SIGNAL FLOW

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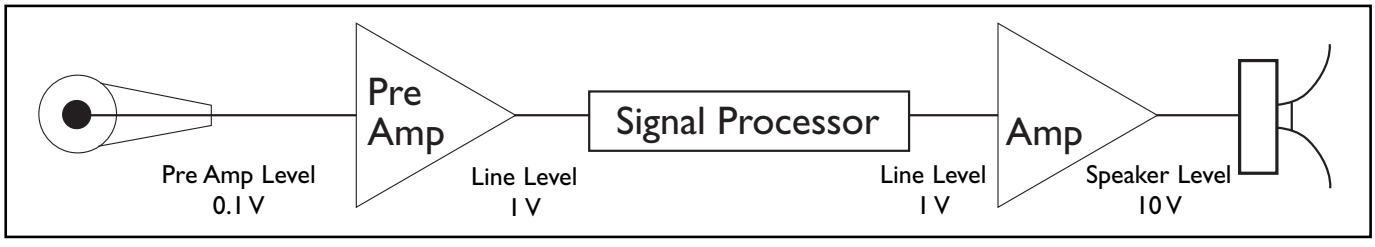
You must understand Signal Flow in order to fully comprehend how a sound reinforcement system functions. Understanding Signal Flow lets you know just which components connect to which and in what order, so that you can hook up the sound system correctly each time.
I am going to teach you about signal flow by introducing you to the Audio Chain, or the sequence in which your sound reinforcement system's individual components, connect together.



The audio chain begins with the microphone. A microphone is a device that changes energy from one form to another. A device that changes energy from one form to another is called a transducer. The microphone is a transducer that changes acoustical energy (sound) into electrical energy (voltage) . The acoustical energy may be the sound of someone's voice or that of a musical instrument.

The sound pressure or acoustical energy arrives at the diaphragm of the microphone and causes it to move or vibrate. The movement of the diaphragm converts the acoustical sound into an electrical signal. This electrical audio signal is now an electrical analogue of the acoustical sound. This electronic analogue is a corresponding electrical representation of the variations in loudness (level), pitch or timbre (frequency content) of the original audio sound striking the microphone's diaphragm. The microphone produces a very small electrical signal. A dynamic microphone that is picking up a loud voice or instrument may produce an electrical signal somewhere in the neighborhood of 0.1 volt.

Voltage is a measure of electrical pressure which determines the amount of potential to perform a task or accomplish some work. Since the microphone level is relatively small, too small to drive the power amplifier, it must be raised in signal level (to a higher potential or voltage) by means of the systems pre-amplifier (pre-amp).

A pre-amp can accept the small voltage that the microphone produces (pre-amp level of 0.1 volt) at its input, and increase or amplify the electrical signal to the next higher magnitude of audio signal level called a line level. Line levels are in the neighborhood of 1 volt when a loud sound pressure wave strikes the diaphragm of the microphone. When we use more than one microphone, we need more individual pre-amplifiers or something called the sound system mixer.

The second component in the audio chain is the audio mixing console. A mixer is nothing more than a number of individual microphone pre-amplifiers in a single package that provides signal gain (amplification) and summing (mixing) of the individual preamp channels and produces a line level signal at the output of the mixer.

The first mixer that I ever used in sound reinforcement consisted of four pre-amp inputs and one line level output. It had volume one, volume two, volume three, volume four, and master volume. It had no tone controls, no monitor or effects sends, just four individual pre-amp channel level controls and a master output level.

My first eight channel mixer consisted of two of these puppies, and my first sixteen channel mixer was made up of four of these units bused or connected together. Today's mixing consoles are very sophisticated with all of their features and functions. In addition to input gain, equalization, monitor and effects sends, we can find: signal inserts, assignment buttons, submaster and master sections, along with multiple auxiliary signal buses, PFL's, LED's, etc.

However, the primary purpose of the mixer is still to raise each of the individual channels, pre-amp signal levels (0.1 volt) to line levels (1 volt), and to sum or join these pre-amp channels together on a common mixing bus or assigned signal routing that appears as a line level output of the mixing console.

