

Amplifiers

The voltage signal created by most transducers is quite small, too small to do appreciable work. Since the ability to do enough work to leave a permanent magnetic particle polarization on a recording medium or cause a loudspeaker to move is a requirement, some way of increasing the power level of the signal is required. Because the signals are electrical in nature, electronic circuits may be used to amplify the signal. This requires increasing both the voltage and current capacity of the signal in a linear way.

Devices capable of increasing the signal amplitude require the input of external electrical energy that the signal can be used to modulate. These include thermionic devices (vacuum tubes) and solid-state devices such as transistors. Each such device uses the small voltage of the signal to control a larger voltage or current provided by a power supply. While simple conceptually, the quality of amplification is dependent on perfect linearity and limited introduction of noise by the circuitry, conditions not always easily met. The design of the appropriate amplifier depends on factors determined by the device providing the signal as well as the device to which the signal is sent.

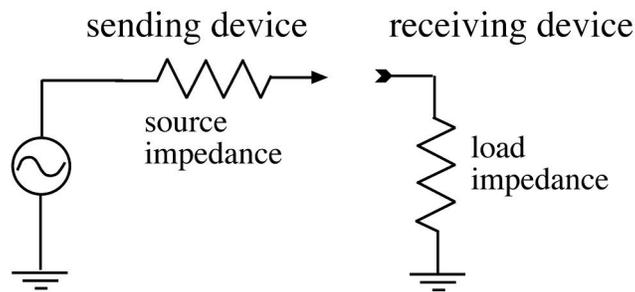


Fig. 1 Load and source impedances

In addition to the amount of voltage gain, one of the main characteristics of an amplifier is the impedance it presents at the input and output. In order to transfer the voltage signal from one device to the next, the load, the input impedance being fed, must be larger than the source or output impedance by at least an order of magnitude. This is especially important when an electromechanical device like a dynamic microphone is connected to an amplifier, because the effect of the load impedance on the transducer can change its operating characteristics. For instance, applying a low impedance load can require more current to flow from the device than it can deliver, causing the voltage to drop. Figure 2 shows the voltage transferred as the ratio of load to source impedance increases.

R_s (ohms)	R_L (ohms)	V_o (volts)
100	1	0.0099
100	10	0.091
100	100	0.5
100	1,000	0.91
100	10,000	0.99

Fig. 2 Voltage transfer as load impedance increases (re:1 V)

Matching impedances between devices is important in any audio system. Since it may be most critical when

electromechanical devices are involved, many microphone preamplifiers provide adjustable input impedances to allow optimal impedance matching for different microphones. Such adjustment is not needed between purely electronic devices as long as the load is much larger than the source impedance.

The other critical characteristic of an amplifier is the gain, or amount of amplification, the device can provide. Most amplifiers provide adjustment of the gain amount in order to handle signals of different amplitudes. How the gain adjustment is made can vary: the circuit gain may be adjustable or a fixed gain may be provided with a level adjustment before or after the gain stage. How this is accomplished makes a difference: a fixed gain amplifier is more easily overloaded if the gain adjustment is made after the gain stage instead of before. A further characteristic of note is whether the polarity of the amplified signal is the same as the input signal: some amplifiers, especially op-amp circuits, invert the signal while others do not.

These characteristics describe the gross level performance of amplifiers, but since we're interested in how amplifiers actually sound in practice, we must concern ourselves with some more detailed characteristics and how these contribute to the sonic performance of the amplifiers. We have so far assumed that any amplifier is completely distortion-free and alters nothing from in the original signal. Such amplifiers do not exist in the real world. Real amplifiers deviate from the ideal in linearity, distortion, and noise and each of these contribute to the sound. The significance of these limitations varies depending on the function of the amplifier: microphone preamps have different requirements from summing amplifiers or power amplifiers. Although all of these amplify, they are each optimized for their specific application.

Microphone amplifiers, usually called preamplifiers, are among the most critical of audio circuits. They must deliver high gains, as much as 70 dB, and interface with a wide range of microphone types. Since any signal recorded through a microphone must also pass through a preamp, the sound we eventually record will contain any alterations generated by the preamp and its interaction with the microphone. Often, a specific preamp will sound better on a particular microphone than do other preamps and the choice of the two may also change from one recording job to another. Sometimes the difference is subtle and sometimes it is quite noticeable, so experimentation is frequently required.

