Gaussian and Laplacian Noise Generator

ECE641 High Performance DSP lab

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Introduction of Noise

- Sequences of random numbers with Gaussian or Laplacian probability distribution functions are needed to simulate a wide variety of natural phenomena Applications of such sequences include channel code evaluation, watermarking, oscilloscope testing, simulation of economic systems, and molecular dynamics simulations[1].



Algorithm of generator

Box-Muller method
For Gaussian noise, we use two uniformly distributed realizations

x_1 and x_2 is two Gaussian random variables. To overcome quantization and approximation error, next stage involves a sample accumulation step that exploits the central limit theorem. l=2 is sufficient. So, the √2 can be avoided.

$$f(u_1) = \sqrt{-\ln(u_1)}, \tag{1}$$

$$g_1(u_2) = \sqrt{2}\,\sin(2\pi\,u_2), \tag{2}$$

$$g_2(u_2) = \sqrt{2}\,\cos(2\pi\,u_2), \tag{3}$$

$$x_1 = f(u_1)\,g_1(u_2), \tag{4}$$

$$x_2 = f(u_1)\,g_2(u_2), \tag{5}$$

$$\frac{x_1 + x_2 + \ldots + x_l}{\sqrt{l}}$$

Algorithm of generator Continue

For Laplacian Noise I choose the algorithm on Wikipedia, which is given a random variable U drawn from the uniform distribution in the interval (-1/2, 1/2], the random variable

$f = -\text{sgn}(U)$ and $g = \ln(1- 2|U|)$

$x = f * g$ which is Laplace(0, *1*)



Look up Table

For calculations in real number, like sin, cos, and ln, I use ram as a lookup table. I initial the possible values into the ram using following equations:

For Gaussian Noise:

X = round (sqrt(-log((1:1023)/1024))*1000);

Y = round (sin(2*pi*((0:1023)/1024))*500);

Z = round (cos(2*pi*((0:1023)/1024))*500);

For Laplace Noise:

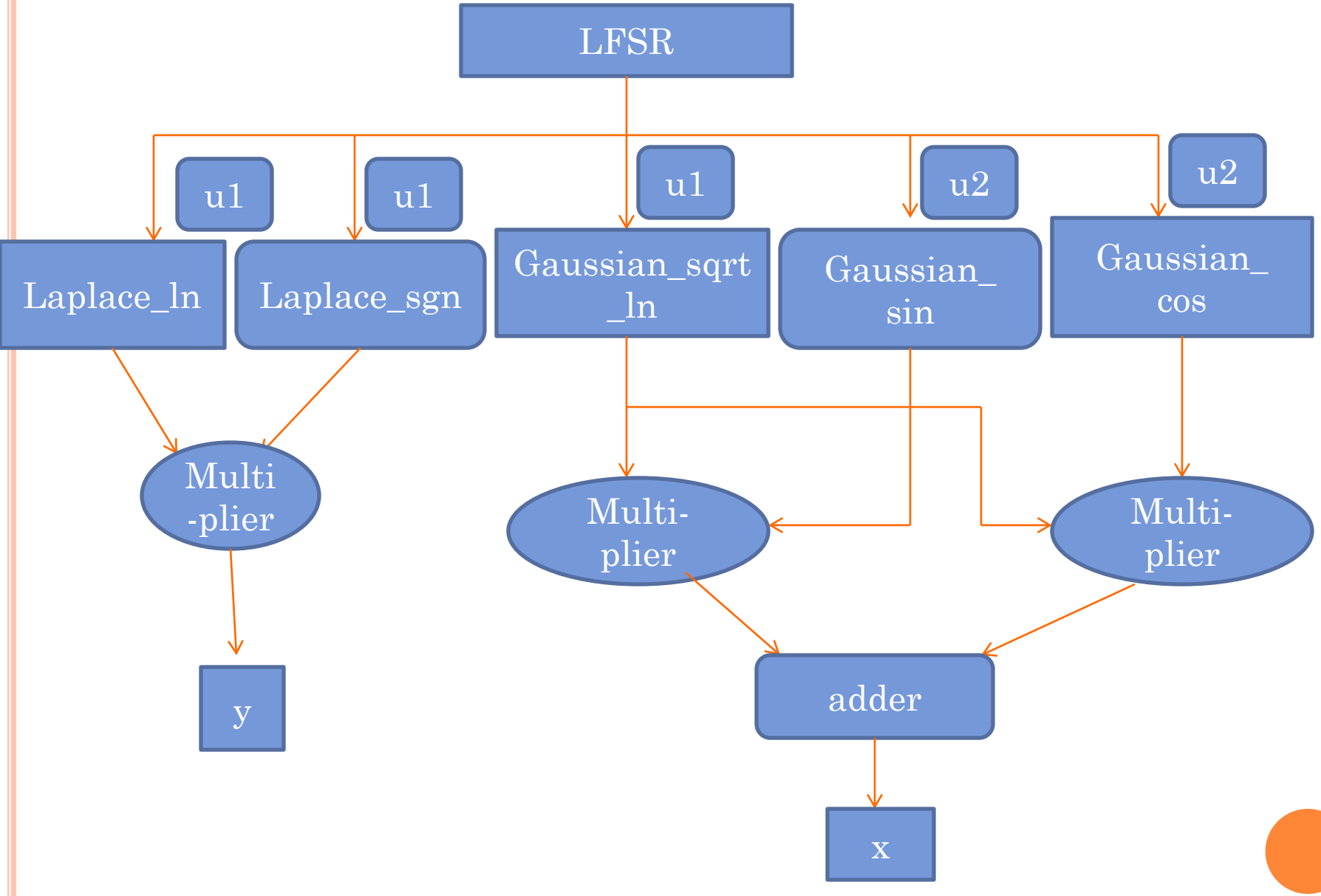
A = round (1000*log(1-2*abs(((1:1024)-512)/1024));

B = round (-500*sign(((1:1024)-512)/1024));

I calculate them in Matlab, then store them as MIF



Block Diagram



Histogram

After generating two sequential Gaussian and Laplacian noise, I choose histogram to demonstrate their PDF abbey the Gaussian and Laplace distributions.

Due to that I multiplied 500,000 on the output of each normal Gaussian and Laplace random variables , the range that I choose to count are

(-∞,-1,000,000); [-1,000,000 ,-800,000);[-800,000, -600,000);[-600,000, -400,000); [-400,000, -200,000);

[-200,000, 0); [0, 200,000); [200,000, 400,000); [400,000, 600,000); [600,000, 800,000); [800,000, 1,000,000); [1,000,000, + ∞)

Control and Display on Board

I designed a component to control a 4-digit 7-seg led display .

I attached the control value to different switches. When switches on, the corresponding LED red will be lighten.

I also implemented the frequency divider and a green LEDs runner to show the speed of the frequency.



Reference

- [1] Dong-U Lee, Student Member, IEEE, Wayne Luk, Member, IEEE, John D. Villasenor, Senior Member, IEEE, and Peter Y.K. Cheung, Senior Member, IEEE A Gaussian Noise Generator for Hardware-Based Simulations IEEE TRANSACTIONS ON COMPUTERS, VOL. 53, NO. 12, DECEMBER 2004

  [2] Wikipedia



Any Question?

Thank you very much!

