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(Research Article)

Extraction of analog useful signal from noisy signal

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Abstract

The signal processing allows extraction of useful information from noisy signal. We must distinguish between the signal, which carries the useful information and the noise which interferes with it. Filtering a noisy signal consists to suppress or attenuate undesired components to improve the quality of the received signal. Analog filtering uses passive (resistor, capacitor, inductor) or active components like bipolar transistor or operational amplifier, while digital filtering (discrete signals) is performed from a programmable integrated structure. Adaptive filtering involves adjusting the filter in real-time based on the signal and noise, which can be especially effective when the noise varies. As long as the changes brought by noise (random signal) are unknown, their amplitudes are random variables. Random (i.e., non-deterministic) signals cannot be completely predicted until they have been observed. In this paper, we design and simulate an analog noisy signal. Using electronics schemes we show how to generate noisy signal and how to extract useful signal from it.

Keywords: Signal; Noise; Analog Signal Processing; Analog Filtering; Simulation

1. Introduction

A signal is the physical medium of information. It is therefore a very general notion used in electricity, electronics, acoustics, optics, mechanics, astronomy, biology, economics, etc. In fact, there is signal if there is measurement or if there is transmission of information from source to recipient.

The noise notion depends of context. For instance, for an operator of a military submarine, the useful signal is emitted by the ships while signals emit by fishs constitute disturbances for the useful signal, and therefore constitute noise. Conversely, for an operator of a fishing vessel, the useful signal is emitted by fishs while other signals are disturbances and constitute noise.

Signal processing has become an essential science now a days. All information processing applications and measurement implement signal processing techniques to extract the desired information.

Analog signal processing is a type of signal processing performed on continuous analog signals using an analog process, while in the digital signal processing the signal is processed digitally.

If we apply a noisy signal at the input of analog filter, which attenuate or suppress undesired frequencies, we obtain at the output the desired frequency (useful signal). Different analog filtering techniques exist like low-pass, high-pass, bandpass, bandcut, and all-pass, depending of the nature of noise. The goal is to extract useful information from the noisy signal.

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Other techniques are used for denoising signal:

- Signal detection, i.e. determining whether a particular signal is in noisy data,
- Denoising (i.e. reducing the noise in a signal as much as possible),
- Approximation, i.e. estimating the underlying signal in noisy data.

2. Materials and methods

2.1. General Information on the Analog Signal Processing

In the noisy signal, the amplitude of noise must correspond to the lower limit of the useful signal in order to isolate information from noise. Noises are primarily classified according to its temporal evolution (continuous, intermittent, impulsive, and variable) or its origin (transport, industry, and neighborhood). Other classifications will be based upon the nature or impact of the noise. Noise disturbances tend to mask the content of useful signal. In the electronic circuits, we have two types of fluctuations (noise), according to their origin: Fluctuations of external origin: Atmospheric and cosmic disturbances, high voltage electrical discharges, electric motors, ignition systems of internal combustion engines, switching circuits, radiofrequency communications, fluorescent lighting tubes noise, scintillation noise. Noise of internal origin: Random movements and discrete nature of charge carriers, avalanche noise, slotted noise. Moreover, different types of noise exist according to their physical origins and characteristics: Thermal Johnson-Nyquist noise, random agitation of carriers. There are many types of signals