The third component making up the audio chain can be one of many signal processors. A signal processor does something other to the electrical audio signal than simply amplify or raise the level of the signal. Pre-amps and power amps amplify or raise the voltage level or gain of the entire audio spectrum of the signal. Signal processors may affect or alter the frequency response. They may gate, compress, limit, or expand the audio signal. They may perform modulated time delays or special effects, such as adding flanging, phasing, chorusing, reverb, delay, or echo to an audio signal.

The microphones and loudspeakers are transducers that change energy in the sound system from one form to another. The mixer (pre-amp) and power amplifiers raise signal level or increase gain. All other components making up the sound system fall then into a very general category known as signal processors, because they further process the electrical audio signal in some manner.

A graphic equalizer is a type of signal processor that takes the audio frequency spectrum (twenty cycles per second to twenty thousand cycles per second) and breaks these

audio frequencies down into a number of discrete bands of frequencies, which can be individually raised (boost) or lowered (cut) in signal level. Some packaged PA sound systems may have five to nine bands of equalization on their graphic equalizer (GEQ).

In professional sound reinforcement there are one octave graphic equalizers (10 band EQ), two-thirds octave equalizers (15 band EQ), and one-third of an octave graphic equalizers (28 - 31 band EQ).

A parametric equalizer is a type of signal processor that enables the sound person to attenuate (cut) or increase (boost) the gain of a selected band of frequencies that can be wide or narrow in spectrum. The parametric EQ uses three controls to adjust these parameters. The frequency control selects the center of the frequency band. The bandwidth control adjusts the Q of the filter, or how wide or narrow the band of frequencies will be. The level control increases (boosts) or decreases (cuts) the signal level (gain) of the selected band of frequencies.

An electronic crossover is another form of a signal processor. The electronic crossover (x-over) takes the audio spectrum and divides it into a number of separate bands of frequencies called bandpasses. Each separate bandpass is then amplified independently in order to drive separate loudspeaker components, each of which reproduce a band of frequencies.

When bi-amping, the audio spectrum is separated into two bands of frequencies by the electronic crossover. All of the frequencies below the selected crossover point (x-over frequency) are called low pass (short for low frequency bandpass), those frequencies above the crossover frequency, are called high pass (high bandpass). Each band of frequencies is then amplified by its own power amplifier (low pass amp and high pass amp), resulting in increased clarity and performance. In sound reinforcement it is possible to operate a sound system 2-way (bi-amp), 3-way (tri-amp), 4-way (quad-amp), or 5-way (pent-amp?).

Compressors and limiters are types of signal processors that reduce or limit the level of the signal, thus reducing the dynamic range of the signal. Dynamic range is the difference measured in decibels between the lowest signal levels (very soft or pianissimo) and the highest (very loud or fortissimo) signal levels that the system can accommodate.

A noise gate is a signal processor that attenuates (reduces the signal level a great deal), or even turns off (gates) the audio signal passing through it, when that signal level falls below a minimum threshold that is adjustable by the user.

A sub category under signal processors are those processors known as effects processors. Reverb, digital delay, flanging, phasing, chorusing, and other modulated time delays are all performed by the effects processor. These effects can be available as individual processors or even in an all-in-one multi-effects unit. There are also effects processors called psycho-acoustical enhancers that generate amplitude and frequency dependent harmonics that are perceived as an increase in the apparent loudness of the signal.

Signal processors that are used in sound reinforcement are those types that can accept line level signals (1 volt on the average but up to 8 or even 10 volts maximum) at their inputs, and produce line level signals at their output. There are some signal processors that were designed for pre-amp or low level signals (0.1 volt) such as the output of an electric guitar or bass instrument. Usually you can hold these devices in one hand, and they operate off of nine volt batteries or a low voltage power supply.

These pre-amp level signal processors usually cannot accept line levels (1 volt or greater) at their inputs. They break up or distort when the line level signal overloads their input circuitry. Also, they cannot produce the maximum line level at their output. This means that they cannot drive subsequent line level components, resulting in reduced signal level and lack of headroom. Headroom is the difference between the average operating level and the point at which the signal is clipped or distorted within the device.

Some signal processors that are used for sound reinforcement can also be used with musical instruments directly. These units have switchable or programmable input and output operating levels, which enable them to accommodate either pre-amp or line level signals.

