Noise in Analog Communication

Maj Chanaka Ranasinghe

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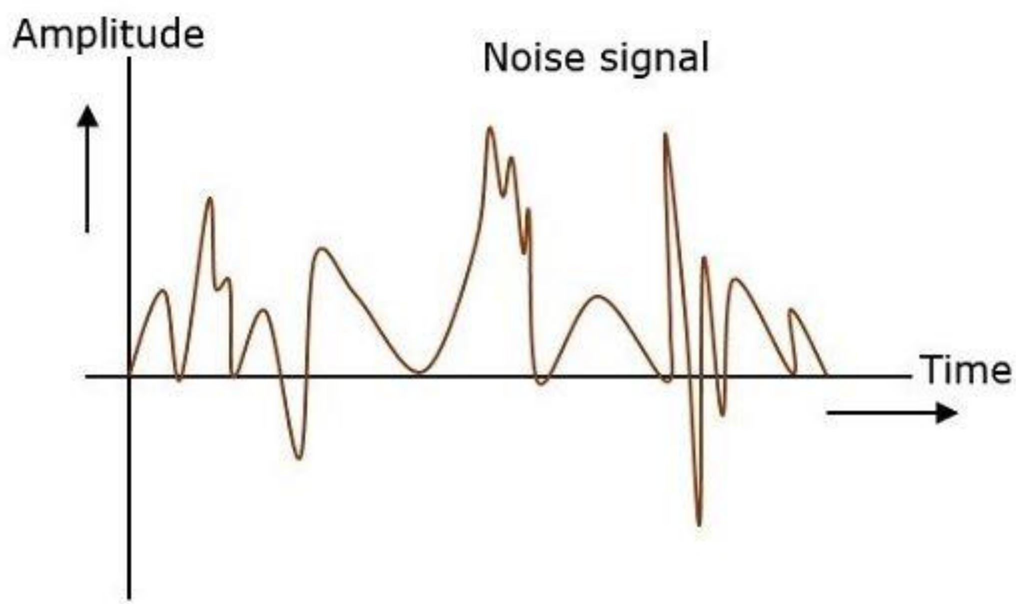
Noise in Communication Systems

- In any communication system, during the transmission of the signal or while receiving the signal, some unwanted signal gets introduced into the communication, making it unpleasant for the receiver, and questioning the quality of the communication.
- Such a disturbance is called as **Noise**.

What is Noise?

- Noise is an **unwanted signal**, which interferes with the original message signal and corrupts the parameters of the message signal. This alteration in the communication process, leads to the message getting altered. It most likely enters at **the channel or the receiver**.
- The noise signal can be understood by taking a look at the following figure.



- Hence, it is understood that the noise is some signal which has **no pattern and no constant frequency or amplitude**. It is quite **random and unpredictable.** Measures are usually taken to reduce it, though it **can't be completely eliminated**.

- Types of Noise
- The classification of noise is done depending on the type of the source, the effect it shows or the relation it has with the receiver, etc.
- There are two main ways in which noise is produced. One is through some **external source** while the other is created by an **internal source**, within the receiver section.

External Source

- This noise is produced by the external sources, **which may occur in the medium or channel** of communication usually. This noise **cannot be completely eliminated.** The best way is to avoid the noise from affecting the signal.

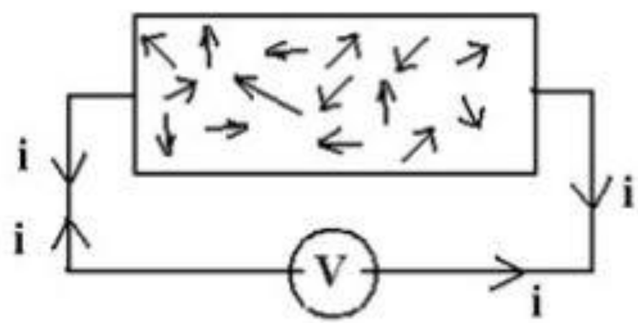
- Examples
- Most common examples of this type of noise are
  - **Atmospheric noise** (due to irregularities in the atmosphere).
  - **Extra-terrestrial noise**, such as **solar noise** and cosmic noise.
  - **Industrial noise**.

Internal Source

- This noise is produced by the receiver components while functioning. The components in the circuits, due to continuous functioning, may produce few types of noise. This **noise is quantifiable.** A **proper receiver design** may **lower** the effect of this internal noise.
- **Examples**
- Most common examples of this type of noise are
  - Thermal noise (Johnson noise/White Noise or Electrical noise)
  - Shot noise (due to the random movement of electrons and holes)
  - Transit-time noise (during transition)
  - Noise Temperature
  - Quantization noise

Thermal noise (Johnson/White Noise)

- Thermal noise is the result of the **random motion** of charged particles (Usually electrons) in a conducting medium such as a resistor.
- This kind of noise is generated by all resistances (Eg. A resister, Semiconductor, real part of the impedance, cable.)



- When the temperature increases the movement of free electrons increases and the current flows through the conductor.

- Experimental results (By Johnson)and theoretical studies by (Nyquist) gives the mean square noise Voltage

$$\boxed{\bar{V}^2 = 4kTBR \ (volt^2)}$$

Where k = Boltzmann's constant = 1.38×10^{-23} Joules per K
T = absolute temperature (Kelvin)
B = bandwidth noise measured in (Hz)
R = resistance (ohms)

- **Example 1**.

One operational amplifier with a frequency range of (18-20) MHz has input resistance 10 k Ω. Calculate noise voltage at the input if the amplifier operate at ambient temperature of 27 ^{0}C.

THE NOISE POWER

- $P = kTB$
  - Where: The noise power, P (in watts)
  - k - is Boltzmann's constant in joules per kelvin, ($1.380\,649 \times 10^{-23}\ \mathrm{J{\cdot}K^{-1}}$)
  - T - is the conductor temperature in kelvins,
  - B - is the bandwidth in hertz.

Example 2:

- Calculate the thermal noise power available from any resistor at room temperature (290 K) for a bandwidth of 1MHz. Calculate also the corresponding noise voltage, given that $R = 50\ \Omega$.

Shot Noise

- Shot noise is **random fluctuation** that accompanies any **direct current crossing potential barrier**.
- The effect occurs because the carriers (**electrons and holes in semiconductors**) do not cross the barrier **simultaneously** but rather with random distribution in the timing of each carrier, which gives rise to random component of current superimpose on the steady current.
- Although it is always present, shot noise is not normally observed during measurement of direct current, because it is small compared to the DC value; however it does contribute significantly to the **noise in amplifier circuits**.

Shot Noise Equation

$$I_s = (2eI_dB)^{1/2}$$

Where: I_s = shot noise current

e = electronic charge 1.6×10^{-19} coulomb)

I_d = dark leakage current (A)

B = bandwidth of system (Hertz)

- **Example:**
- Calculate the shot noise component of the current present on the direct current of 1mA flowing across a semiconductor junction, given that the effective noise bandwidth is 1 MHz.