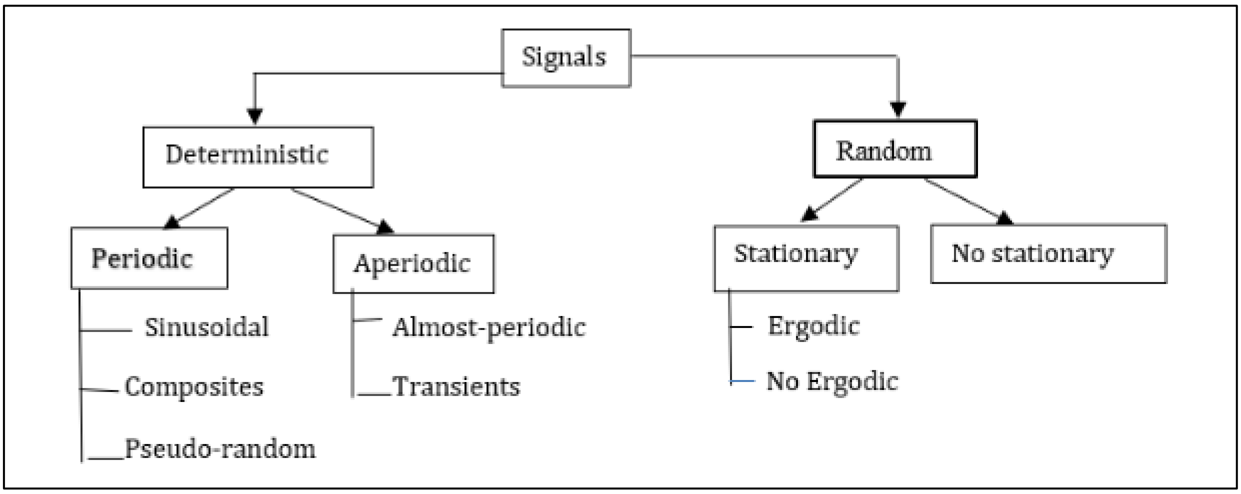

Figure 1 Classification of signals

We group them belonging to the same family according to given characteristics:

The amplitude of noise must correspond to the lower limit of the useful signal in order to isolate information from noise. Noises are primarily classified according to its temporal evolution (continuous, intermittent, impulsive, and variable) or its origin (transport, industry, and neighborhood).

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In the electronic circuits, we have two types of fluctuations (noise), according to their origin:

Fluctuations of external origin:

Atmospheric and cosmic disturbances, high voltage electrical discharges, electric motors, ignition systems of internal combustion engines, switching circuits, radiofrequency communications, fluorescent lighting tubes noise, scintillation noise. Noise of internal origin:

Random movements and discrete nature of charge carriers, avalanche noise, slotted noise

Moreover, different types of noise exist according to their physical origins and characteristics: Thermal Johnson-Nyquist noise, random agitation of carriers, Shot noise, Digital noise, quantification noise etc.

The term "analog" indicates that the signal is mathematically represented as a series of continuous values, while the term "digital" indicates that it's represented by a series of discrete values. Analog values typically correspond to voltage, electrical current or electrical charge.

Common analog processing elements include capacitors, resistors, and inductors (passive elements) and transistors or operational amplifiers (active elements).

Analog signal processing include:

- Protection of information against noise, such as techniques to reduce the error rate or to counter channel effects (equalization techniques),
- Development of electronic applications, such as selective filtering,
- Implementation of various modulation/demodulation, coding / decoding, filtering techniques, etc.
- The diagram below gives us the principle of signal processing:

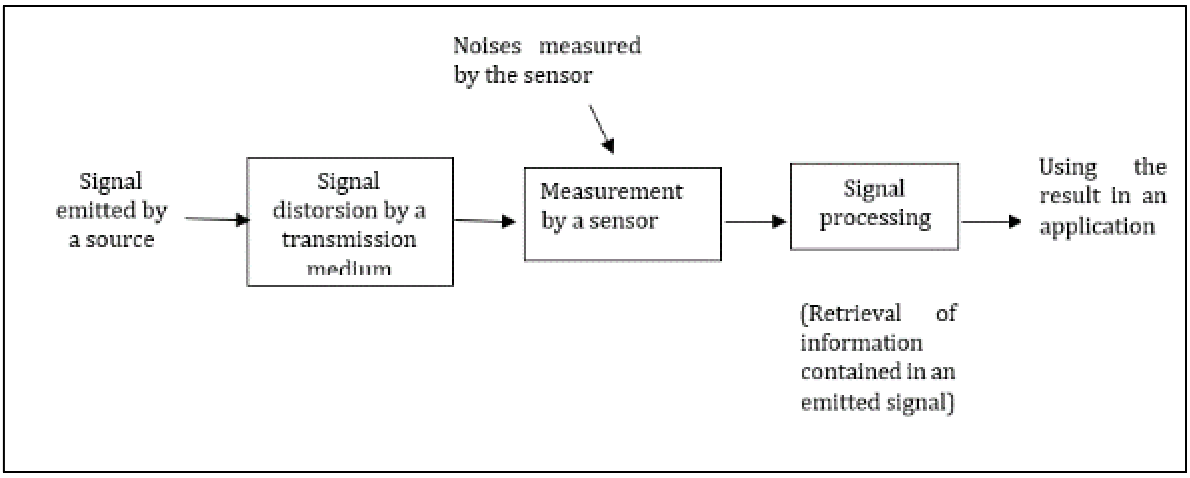

Figure 2 The principle of signal processing

Analog filtering is used in signal processing to extract useful signal from noise. It concerns fields like audio, radio, telecommunications and scientific instrumentation. There are different types of analog filters, including low-pass (allow low frequencies), high-pass (allow high frequencies), bandpass (allow intermediate frequencies), and bandcut (allow low and high frequencies).

The filter circuit choice depends of the nature of noise, desired frequencies, transfer function of the filter, and its applications.

If we apply the noisy signal at the input, the filter will gives us the useful signal at output.

As advantages, analog filters are relatively simple to design and build and does not generate clock noise.

They offer good resolution, and are not limited by the number of bits like in the case of digital filters.

They can be cost-effective, especially for applications where cost is an important factor.

To extract an audio signal that contains extraneous noises we use for instance a low-pass filter. It eliminates at the input higher frequencies (where noises are usually found) and gives us at the output low and intermediate frequencies.

In addition to filtering, there are other techniques for noisy signals processing:

Signal detection, i.e. determining whether a particular signal is present in noisy data, Denoising (i.e. reducing the noise in a signal as much as possible, Approximation, i.e. estimating the underlying signal in noisy data).

The signal-to-noise ratio (S/B) is a measure of the intensity of noise in a signal. It's the ratio of signal power (P_S) to noise power (P_B) and is usually expressed in decibels:

$$(S/B)_{(dB)} = 10\log_{10}(Ps/P_B) \quad (1)$$

The Noise Figure (NF) is expressed in dB:

$$NF_{(dB)} = (Se/Be)_{(dB)} - (Ss/Bs)_{(dB)} \quad (2)$$

With : $(Se/Be)_{dB}$, the signal-to-noise ratio at the input and $(Ss/Bs)_{dB}$, the signal-to-noise ratio at the output.

As the quadrupole adds its own noise, the noise figure is always greater than 1.

The Excess Noise Ratio is defined by:

$$ENR = NF - 1 \quad (3)$$

Some application domains of analog filtering are: Telephony, Telemetry, Telecommunications, Microwaves, Noise, Rejection, protection, Image processing, Energy distribution network, Speech processing, Digital data acquisition, Avoid spectrum folding Seismic Scientific instrumentation, Modeling of the transfer function of the telescope, EEG signals, Biomedical, Motion detection in the band ¬ [9 – 11] HZ Karaoke Etc.

