NOISE AND PERTURBATIONS

INTRODUCTION

$$V_{zg} = \sqrt{4kTR\Delta f} \qquad (0.1)$$

According to the IEEE dictionary, electrical noise is defined as the set of all unwanted disturbances that overlap over the useful signal and tend to mask its content.

The noise present in an electronic system can be classified into two categories:

1) Noise generated inside the system
In linear circuits, the noise originates mainly from the discrete nature of the charge carriers and is related to the random fluctuations of the number of carriers that cross a given section. This noise is inevitable.
The best known example is the thermal noise, caused by the random movements of electrons in a metal bar subject to a difference of external potential. The noise voltage that appears at the terminals of the bar has a zero mean value, but an effective value given by the relation (0.1) in which k is Boltzmann's constant, T is absolute temperature (in Kelvin), R is the resistance of the bar and Δf is the band of frequencies of the device used to measure the voltage.

2) Noise coming from outside the system
This is called a parasitic signal or disturbance. There are two categories:
Atmospheric disturbances and industrial parasites
Useful signals present in a circuit, which manage to pass through the paired couplings

in the neighbouring circuits.

The importance of noise

To judge the importance of noise, we will present two examples. The first refers to telecommunications, and the second refers to an industrial application.

The case of telecommunication systems

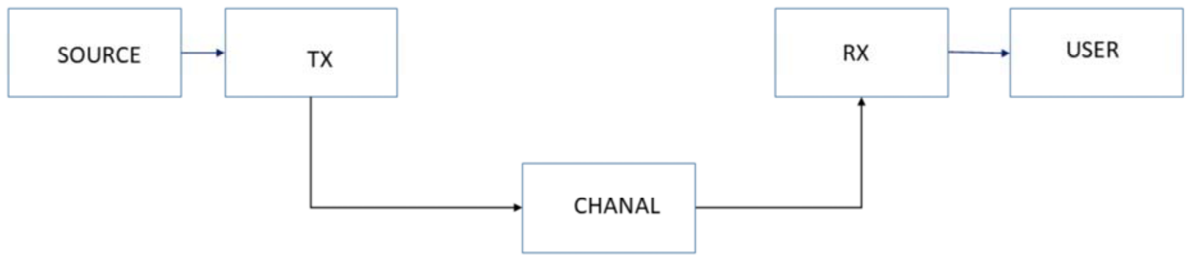

Fig.0.1

The structure of a telecommunications system is shown in Fig.0.1.
The role of the TX transmitter is to encode (modulate) the information emitted by SOURCE, in the form of a convenient electrical signal adapted to the channel
At the receiver, RX, the reverse operation (demodulation) takes place to extract the useful information that we deliver to the user.
Assuming that the signal source is ideal (neither internal noise nor interference), the signal emitted to the channel is contaminated only by the internal noise specific to the circuits in the transmitter, which remain at a much lower level than the signal.
During propagation through the channel, a multitude of parasites interfere with the useful signal; their effect is further enhanced by the fact that the signal suffers a severe attenuation during the propagation in the channel (propagation that can reach tens of thousands of km in the case of satellite communications). For this reason, the first thing to consider at the RX receiver level is to amplify the received signal to more convenient levels, at the same time filtering out some of the overlapping disturbances. Later, by demodulation, the useful signal is extracted, but be careful, this is inseparable from the internal noise that contaminated it at the transmitter level. Worse, each stage of the receiver through which the signal passes adds its own noise.
Nothing can be done to eliminate the internal noise added to the useful signal. The only degree of freedom of the engineer remains the design of low noise circuits,

especially at the receiver level, where the signal reaches a very small amplitude. Thus we understand the importance of pre-amplification and the need to have at this level not only low internal noise circuits, but also a good protection against parasites present around.

Consequently, in all communications systems, the assessment of global noise is an important task, for two reasons:

- The noise determines the lower limit of the signal level that can be processed by the system.
- The channel capacity depends on the signal / noise ratio existing at its output. Shannon demonstrated that an ideal system has a capacity proportional to the logarithm of the ratio (S + N) / N, where S represents the average signal strength and N is the effective power of noise.

The case of industrial applications

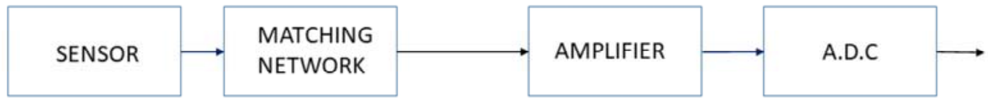

Fig. 0.2

The typical industrial application involves a sensor that transforms a non-electrical parameter (pressure, temperature, flow, etc.) into a weak electrical signal. This signal is brought to the entrance of an amplifier (fig.0.2) through a coupling network, which performs a match between the two floors. At the output of the amplifier, the signal undergoes an analog-to-digital conversion, which allows later a digital treatment and the display of the value.

In principle, any sensor provides an electrical signal that corresponds to the applied stimulus, having two categories of deformations:

1) Systematic distortions arising from the non-linear transfer function of the sensor, from its limited dynamics, etc. Their origin is in the operating principle, in the manufacture, in the calibration or in the aging of the sensor. All these factors are well defined and specified by the manufacturer, therefore they are easy to consider in the process of designing the circuits in order to compensate them.

2) Random perturbations superimposed on the signal, which are described only by their statistical properties. It is, in fact, what we call electrical noise, which is mainly determined by the sensor and the first stage of the amplifier. The contributions of the following stages are often negligible, assuming that the first stage of the amplifier has an important gain.

Under these conditions, the signal that appears at the input of the converter is affected by the noise of the sensor and the noise added by the amplifier.

In order to have a high accuracy in displaying the numerical value corresponding to the amplitude of the analog signal provided by the sensor, the designer is predisposed to choose a converter with very good resolution, characterized by a very small progression step (the value of the least significant bit - LSB).
For example, for a maximum output of 5V it can choose between a 10-bit converter (LSB = 5mV) and a 16-bit converter that offers an LSB = 77 µV. Assuming that the total noise of the analog signal is 180 µV, it is obvious that it is useless to choose a 16 bit converter!
In reality, the analog signal of the sensor is far from 5V, but rather it is of the order of the millivolts. The progression step will be slowed down, in this case, up to usual values of a few tens of nanovolts, which justifies the need for a very high gain amplifier and at the same time low noise. These two goals are constraints that are difficult to impose on design.
Consequently, whenever a high precision of analog-to-digital conversion is required, all sources of noise must be rigorously evaluated, both internal and external.

Conclusion

"Noise is like a disease: never impossible, all we can do is prevent it. Once it appears, it is impossible to cure it; all we can do is to ease the suffering, or get used to living with it. The choice depends on the nature of the disease, its magnitude and, above all, the cost of the treatment "- Sheingold.