White noise source flat from 1Hz to 100kHz

Steve Hageman - September 12, 2013

White noise is very useful in testing many types of circuits. When combined with an FFT analyzer, a flat noise source can make for quick and easy gain plots of circuits. If the noise into a circuit is flat and of known quantity, then the gain of the output circuit is easy to determine, even visually. This method has been used at least as far back as 1978 on the HP3582A Low Frequency Spectrum Analyzer [1].

The “modern” way to generate white noise is to use a digital shift/feedback register arrangement in a CPLD or FPGA. Some authors have even created a parallel arrangement of microcontrollers to generate Gaussian white noise.

The implementation below is all analog, and the parts are even available in through-hole varieties if desired, making prototype construction easy.

It is well known that Zener diodes are a good source of wideband noise. The trick is, as always, to find a diode that is flat over the frequency range you need. Jim Williams used a conventional 6.8V Zener in his 5MHz wideband noise generator. Also common is to reverse bias the base to emitter junction of a NPN transistor and use this as a noise diode.

The design goal here was to generate a large amount of noise that is flat over the frequency range of 1Hz to 100kHz for FFT testing purposes. The 6.8V Zener diode designs do in fact have wideband noise, but I found them to have large amounts of 1/f noise at low frequencies, and are not flat down to DC. In this design, I used instead the trusty 12V Zener as a noise source. I have found that these diodes are flat over the frequency range, have a large amount of intrinsic noise, and operate very well over the discharge life of the 9V batteries used [2].

The intrinsic noise of the diode chosen when it is biased to 18V through 1MΩ is approximately 20mV RMS. This was fortuitous scaling, as the P-P value is approximately five times this, or 100mV P-P.

To keep the DC offset errors in check I used the venerable LF412 dual JFET-input op-amp to amplify the diode noise in two x10 steps.

Figure 1 shows the resulting circuit. The Zener diode is biased from the two 9V batteries in series (18V) through 1MΩ. The LF412 is operated split-supply between the 9V batteries. The low input current and low offset voltage allow the elimination of any bulky output coupling capacitors, as the output’s DC value is within millivolts of ground. While the LF412 is not a low noise op-amp, its noise level is still well below the intrinsic noise level of the diode and is not a concern here.

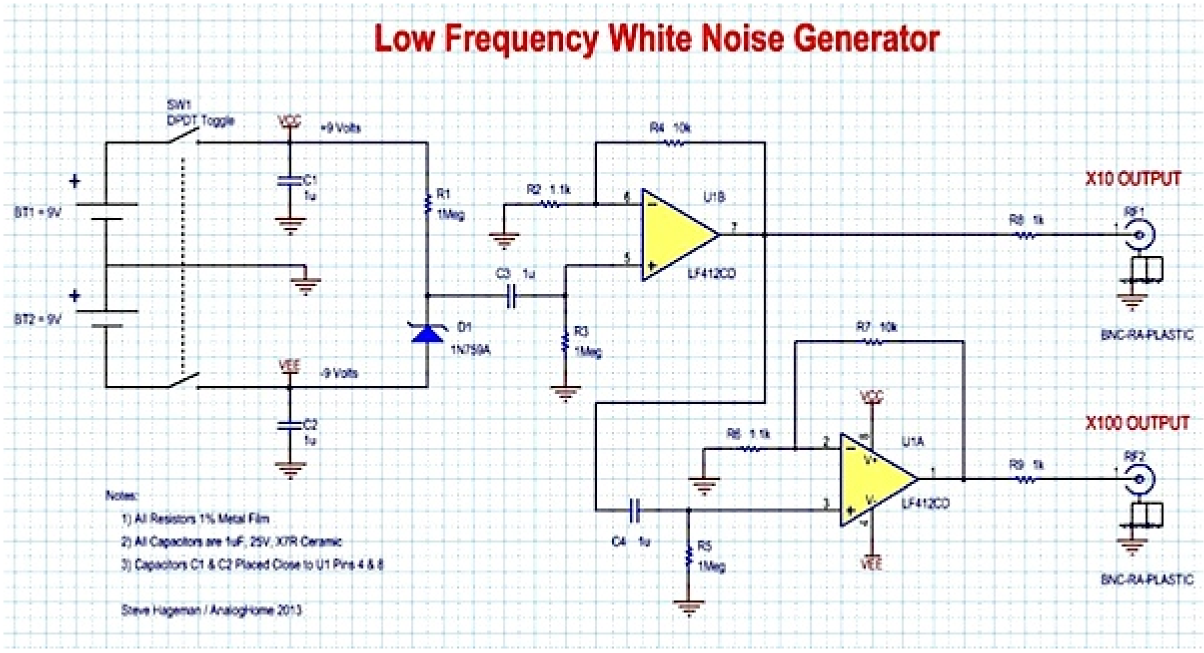

Figure 1 This low frequency noise generator produces 1 or 10 volts P-P over a frequency range of 1Hz to 100kHz.