Process of Denoising an Analog Signal

The principle of denoising signal is illustrated in the diagram below:

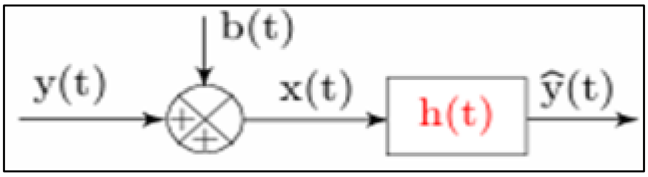

Figure 3 The principle of denoising signal

During the propagation of information y (t) from the transmitter, the noise b(t) interferes to produce the noisy signal x (t). To denoise x(t) and thus allow the recipient to have a denoised information, we use an appropriate filter of transfer function h(t). The received information is:

$$\hat{y}(t) = x(t)*h(t) = [y(t) + b(t)]*h(t) \text{ with}$$

$$x(t) = y(t) + b(t), \text{ in decibels } [4]$$

The complex transfer function h isolates the useful signal by eliminating the undesirable frequencies (noise). In order to avoid signals distorsion within a certain BandWidth (BW), following conditions must be satisfy: The module of the transfer function |h| must be constant.

The group propagation time (tg) must also be constant.

By definition, tg = dϕ (w) / dw [5]

If the phase ϕ is linear and |h|= 0, then the filter is ideal.

3. Results and discussion

3.1. Simulation: Presentation of Software

Figure 4 Proteus-ISIS simulator

An electronic simulator is a software modeling the operation of electronic circuits in order to be able to envisage and analyze their behavior. There are various levels of simulation, according to the degree of smoothness and the scale of simulation. To simulate our electronic circuit, we use software ISIS of Proteus. It's mainly used to draw electric diagrams in order to detect certain design errors. In documentations, it controls the majority of the graphic aspect of the circuits. The software ARES is a tool of edition and routing which completely perfects ISIS.

The software places the components automatically and carries out also the routing automatically. ISIS-Proteus is an electronics simulation software. It's the ideal tool for electronics students or companies specializing in this field. Easily check the functionality of your electronic schematics from your computer. to its wide range of options and the ability to create documentation, making it a particularly comprehensive tool

3.2. Environment of Work of Isis

We did our simulation under the environment of work of ISIS Professional version 8. Figure 5 below shows its interface

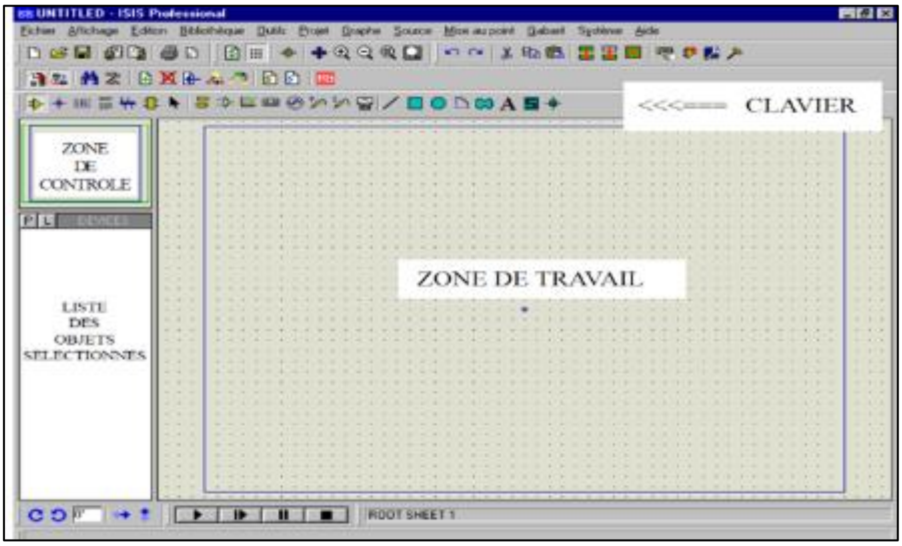

Figure 5 The environment of work of ISIS professional version 8

3.3. Generation of a Noisy Signal

A generator of noisy signal converts sound waves into electrical signal that can be used to trigger an alarm or indicate the presence of sound. The circuit includes:

A microphone or buzzer (acoustic sensor) to capture the sound waves and convert them into an electrical signal,

An amplifier reinforces the electrical power of signal produced by the microphone and increases the voltage,

The comparator compares the amplified signal to a preset threshold to be considered as « noisy signal ». If the signal exceeds the threshold, the comparator switches the trigger threshold,

At the output a LED or another alert device is activated.

