An inexpensive MP3-Player based 45-kHz band noise generator for engineering and scientific applications

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Abstract. In this study we propose a home-made setup based on MP3 Player for producing high quality noise-like shape voltage with 45-kHz frequency band. The proposed generator’s output signal is investigated both theoretically and experimentally.

1. Introduction

Noise-like-shape voltage is widely used as the test signals [1, 2], for «black box» investigation [3], for random quantities simulation, and for device diagnostics [4, 5, 6]. However the price of the commercially available noise generators is very high. Moreover, the most number of generator schemes produce very wide-frequency band output, which complicates its digitizing (Kotelnikov-Nyquist theorem), so the problem of the band limitation is also actual. Here we propose the simple low-cost noise-shape voltage generator with uniform spectrum limited in the 45-kHz band. This frequency range is important, e.g., for impedance spectroscopy and ultrasound applications.

2. Working principle

To obtain the output in the 45-kHz band we have used the commercially available MP3 Player (Quba, China, 25-kHz band, dimensions 5×5×5 cm$^3$) and AD835 analog four-quadrant multiplier (Analog Devices, USA, dimensions 5×4×1 mm$^3$) for providing the heterodyne transformation [7, 8]. To be specific, we have prepared the audio-file, one stereo channel (e.g., left channel) of which contains 25-kHz band noise-like data, another channel contains single-sine data with frequency 20 kHz. The outputs of the both channels were then multiplied by AD835, which results in generating noise-like voltage with 45-kHz band (figure 1). The audio-file was created using Adobe Audition v 1.5 software.

From the mathematical point of view, for the modulated $V(t)$ we have

$$V(t) \sin(2\pi f_B t) = V(t) e^{2i\pi f_B t} - e^{-2i\pi f_B t} \div 2i$$

$$\Rightarrow \frac{V(f+f_B) - V(f-f_B)}{2i},$$

where $f$ is frequency, $f_B = 20$ kHz is single-sine output frequency, $t$ is time, $\div$ means the Fourier transformation, $V(f)$ is the Fourier image of $V(t)$. Multiplying by the exponent the in time domain corresponds to the shift in the frequency domain. So, the resulting output signal spectrum will be sum of the left- and right- shifted by 20 kHz $V(t)$ spectra, which leads to
Figure 1. The proposed noise generator scheme. The MP3 Player produces 25-kHz band output from one channel ($x$), and sine-shape output with 20 kHz frequency on another ($y$). Further, both MP3 Player’s outputs are multiplied by the AD835 scheme, which results in generating 45-kHz band noise-shape output. The input $z = 0$, because it is connected to the ground. The $V_0 = 1.05$ V is scaling voltage value. The pins 3 and 6 are connected to negative and positive voltage supply, respectively. Here we want to warn, that AD835 polarity reversal disturb the scheme. The pins 2 and 7 are connected to ground. Pin 5 produces the multiplier output.

Figure 2. The scheme of the heterodyne transformation (Eq. 1) of the spectrum (except for sign). Blue line is the real part of the original spectrum, red line is the imaginary part of the transformed spectrum. Here original spectrum is located in $[-f_B; f_B]$ kHz band and $f_B$ is also the heterodyne frequency. It should be noticed, that both spectra are located in negative and positive frequency domain, because $V(t)$ and $V(t) \sin(2\pi f_B t)$ are real functions.

the desired extension of the frequency band up to 45 kHz. With out loss of generality figure 2 illustrate spectrum transformation for the case when modulation frequency $f_B$ is equal to $V(t)$ frequency band.
3. Experimental approbation and discussion
For the measurements of the generator’s and MP3 Player’s outputs we have used the L-Card E20-10 analog-to-digital converter (ADC) (L-Card, Russia). The sample rate was 500 kHz, data collecting time was 500 ms. The signal’s spectra were calculated from the time-domain data by fft routine in the MatLab package. The output signal frequency response measurements of the proposed generator and MP3 Player in the range up to 250 kHz are given in figures 3(a-c). For comparison on figure 3(d) presented spectrum of the output’s noise-like voltage produces by commercially available arbitrary shape voltage generator AKIP-3413-3 (AKIP, Russia).

![Figure 3](image)

**Figure 3.** The obtained experimental spectra from various sources. (a) Spectrum of the MP3-Player noise-like data output; (b) spectrum of the produced by MP3-player sine-like 20-kHz output; (c) spectrum of the assembled noise generator output; (d) commercially available noise generator AKIP-3413-3 output’s spectrum. The harmonics amplitudes of the proposed generator output spectrum in the range up to 45 kHz are two orders greater that the higher harmonics amplitudes, contrary to AKIP’s output. The appearance of the negligible low amplitude heterodyne obertones in AD835’s output, probably, is connected with AD835’s inter-channel interference.

One can see that the proposed generator’s output’s spectrum high-amplitude harmonics are mainly located in the range up to 45 kHz and all of them has the steadily none-vanishing amplitude. In the other spectrum part (>45 kHz) the harmonics have the two orders lower amplitude, contrary to AKIP’s output spectrum, which uniform in all measurement range. It should be noticed, that the generator band limitation allows to not use the over-sampling technique and the high-cost input low-pas filters at the ADC inputs, which simplifies overall
circuit and makes digitizing experimental results more affordable [9].

4. Conclusion
The developed noise generator produces fine and stable output signal with approximately uniform spectrum in the 45 kHz range. It can be successfully used for such engineering and scientific problems as producing exiting voltage for electrical impedance spectroscopy, ultra-sonic waves generation for acoustic and music research, as external noise source for modeling high-noise conditions. Additionally, our device is portable and simple to bring into use, which makes it very perspective as a prototype for creating the portable electrical impedance spectroscopy bio-sensors based on available in market and widespread electronic components.

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