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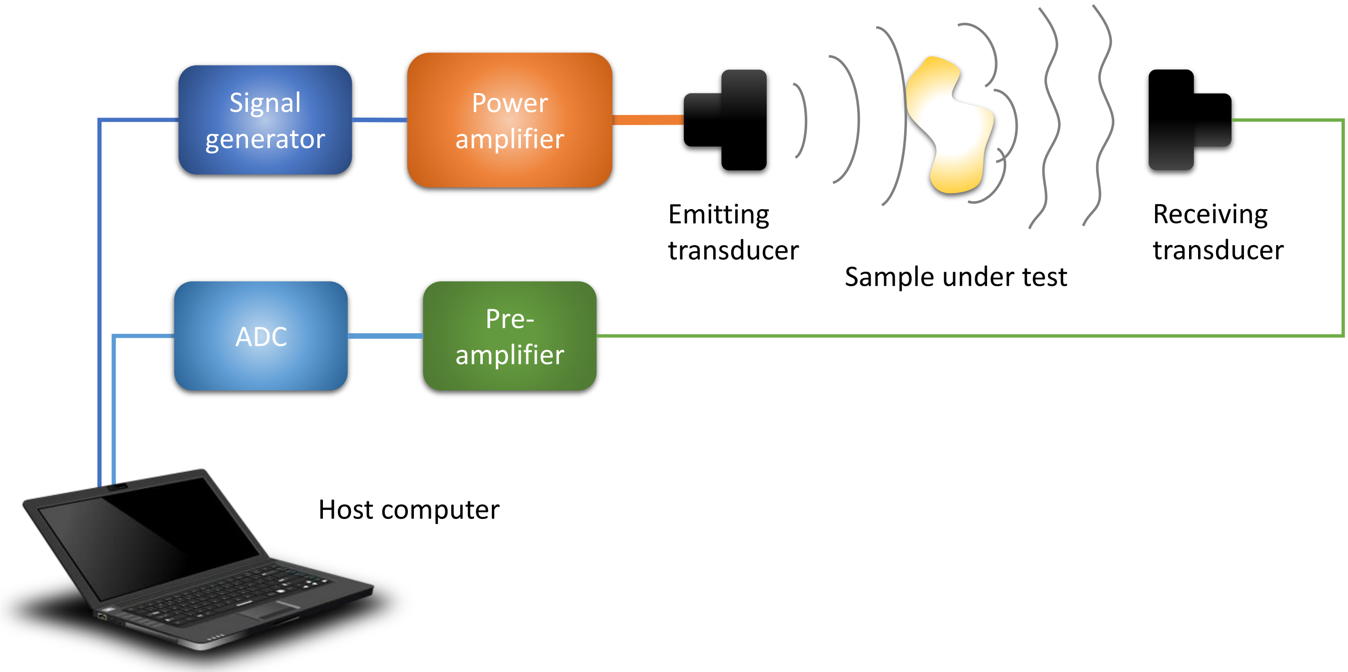
Introduction:

The figure below shows the scheme of an acoustic or ultrasonic measurement system. This system is widely employed in the characterization of samples for spectroscopic studies, measurement of viscosity or speed propagation and high precision flow-meter among other many applications. This note is aimed to people who is starting in the field of acoustics or ultrasonics. During the following sections, the operation and main parameters of the different components of the system will be explained.



Signal generation:

A signal generator provides the excitation waveform intended to apply to the sample, which consists of a low-voltage signal of typically a few volts. The signal generator is usually implemented with commercial function generators or dedicated digital to analog converters (DACs). The choice of a specific device will depend on the frequency and the waveforms required for the experiments. The sampling frequency of the device must higher than the Nyquist rate, which is twice the maximum frequency of the excitation signal. The different waveforms that can be employed in the measurement procedure will be discussed in a later section.

