

True White Noise Generator with Pink and Brown Noise Outputs
SLG47004

This application note describes how to design and build a true White noise generator with Pink and Brown noise outputs using the OPAMP PAK SLG7004. Such a device is primarily used in testing and measuring parameters of different analog equipment. The application note comes complete with a design file that can be found in the [Reference](#) section.

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1. Terms and Definitions

DFF	D-type Flip-Flop Trigger
IC	Integrated Circuit
OPAMP	Operational Amplifier
OSC	Oscillator

2. References

For related documents and software, please visit:

<https://www.dialog-semiconductor.com/configurable-mixed-signal>

Download our free Go Configure software Ref. [1] to open the .gp file [5] and use the GreenPAK development tools Ref. [2] to freeze the design into your own customized IC in a matter of minutes.

Renesas Electronics provides a complete library of application notes Ref. [3] featuring design examples Ref. [1] as well as explanations of features and blocks within the Dialog IC.

- [1] [Go Configure Software](#), Download, and User Guide, Renesas Electronics
- [2] [GreenPAK Development Tools](#), GreenPAK Development Tools Webpage, Renesas Electronics
- [3] [GreenPAK Application Notes](#), GreenPAK Application Notes Webpage, Renesas Electronics
- [4] [SLG47004 Datasheet](#), Renesas Electronics
- [5] [AN-CM-351 White Noise.gp](#), GreenPAK Design File

3. Introduction

White noise has a frequency characteristic that raises the power level by 3 dB with each increasing octave and is not suitable for response testing. By combining a 3dB per octave filter and a White noise source, we can get a very good approximation to 'perfect' Pink noise, where the power in octave, for example, 40 Hz to 80 Hz is exactly the same as in the octave 10 kHz to 20 kHz. For audio testing, a Pink noise source is an invaluable tool. It is essentially a flat frequency response noise source, and will quickly show any anomalies in speaker systems, room acoustics, and crossover networks.

Adding one more 3 dB per octave filter to the Pink noise output will convert it to Brown noise. It has a very pleasant and relaxing effect on a listener reminding the sound of pouring rain. Brown noise is often used in the medicinal area as a treatment for anxiety and insomnia. Listening to the Brown noise is helpful while meditating, having a calming effect it can speed up the process of entering a state of trance.

Unlike similar devices which are built around pseudo-random number generators, the device presented in this paper has a true random number generator. This feature can be also used in a variety of digital applications such as spread-spectrum communications, security, encryption, and modems require the generation of random numbers.

The circuit described in this document is designed using only one SLG47004 IC that contains all required digital and analog macrocells. All in one tiny STQFN-24 package.

The device is built of three major blocks, see the block diagram in [Figure 1](#):

