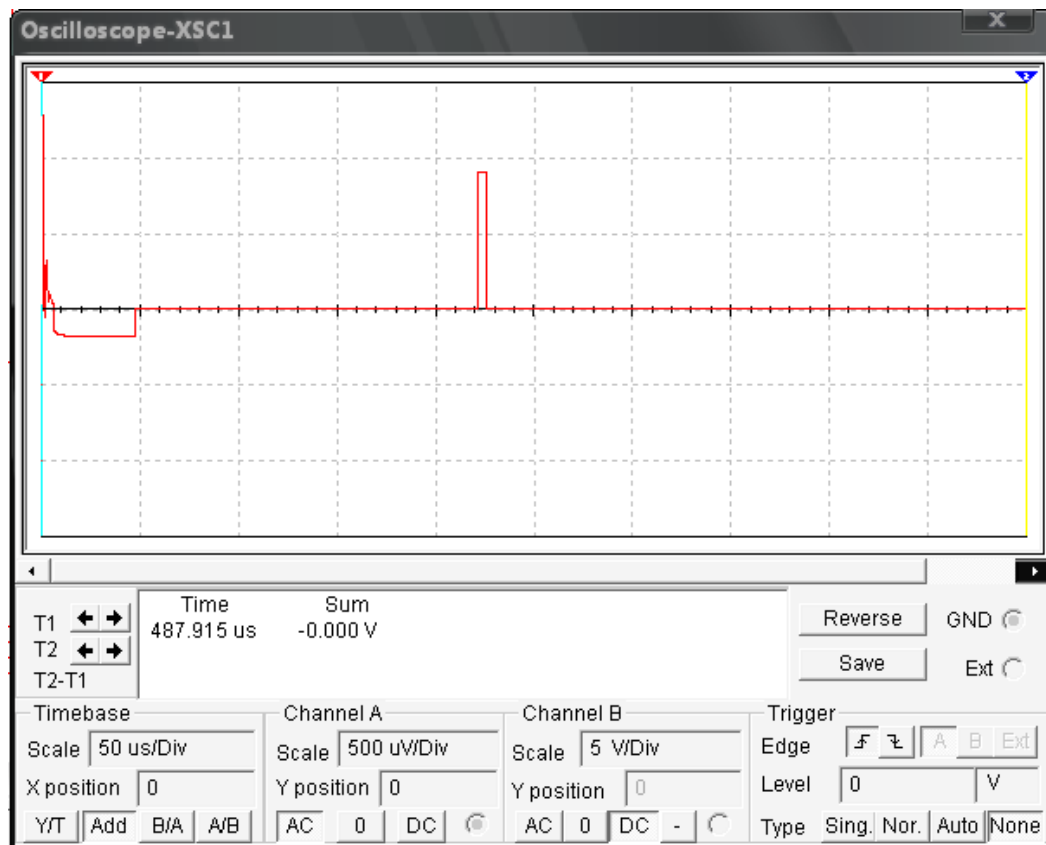


Figure 9: A better view of the analog output section.