The scheme in presented in the Figure 6 allows the detection and generation of the noisy signal.

An example of a noisy signal is shown in the Figure 7. It contains both noise and information. The denoising process is explained in the next section.

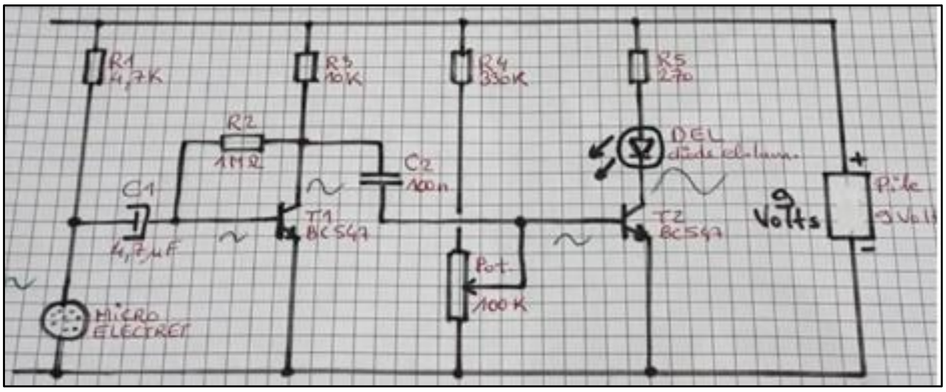

Figure 6 Generator of noisy signal

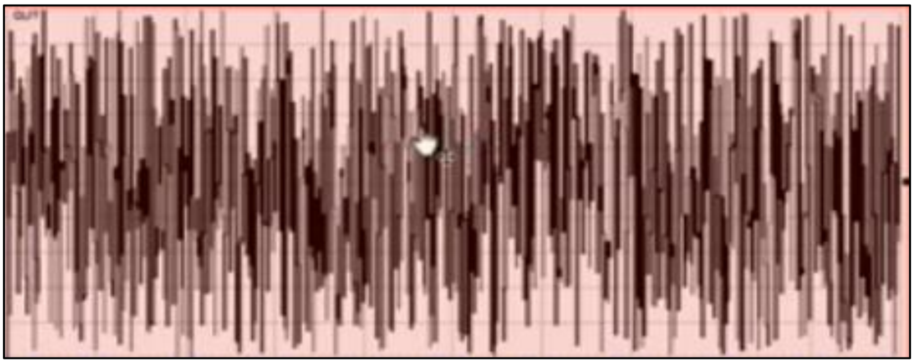

Figure 7 An example of a noisy signal

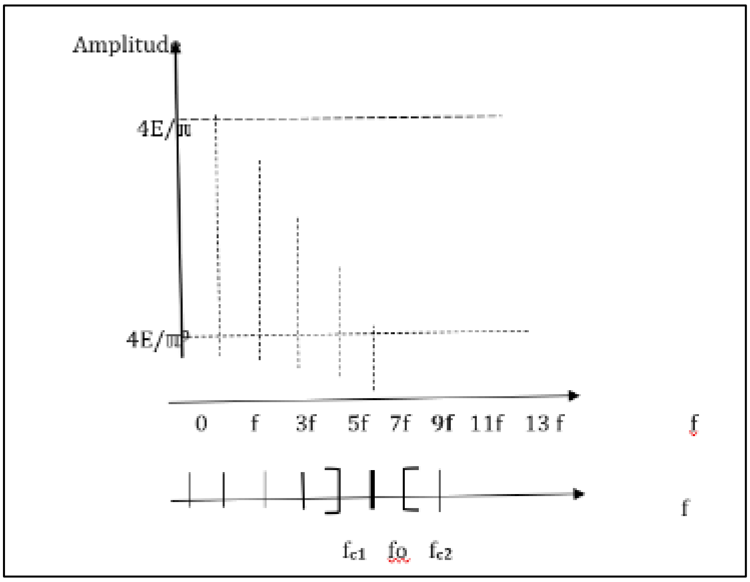

Figure 8 The amplitude spectrum of the signal

The denoising process is can be explained as follow: we use an analog bandpass filter (L-C-R) for the extraction of the useful signal (Figure 9). At the filter input, we apply a signal which equation is done by the equation (6). It will suppress all harmonics representative of noise at the input and give at the output the unique useful signal.