The Zener Noise is amplified by U1A and U1B in two x10 steps, to approximately 1V P-P and 10V P-P. If this is too much noise for the circuit under test, then the 1kΩ R8 & R9 can be used to advantage in making a voltage divider to lower the noise level to any desired value.

Figure 2 shows the resulting noise of the circuit, which is flat from 1Hz to 100kHz. The slight high frequency roll-off at 100kHz in the x100 output is less than 0.5dB and could be accounted for by adding some frequency dependent gain to U1B if desired, but for my purposes this was unneeded. For comparison, **Figure 2** also shows the noise plot of an LM317 regulator operating with minimum capacitors, as this configuration is normally regarded as a “Very Noisy Regulator”, but it is nothing compared to a 12V Zener diode and some gain.

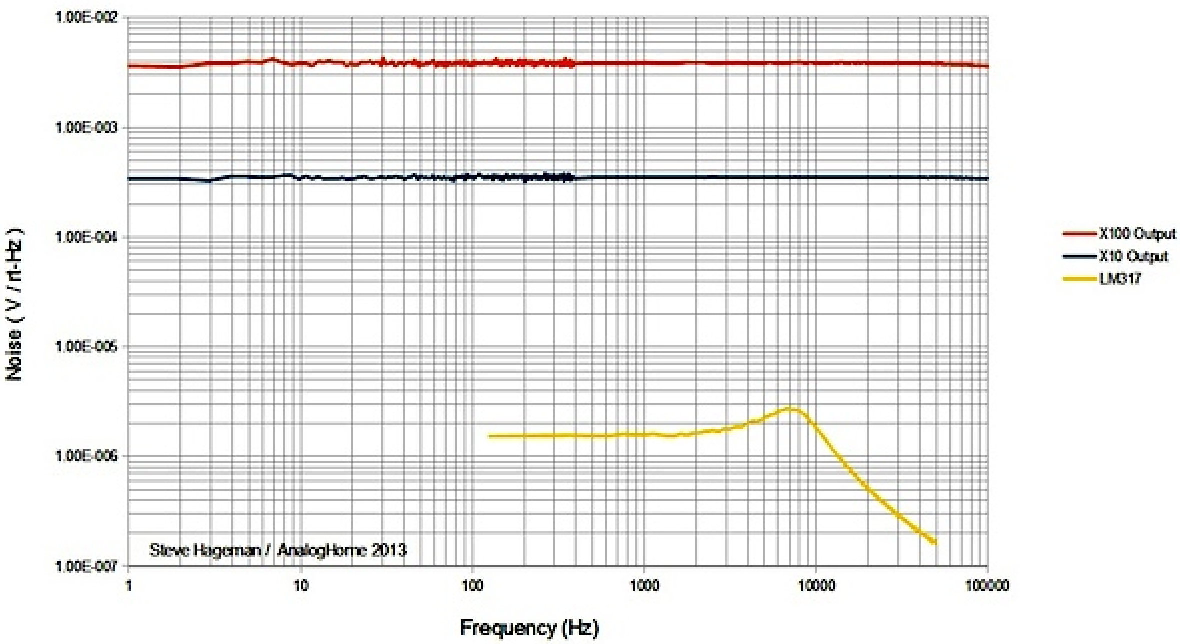

Figure 2 The power spectral density of the noise output is very flat from 1Hz to 100kHz. As a comparison, the noise of an LM317 regulator is also plotted, as this regulator is normally thought of as being very noisy.

Due to the use of stable, low power FET amplifiers and ceramic coupling capacitors, the 1/f noise induced by temperature gradients from stray air currents is kept to a minimum. Still, the design should be operated in some sort of enclosure, and kept away from circulating air currents, for maximum stability.

The circuit draws just 4mA, and if the batteries are used down to 7V, the expected battery life from regular alkaline 9V batteries is greater than 100 hours. The noise of the circuit as designed varies by approximately 15% over the life of the batteries; if desired, a more complex and stable biasing arrangement for the Zener could be employed to improve this.

References:

[1] Pendergrass, N., Farnbach, J., "A High Resolution, Low Frequency Spectrum Analyzer", Hewlett-Packard Journal, September 1978.

[2] I tested 5 each 1N759A and 1N4742A diodes with essentially the same results, based on the samples I had either would work in this application.

Also see:

- Zener diode and MMICs produce true broadband noise
- 1/f Noise—the flickering candle
- White-noise generator has no flicker-noise component
- Noise in the time dimension: the strange case of flicker
- The pink noise tangent principle
- Resistor Noise—reviewing basics, plus a Fun Quiz