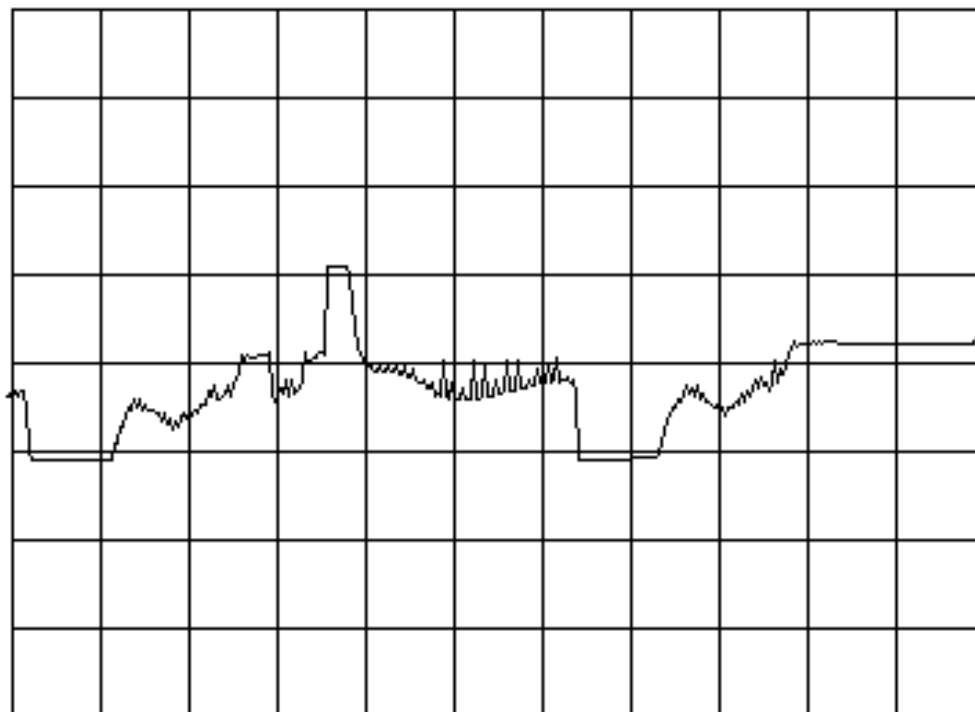


Figure 10: Analog noise output.

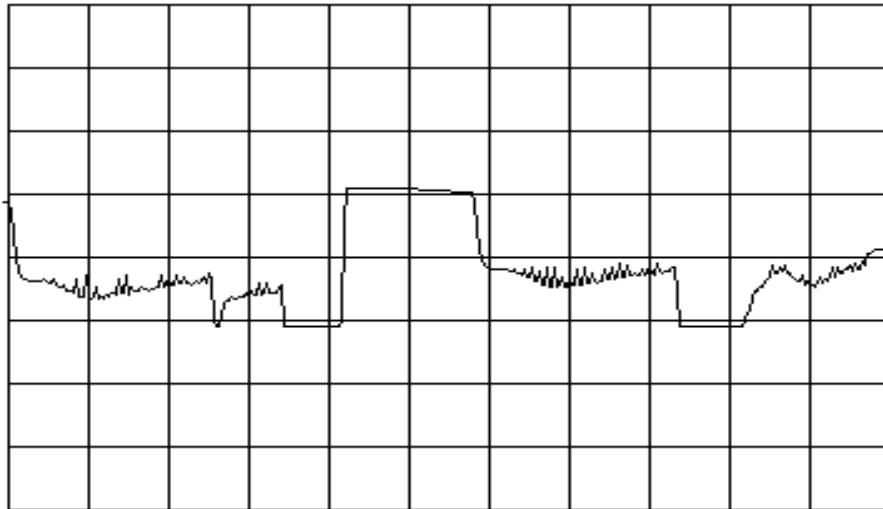


Figure 11: Analog noise output.

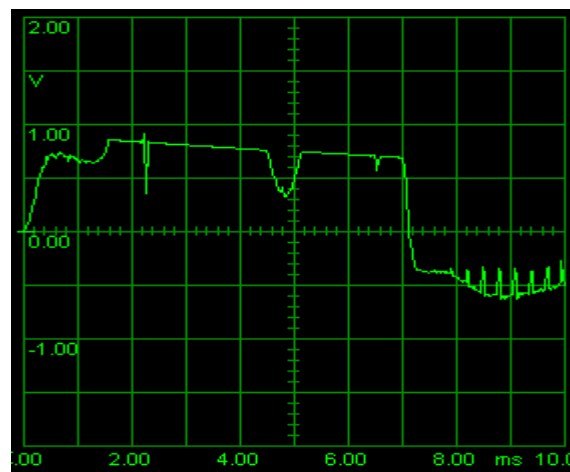


Figure 12: Another output of the noise generator.