Power amplifier:

Since signal generators are not designed to drive power loads, its output must be connected to a power amplifier that converts the low-voltage signal into a high-level signal capable of exciting the transducer. For example, in the case of an acoustic experiment this device can be an audio amplifier that drives a speaker. For ultrasonics, piezoelectric transducers may require a high voltage amplifier, especially if a high attenuation is expected to occur into the sample. In this sense Ciprian offer the family HVA of high-voltage amplifiers which can provide up to $800V_{pp}$ and $2A_{RMS}$. It is important to check that the bandwidth of the amplifier covers the frequency range of the employed signals as well as other parameters. Please check the note “Power amplifier basics” for further information about power amplifiers.

Measurement pre-amplifier:

An acoustic or ultrasonic wave is generated by the emitting transducer, crosses the sample and reaches the receiving transducer. The electric signal coming from the receiving transducer is often very weak, leading to the necessity of a pre-amplifier. Such an instrument can be a device specifically designed for the transducer, like the case of capacitive microphones that requires a high DC bias voltage. In other cases, a generic signal pre-amplifier can be directly employed. For this purpose, Ciprian recommends its family of low-noise amplifiers LNA which provide a high gain to the received signal while keeping the noise to a minimum.

Acquisition of data:

The received signal must be converted to digital data for its processing. This task is usually performed by oscilloscopes or dedicated boards with analog-to-digital converters (ADC). The most important parameter of a converter is its sampling rate. It not only must be higher than the Nyquist frequency, but also should exceed this limit at least by factor of 10 if possible. Although in theory it is possible to operate near the Nyquist frequency without loss of information, in practice the noise strongly influences the acquired data near this limit.

When not only the amplitude but also the phase or the time of flight of the signal are intended to be measured, it is required that the ADC is synchronized to the emitter. This task can be implemented for example by sending a trigger signal from the host computer to both signal generator and ADC. Some systems such as PXI allows the internal communication of its different boards, making it possible to send trigger signals without adding external cables.

Excitation signal:

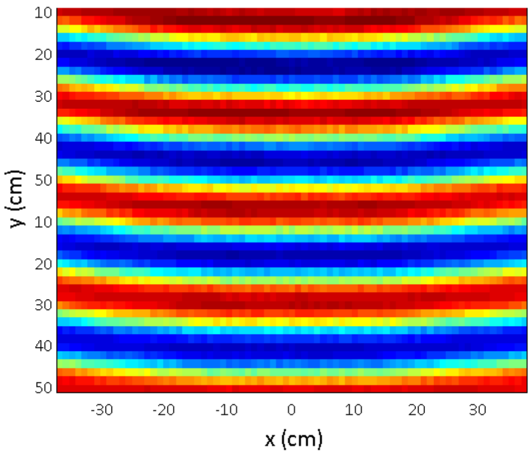
The signal employed in the characterization of the samples has a strong influence in the quality of the results. If the emitted wave can reach the receiving transducer through paths different than the sample (for instance through a reflection in a wall), pulsed operation is highly recommended. Here a short signal is emitted, and the receiving system only captures the first pulse which usually corresponds to the path crossing the sample while the rest of received pulses are ignored. This method avoids the necessity of measuring in anechoic spaces that are not always accessible.

The emitted signal must contain the frequencies at which the sample is intended to be measured. In addition, its spectrum should be as flat as possible, although any irregularity can be compensated later by the measurement software. Broadband signals such as chirps are good candidates for this purpose. Some experiments working with pulsed operation present a very low time of acquisition before an unwanted reflection appears. In these cases, the excitation signal must be short. A broadband excitation may result in a poor distribution of energy over the wide spectrum, leading to noisy acquired data. It is here recommended to apply a monochromatic wave (a tone burst or a modulated Gaussian pulse) that concentrates all the energy in a single frequency. Thus, the whole spectrum is characterized by performing a discrete sweep where a single frequency is characterized in each step.

For further information about excitation signals, readers are addressed to the note "Excitation signals for ultrasonic testing".

Extensions of the system:

The system described so far is suitable for most applications and test techniques concerning acoustic and ultrasonic systems. An additional functionality can be implemented with the inclusion of step motors that displace the receiving transducer. The step motors sweep a line, area or volume while an acoustic/ultrasonic measurement is performed at each point. This way one can get pressure maps such as the figure below. It corresponds to the real characterization the acoustic field emitted by a speaker at 3.0kHz:



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