1. True random number generator
2. 32-stage linear feedback shift register
3. Double 3 dB per octave filter

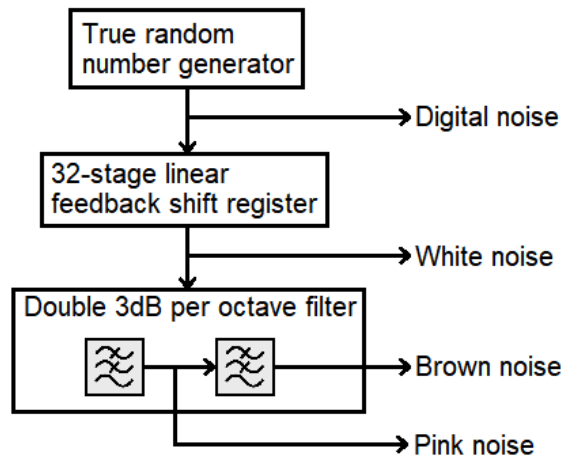


Figure 1: Block Diagram

4. GreenPAK Circuit Design

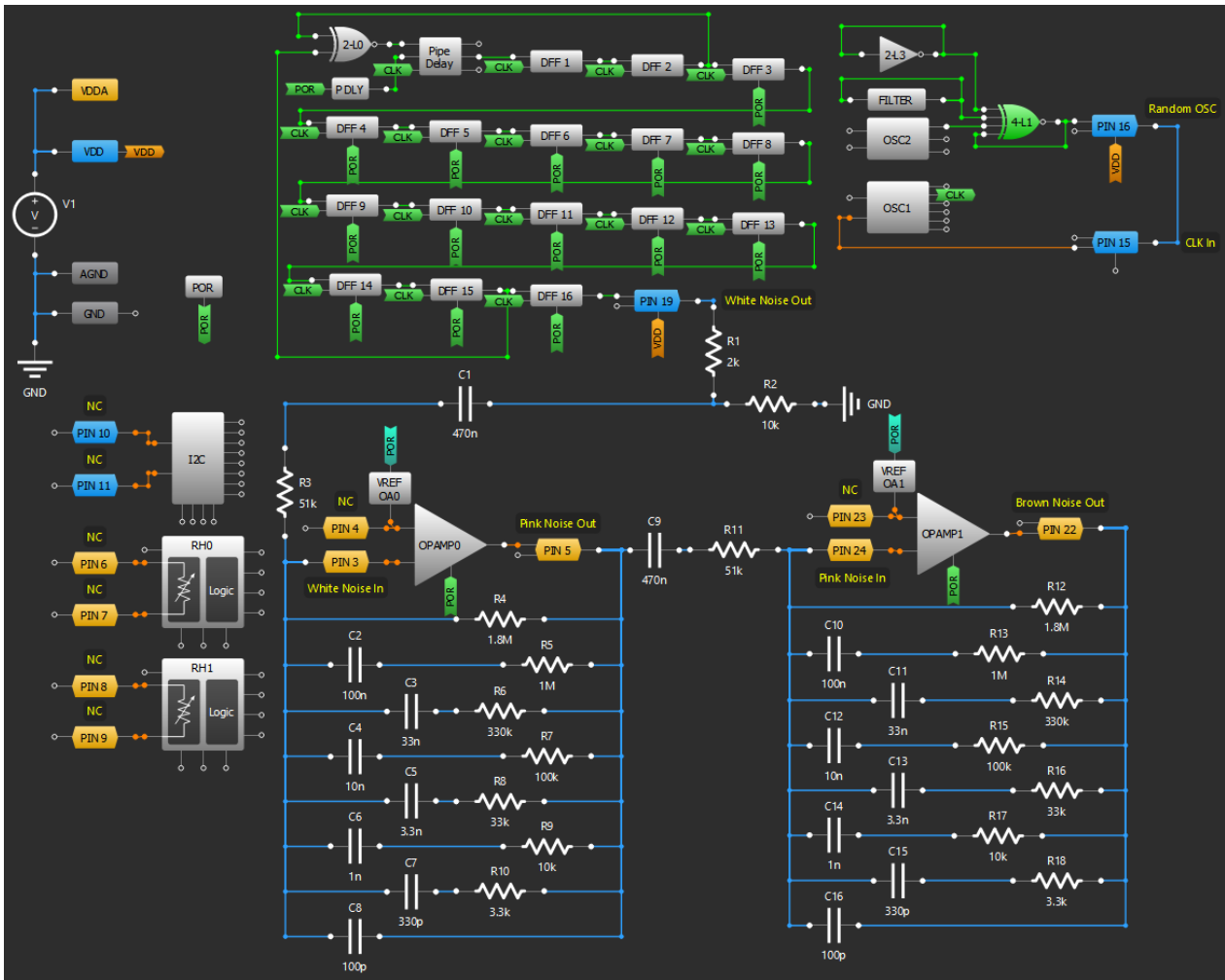


Figure 2: True White noise Generator with Pink and Brown Noise Output Project

4.1 True Random Number Generator

The most common and effective way to design a true random number generator is to have numerous asynchronous different frequency oscillators connected to an XOR gate. As a result, the gate will output a random sequence of ones and zeros. The more unstable the oscillators are, the more random the output sequence is. See Figure 3.