In the past, some signal processors have had different input and output jacks to allow the device to be used at either operating level. If the jack or switch is labeled -10 dB or even -20 dB, that would be the pre-amp mode. If the jack or switch position is labeled 0 db or +4 dB, that is the line level mode of operation. It is very important for the sound system operator to assign the unit's input and output for the correct operating level.

There is usually a difference in application between normal signal processors and those that do special effects. More often special effects signal processors are used in what is called a "side chain" operation. In a side chain patch, the signal is taken out of the mixer and sent to the effects signal processor. Then, from the effects processor's output, the signal is returned to the mixer itself (usually returned to a channel, although it can be returned via of an effects return or auxiliary return). Standard signal processors (non-special effect) are inserted directly in the line of the electrical signal flow.

Effects mixing buses in consoles are normally set up to send a separate mix of signals from any of the individual channels to the chosen effects processor. This "Effects Send" is post (after) the channel slider or level control. Increasing the level of the channel in the front of house (FOH) or main mix causes the level going to the effects processor to increase likewise. So, as the operator increases the level of the channel slider, there is also a corresponding increase in the level of the effects send signal from the channel. In these side chain applications, the effects processor is usually run strictly "wet" (all effect). This results in the effects mix tracking in level directly along with the dry signal of the channel that is routed directly to the house mix.

After the signal processors, the fourth component in the sound reinforcement audio chain is the power amplifier. The power amplifier, as the name implies, delivers power to the sound system loudspeaker in the form of higher levels of voltage and current.

The power amp accepts line levels (1 volt) at its input, and produces speaker levels at its output. Speaker lev-

els are in the neighborhood of 10 volts when a loud voice or instrument is reinforced by the sound system.

The power amplifier's output voltage capability can be 40 volts for a 400 Watt amplifier (P = V x V / R, 40 volts x 40 volts / 4 ohms = 1600 / 4 = 400 Watts. A more powerful amplifier will produce even more than 40 volts at its output.

Up until now, our electronic audio components have dealt with pre-amp and line level signal or small voltage signal levels. When producing larger speaker levels, the power amplifier also sends a respectable amount of current to the loudspeaker.

Current is the rate of electron flow, measured in amperes (amps). Current is what actually causes work to be accomplished. Prior to the power amplifier, we have not tried to do any work with the audio signal, so we haven't had a high level of current flow.

Now that the power amplifier is driving the loudspeaker and converting this electrical energy into acoustical energy, the power amp must deliver significant amounts of current to the speaker. A 400 Watt amplifier will deliver 10 amperes of current to a loudspeaker load of 4 ohms (P = I x E, 10 amps x 40 volts = 400 watts).

Because it is the current delivered to the loudspeaker that gets the work done, the power amplifier's electrical power cord should be connected directly to the House AC Mains.

Do not use some light gauge electric "hedge clipper" type of extension cord. If you must use electrical extension cords to reach the power amplifier, make sure that they are the heavy duty, heavy gauge, grounded type of electrical power extension cord.

The fifth and final component in the audio chain is the loudspeaker. Like the microphone, the loudspeaker is a transducer that changes energy from one form into another. The loudspeaker changes the electrical audio signal back into an acoustical signal of sufficient loudness (audio level) to enable it to be heard by the distant listeners.

The loudspeaker must be capable of handling the high voltage and current produced by the sound systems power amplifier. The loudspeaker offers resistance or opposition to the flow of current from the power amp. Since this resistance to current flow varies with frequency, we use the term impedance when discussing the loudspeaker's opposition to current flow.

Impedance takes into account the types of resistance offered to a voltage that is alternating in its direction of current flow. Alternating Current (AC) encounters a different type of opposition to the rate of current flow through the loudspeaker's voice coil. Music or speech creates a signal of alternating current, which changes in direction twice for each audio cycle as opposed to a direct current or DC which does not change direction. The loudspeaker system can offer both an inductive and a capacitive form of opposition to the flow of current from the power amplifier.

The five components that I have just covered make up the complete audio system or chain of audio components. The direction of the flow of the audio signal through this audio chain of components is called signal flow.

When some people see a large sound system they are intimidated by its apparent complexity. The most complicated sound reinforcement system can be broken down into the five basic components that I have just covered. The large system contains the same five basic components, there are just more of them.

I hope this article on signal flow helps you to better understand your sound reinforcement system.