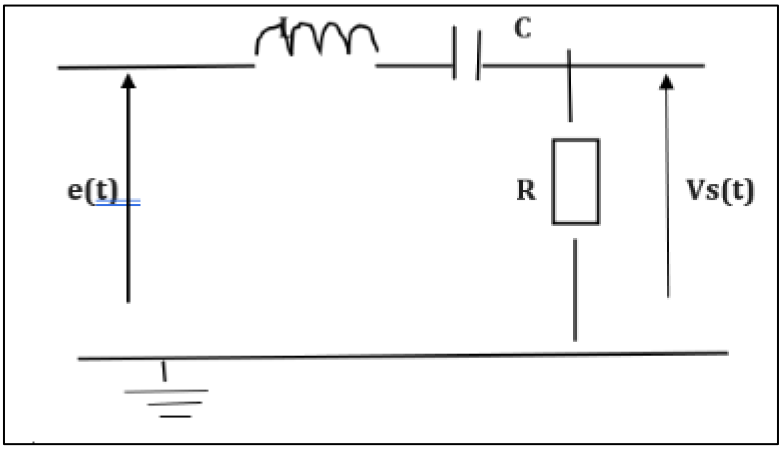

Figure 9 Analog Bandpass Filter

Therefore, the filter characteristics (Transfer function and bandwidth) must be adjusted in order to generate at the output the desired useful signal. Through simulation, we did changes at the level of the filter components (resistor, inductor and capacitor) till we didn't have a good output (Figure 10).

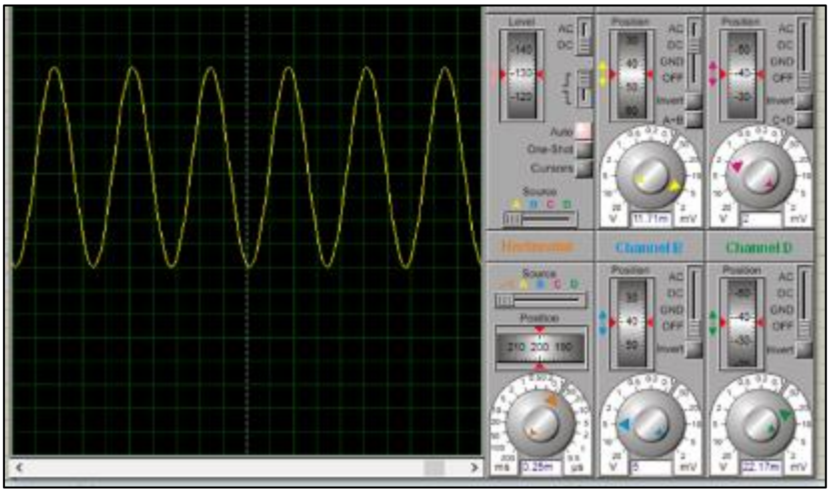

Figure 10 Useful Signal at the filter Output

4. Conclusion

During the propagation of information on the transmission medium from the transmitter to the receiver there is noise interference

The practical realization of analog bandpass filter needs an optimization of filter parameters. We must therefore adjust the values of components of the filter to be enable to extract the useful signal.

In this paper, we simulated an analog filter using ISIS software from proteus which contains in its library, the components such as inductors, condensators, resistances, transistor, operational amplifiers.

At the reception, we use the filtering technique to extract the useful signal.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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