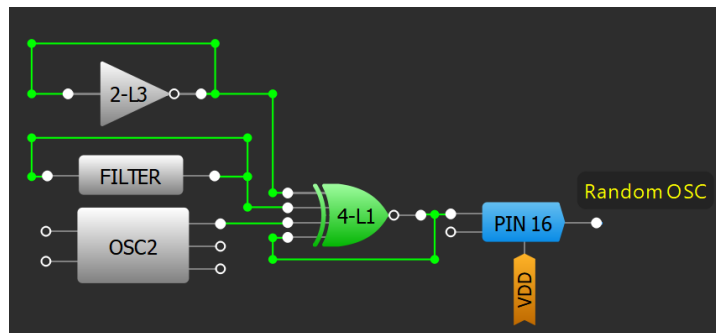


Figure 3: True Random Number Generator. Part of the Project

True White noise Generator with Pink and Brown Noise Outputs

The first OSC is made of an inverter gate that has its output connected to its input. It uses its output resistance and input capacitance to rotate the output signal phase at 180° forcing the gate to oscillate at a maximum possible frequency which is close to 55 MHz.

The second OSC is built on the Filter macrocell with an inverted output. It uses the same principles as the previous one but has a built-in RC chain which reduces the frequency to about 5 MHz.

The third oscillator is the 25 MHz OSC2 macrocell.

All three OSCs send their signals to a 4-bit NXOR macrocell which also has one of its inputs connected to its output creating one more oscillator.

It should be noted that all oscillators, except 25 MHz OSC2, are highly unstable. Their frequencies and phases fluctuate depending on several external and internal factors, such as temperature and voltage, making them perfect for generating a truly random digital sequence.

As a result of mixing all four OSC signals, the NXOR gate will output a completely random sequence of ones and zeros.

4.2 32-Stage Linear Feedback Shift Register

The linear feedback shift register is used to smooth out the spectrum. Make it more suitable for audio purposes.

Pin 15 serves as an input for the built-in random digital sequence. It should be connected to Pin 16 externally. But, it is also possible to connect it to an external source. If a simple square wave oscillator is used for this purpose, the device will still generate its output signals, but in this case, the White noise output will become pseudo-random, which is still acceptable for many applications. The benefit of this is the ability to control the output noise bandwidth by changing the input frequency.

The input signal, whether from the built-in generator or external, goes through the OSC1 macrocell, which is not oscillating but passes the signal through the two frequency dividers /8 and /12. This lowers the frequency down to the audio spectrum.

The first 16 stages of the linear feedback shift register are built on the Pipe Delay macrocell which conveniently consists of 16 DFFs connected in series. The rest of the stages are made of the cascade of the DFF1 to DFF16. The feedback is achieved by connecting the outputs of two DFFs (DFF2 and DFF15, stages 17 and 31) to the shift register input through the NXOR gate (see [Figure 2](#)). Altogether these macrocells make a 32-bit linear feedback shift register. Resulting in very smooth White noise on its output.

4.3 Double 3 dB per Octave Filter

The output filter consists of two identical 3 dB per octave filters connected in series. Conveniently, the SLG47004 has two OPAMP macrocells suitable for this purpose. Also, each OPAMP has its own Vref (VDD/2 in this design) connected to the non-inverting input. This reduces the count of the external components eliminating the need for an external resistive voltage divider. The OPAMP0 outputs the Pink noise and the OPAMP1 – Brown noise.

The filters shown in this design are complex, but linear over a wider range ... 1 Hz to 100 kHz within 1 dB across the full 50 dB range. They've been deliberately designed to be as flat as possible. It is possible to get better than shown, but the number of sections grows alarmingly. The frequency for each filter section is shown in [Figure 4](#), and each covers approximately one decade.