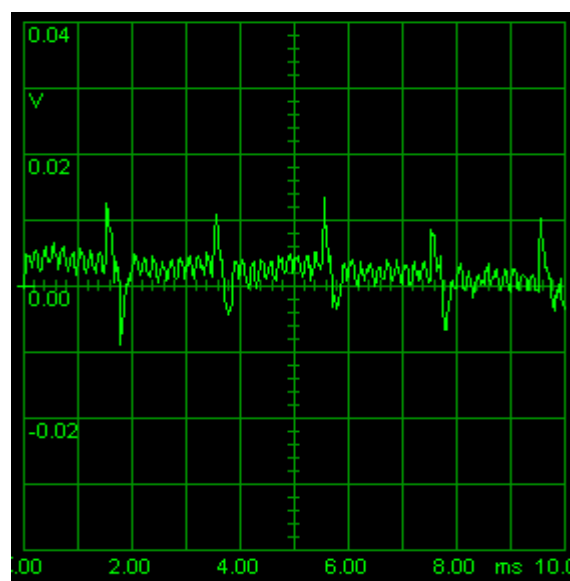


Figure 13: Output of digital noise obtained.

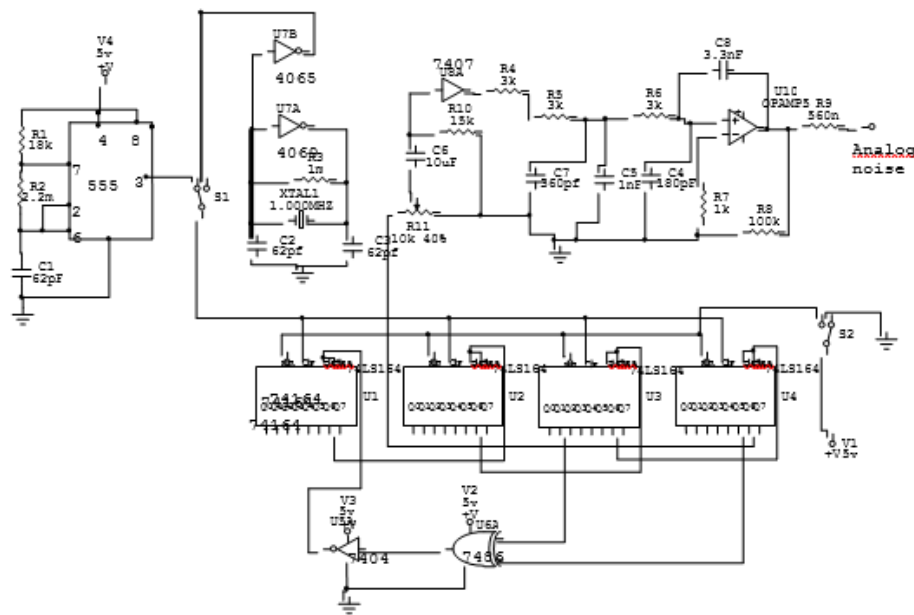


Figure 14: Complete circuit diagram of the Noise Generator.

This show that the noise generated is wide band noise that is white noise. The noise generator generates white noise which has a constant spectral power density and therefore contains all the frequencies equally strongly up to the limiting frequency. It thus fulfils the function $\sin x/x$.

All simulation of the wave pulse of the noise generator, before and after the outputs are shown in appendix A.

V. DISCUSSION

This research work has explored a lot about noise generator in Electrical signal designed in communication. Although noise is electrical signal that has no pattern and their sources are unpredictable in value; but it can be use in sample of data. For example, a controller signal machine in a Brewery company situation when bottling sample are normally taking at random, the analogue noise output is injected into the input of the controller signal machine with a preset voltage (voltage timer) say noise voltage of 4v which the control signal sense it to the robotic arm which it enables it to pick up the sample bottle on the conveyor line. This continuous in random only when or pending when preset noise voltage of 4v will clocked. Also, it can be use in jamming transmitters and receivers only when same frequencies are transmitting and the output of the noise generator is injected into the input of the transmitter.

The noise generator implemented was used to measure the noise figure of amplifier; therefore, noise figure is a figure of merit for amplifiers.

VI. CONCLUSION

There is a slight difference between the experimental results and the theoretical predictions. This is due to the nature of the components, the accuracy of the apparatus, and impedance matching. But the results are however satisfactory. An oscilloscope is an often overlooked, but excellent device for measuring white noise. The rms value of white noise is approximately equal to the peak to peak value taken from the oscilloscope, divided by eight.

From this research work, we conclude that although noise is an unwanted signal, it can be useful when deliberately generated for study.

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