Microphone loading by the preamp is most acute with dynamic microphones, where the load interacts directly or through a transformer with the electromechanical element. Ribbon microphones, with their low output levels, require high gains and proper impedance matching. Moving coil dynamic microphones like the Shure SM-57 are quite sensitive to the preamp load and can sound dramatically different into a simple solid-state preamp and a transformer-coupled, well-designed preamp. Engineers are sometimes surprised how good inexpensive dynamic microphones can sound when used with a preamp that is optimally suited to that particular microphone. Since capacitor microphones have built-in amplifier circuits and produce higher output levels than dynamics, they are less sensitive to loading and do not require as much preamp gain. In fact, the high output level of capacitor microphones can cause overloads in preamplifier input circuitry and must sometimes be used with attenuators.

It is often thought that tube amplifiers are inherently different-sounding from solid-state amplifiers. When circuits are properly designed and constructed, the sonic differences are relatively small. The way the gain devices function do create some differences in noise and distortion characteristics, but both types can produce quiet and clean amplification or gritty distorted sound depending on the way the circuits are implemented. Since both types of sound are sometimes desirable, we want to be able to select the type of amplifier that best suits the job we're trying to accomplish.

Voltage amplifiers can be classified in many ways: according to the gain element type, the circuit topology, and the function of the device (mic preamp, power amp, etc.) After the choice of the active element is made, the circuit topology determines much of how the circuit will sound. We can classify amplifiers according to what

portion of a sine wave signal the output device(s) conduct current. A transistor or tube running from a single voltage supply is called class A and its signal never swings through zero volts: the output device conducts current for the entire 360° of the input sine wave. The input signal is offset, or biased, so that the output swings around a voltage halfway between the power supply voltage and ground. While this causes large power dissipation, it produces a linear output because the voltage never crosses zero volts. A more efficient circuit uses complementary devices in a push-pull arrangement and requires a bipolar power supply so that the signal can swing negative as well as positive. Each output device conducts current only on half the 360° sine wave input and these amplifiers are called class B. Some amplifiers are intermediate between these types and are called class AB, with each output device conducting on between 180° and 360° of the input sine wave. These topologies trade off between zero-crossing distortion and high power consumption. Many of the most desirable amplifiers, regardless of function, are class A.

Another consideration related to the circuit topology is that of feedback. Many amplifier designs rely on negative feedback to stabilize the performance of the amplifier. Op-amps are a popular and simple example of the use of negative feedback, but feedback is not limited to op-amp circuits. By subtracting a portion of the output signal from the input, the gain and distortion of the amplifier can be improved. This can also degrade the transient performance of the amplifier if the feedback network introduces time lags between the output and input. Since tube circuits may be used with little or no feedback, they may be able to reduce the negative effects of the feedback circuitry used in many solid-state designs.

In addition to the topology, the use of transformers can contribute to the sound of an amplifier, in both good and bad ways. The saturation of the iron core by the magnetic field imparts a characteristic sound to circuits using transformers. Well-designed transformers minimize low-frequency distortion and produce good bandwidth performance, but cheap poorly designed transformers can degrade both of these factors. Good quality transformers are expensive, but they are desirable not only for their “sound”, but because they are useful in eliminating ground loops from amplifier input stages. They also provide optimal loading for certain types of microphones, notably moving-coil and ribbon dynamic designs that are sensitive to loading effects. Since transformers are able to provide voltage gain, they can increase the overall gain of an amplifier without demanding more gain from the active circuit elements and may be used to match impedances between stages of amplification.

Another consideration, especially in input amplifier stages, is headroom: how much voltage the circuit can provide above that required by the signal’s voltage swing. Tube circuits can provide up to hundreds of volts and therefore can provide more headroom than solid-state circuits that are generally capable of providing around 30 volts or so. It is possible to use high-voltage transistors, but most audio amplifiers run on +/- 15 to 18 volts if they use op-amps. While this can be sufficient, care must be exercised in the design to guarantee optimal signal levels. Headroom is also critical in summing amplifiers where many signals are combined.

The choice of amplifiers can be made on many grounds, but the final decision is one of sound. We sometimes want the straight-wire-with-gain approach and sometimes prefer an amplifier with “character”, one that adds to the sound in a desirable way. By understanding the performance characteristics of the particular amplifiers we are using, we can obtain the behavior we desire.

© 2005-2012 Jay Kadis (For educational use only)

A full version of this chapter is now published in print form, available from Amazon, other online booksellers and local bookstores:

The Science of Sound Recording
Jay Kadis
Focal Press, 2012 ISBN 978-0-240-82154-2