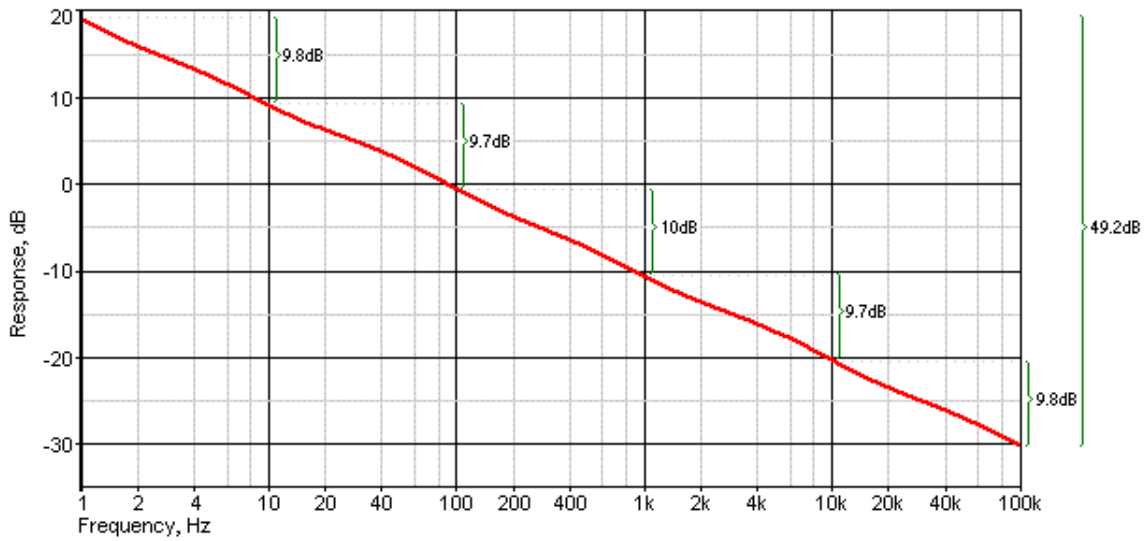


Figure 4: Frequency Response of Single Filter

As can be seen, the curve is almost a perfectly straight line from 1 Hz to 100 kHz. The attenuation for each decade is also shown - they don't add up to the total because the individual decade values have been rounded to one decimal place. For any individual decade, (e.g. from 400 Hz to 4 kHz, or from 27 Hz to 270 Hz) the error is less than 1 dB, and in most cases will be less than 0.5 dB. It is almost impossible to get any noise signal to have a perfect Pink noise characteristic. Adding extra breakpoint frequencies doesn't improve the response shown above. Decade spacing appears to be close to optimum. There is a small amount of ripple in the filter slope (this is visible in the plotted response). This is a characteristic of all 3 dB/octave filters. This should be considered a very good result, especially since it uses a simple cascade of standard component values. Note that the capacitors C1 and C9 (see Figure 2) act as a High-pass filter cutting low frequencies. This effect is not shown in Figure 4.

For a reason that frequencies below 20 Hz can have a high amplitude, and can easily cause amplifier clipping and/or excessive speaker cone displacement, a High-pass filter must be used. If the signal is connected to a tweeter via an amplifier but without a filter, it is virtually guaranteed that the tweeter will be destroyed. The filter maintains a boost at well below 1 Hz - it has a maximum at 0.1 Hz (25 dB boost), therefore, the values of C1 and C9 were chosen to eliminate a potentially low frequency.

Because of the potential for high energy at very low frequencies and damaging high frequencies, the IEC has defined a standard filter that can be used with Pink noise generators. IEC 60268-1 defines a filter that is substantially flat between 22.4 Hz and 22.4 kHz, see Figure 5. The required response is shown below. This filter must be implemented if the device is going to be tested to any IEC standard that specifies band-limited pink noise. However, most power amplifiers have limited bandwidth, so cutting low frequencies using just C1 and C9 is more than enough to work with standard equipment.

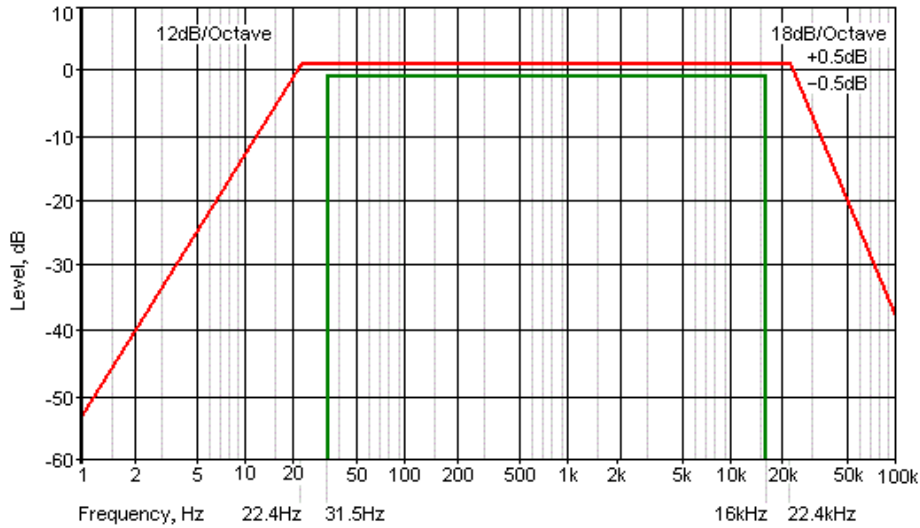


Figure 5: IEC Pink Noise Filter Response

As mentioned earlier, one 3 dB per octave filter connected to the White noise source produces a Pink noise. A similar filter connected to a Pink noise source produces a Brown noise.

Brown noise, also called Red noise, produces a rumbling sound that's deeper with a bass-like tone than Pink or White noise. The sound level decreases as the frequency goes up more than it does in Pink noise. It's similar to a steady heavy rainfall or a shower with good pressure. Doctors recommend using this sound instead of Pink noise to give it a deeper, grainier effect.

Studies show that Brown noise might help lower symptoms if you have ringing in your ears. It's also shown to improve your thinking skills. More research is needed to see if and how Brown noise affects sleep.

4.4 Real Life Prototype

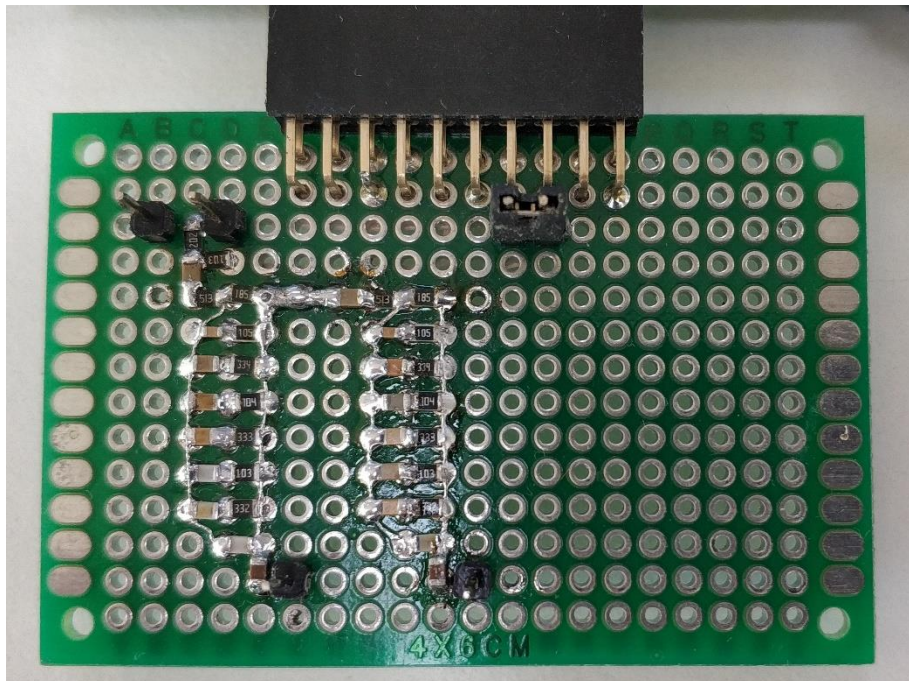


Figure 6: Filter External Components on Prototyping Board

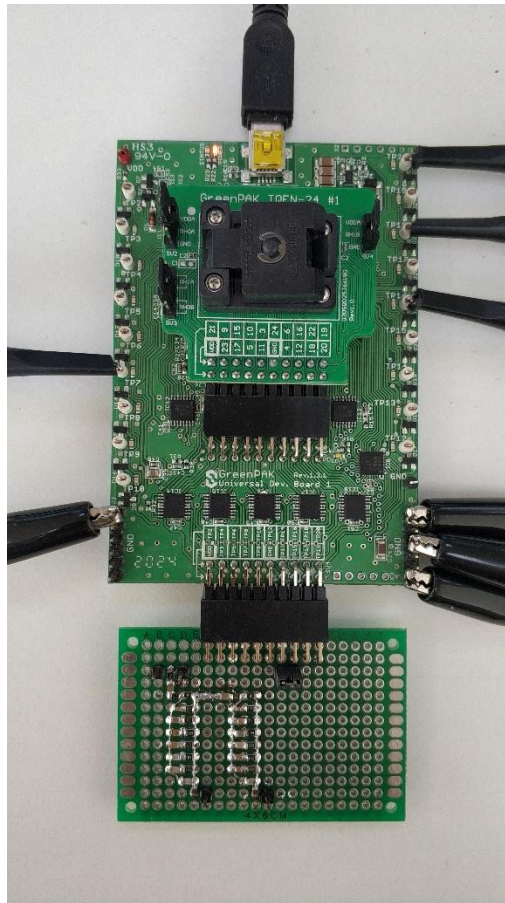


Figure 7: Prototyping Board Connected to GreenPAK Advanced Development Platform

4.5 Spectrum Analyzer Screenshots

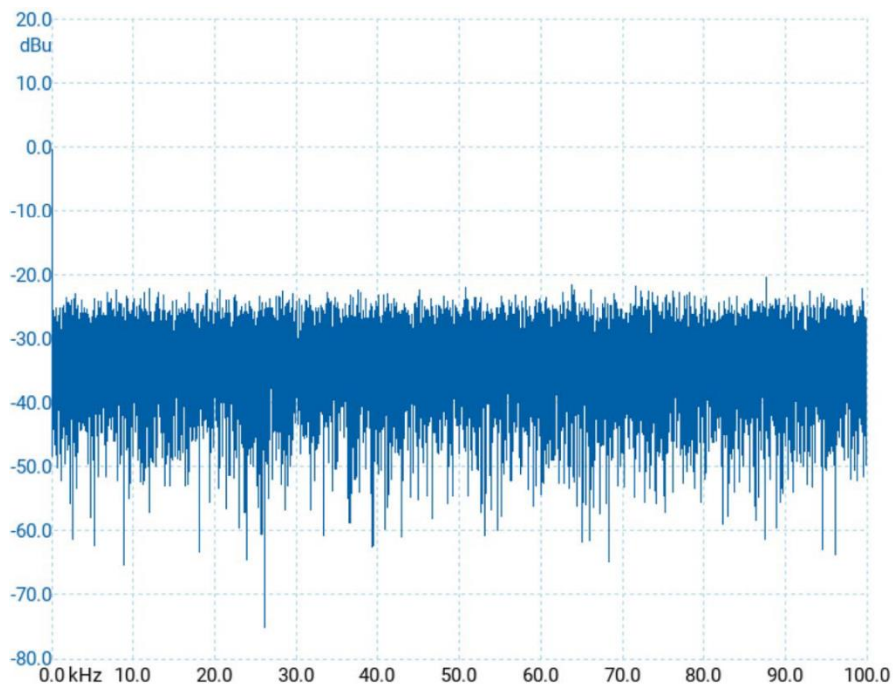


Figure 8: Digital Noise Output Spectrum

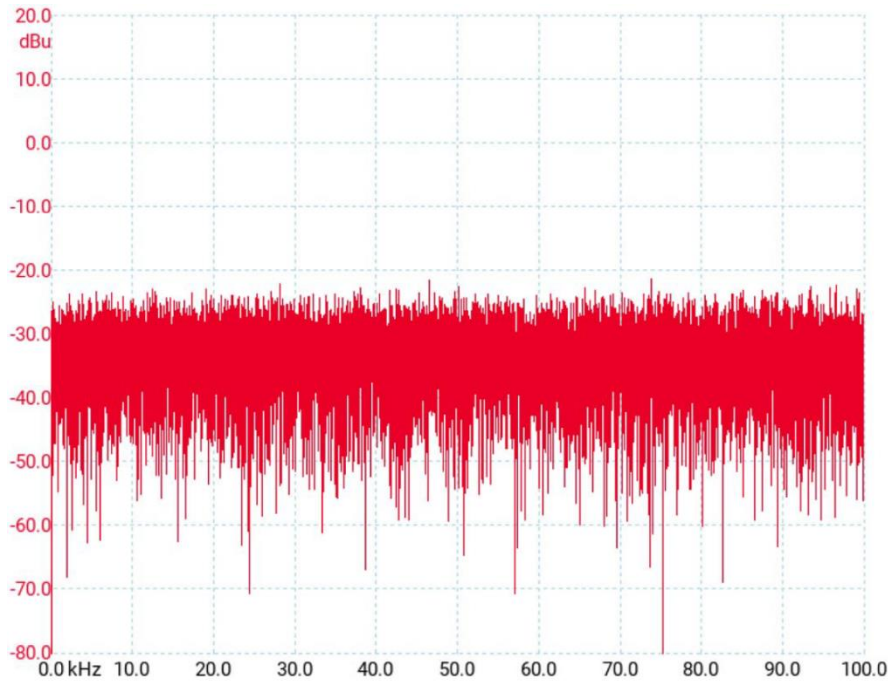


Figure 9: White noise Output Spectrum

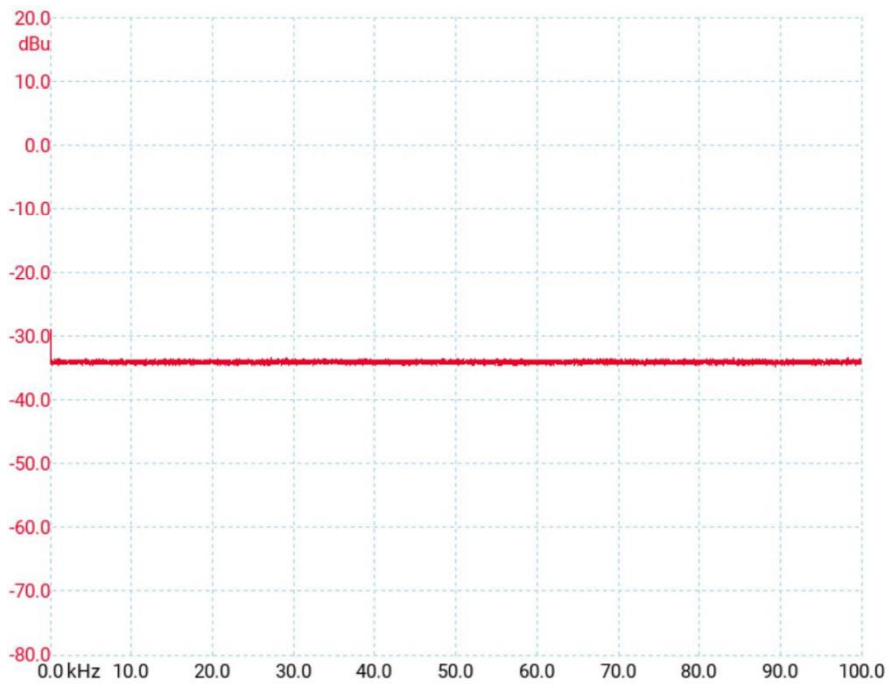


Figure 10: White noise Output Spectrum Average Value

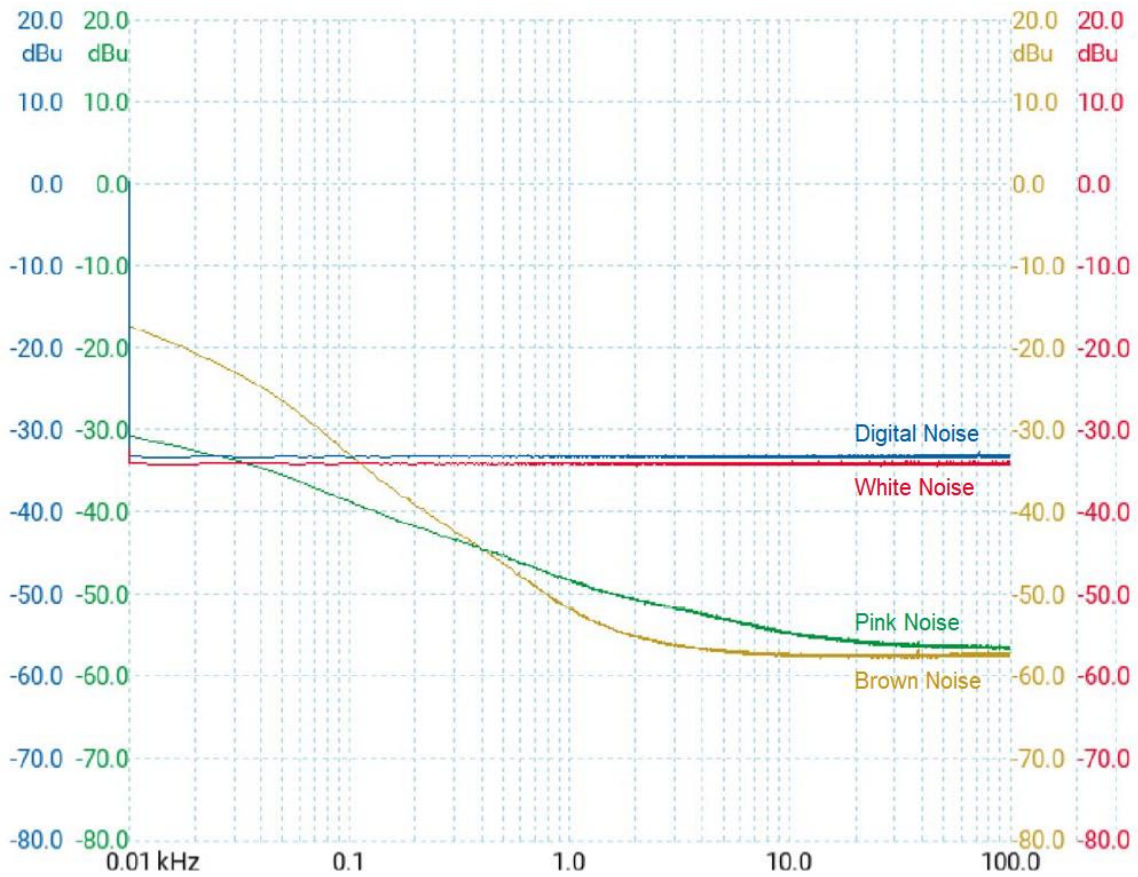


Figure 11: All Outputs Spectrum Average Value. Logarithmic Scale

5. Conclusions

As can be seen, designing and building a true White noise generator with Pink and Brown noise outputs using the SLG47004 IC is very easy. The chip contains all necessary digital and analog macrocells with spare leaving room for further improvements.

6. Revision History

Revision	Date	Description
1.00	Sep 28, 2022	Initial release.

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