Making Connections

It is not necessary to have an engineering degree to be a successful electronic musician. In fact, most of us will never take the cover off of an electronic device, let alone design one. We do have to connect devices together however, and since the instructions for doing that are usually written by electronics engineers, we have to understand a few fundamental concepts.

First, remember that electricity flows in circles. That means that connecting two pieces of equipment requires two wires (called "hot" and "return"), that run from the output terminals of the device originating the signal to the input terminals of the receiving device. Do not confuse this with stereo; stereo connections require four wires, two for each channel.

Impedance revisited

The toughest concept to grasp is impedance. You learned in the essay on basic electronics that impedance is related to the amount of current that will flow in a circuit with a particular voltage. (Low impedance implies high current.) You also learned that impedance can vary with the frequency of a signal.

When we discuss the impedance of a device, we are talking about either the input impedance or the output impedance. (Most devices have an input and an output.) The input impedance of a device is an indication of how much current is required to make the device function. It is a real quantity that can be measured with a little ingenuity. The output impedance of a device is a fiction that suggests how much current is available. It really indicates the expected input impedance of the next device along the line. In other words, when a manufacturer says "output impedance:150 ohms"; he really means: "This thing should work properly if it is connected to a device of 150 ohms or greater input impedance."

There was a time when output impedance (also called source impedance[1]) was carefully matched to the input impedance of a connected device, because that is the most efficient way to transmit power. However, since a connection will work if the input impedance is higher than the source impedance but will not if the input impedance is too low (low impedance requires more current, remember.) engineers tried to design circuits with somewhat higher input impedance than actually necessary, and lower output impedance. (A low output impedance implies that lots of current is available.) There is a limit to how high input impedances can go; if it is too high, unwanted low current sources like radio stations will begin to affect the circuit. The usual ratio of input impedance to source impedance is 10 to 1[2] .

Signal level

Another important concept is signal level. This is a measurement of the voltage expected at the output of a device. If the device has a VU meter this is the output at 0VU; otherwise, it is the strongest undistorted output available. Again, there are elements of fiction in the published specs. Engineers like to add extra capacity (called headroom) in the expectation that the device will be operated incorrectly. The measurement is specified in dB, which as you have learned from the essay on decibels , requires a reference value. The reference will either be 1 milliwatt (about .775 volts if the load is 600 ohms) or 1 volt (with the circuit unconnected). The first reference is noted dBm, the second dBv; the difference between them is about 2 dB.

Both the impedance and signal level have to be compatible if devices are to work properly together. Since manufacturers want their products to be useful, they tend to match existing standards for similar devices. Here is a rundown of what you will probably find:

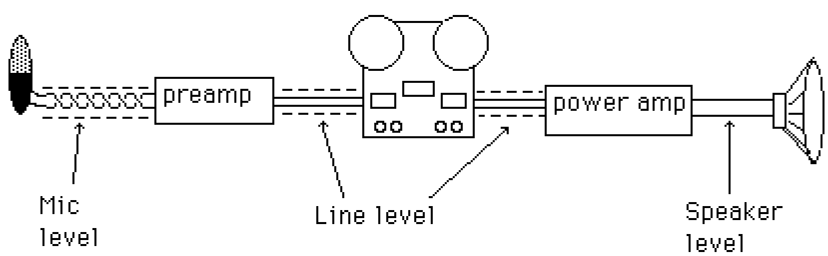

Fig. 1 typical connections

Microphone level

Microphone levels are of necessity very weak signals, generally around -60dBm. (The specification is the power produced by a sound pressure of 10 microBars) The output impedance will depend on whether the mic has a transformer[3] balanced output (see the microphone essay for details). If it does not, the microphone will be labeled "high impedance" or "hi Z" and must be connected to an appropriate input. The cable used must be kept short, less than 10 feet or so, to avoid noise problems.

If a microphone has a transformer, it will be labeled "low impedance", and will work best with a balanced input mic preamp. The cable can be several hundred feet long with no problem. Balanced output, low impedance microphones are expensive, and generally found in professional applications. Balanced outputs must have three pin connectors ("Cannon plugs"), but not all mics with those plugs are really balanced. Microphones with standard or miniature phone plugs are high impedance. A balanced mic can be used with a high impedance input with a suitable adapter.

Any microphone cable must be shielded to reduce pickup of radio signals and other unwanted electromagnetic effects. The shield is a tube of braided thin wire that surrounds the current carrying wires and is connected to the metal case of the microphone preamp. Shielding works by the "Faraday effect", which states that a charge induced in a metal body accumulates at the outer surface of that body. If the microphone is unbalanced, there may only be one wire within the shield; return current is brought back to the mic along the shield itself.

Speaker levels

Speaker connections are also specified in terms of impedance. The tradition is to match amplifier impedance to speaker impedance. Again, it does not cause a problem to connect a low output impedance to a somewhat higher input impedance, but the opposite situation can result in a blown power amp. Most speaker systems are specified as 8 ohms, although a few are 4 ohms. Amps will clearly state the impedance expected. (This spec is another fiction. Speaker impedance varies wildly with frequency; the rated number is the lowest value encountered.)

Amplifiers and speakers are rated for power output or power handing capacity. You should match these figures also; otherwise, you run the risk of damaged speakers or not enough sound.

Transformer coupled speaker lines are used in situations where one amp must drive a lot of speakers (as in, for instance, a hotel PA system.) These are called high impedance or "70 volt" systems, because the transformers are put in backwards compared to mic and line connections. Equipment designed for this approach is not appropriate for hi-fi music systems.

Speaker connections should not be shielded, because the power transmitted in speaker lines is much greater than any induced signal, and there are side effects of shielding that can change the frequency response.

Line level

Most of the interconnections between audio devices pass line level signals. There are two standards in use in this country: consumer products usually operate at -10dBv, while professional devices produce outputs at +4dBm. In professional installations, all connections are brought to a central patch bay for convenience in changing configurations of equipment. This may entail rather long cables, so transformer balanced inputs and outputs are often used. The distinction between "consumer" and "pro" audio gear is rather vague; it really has more to do with reliability than fidelity. There is even a class of equipment called "semi-pro", which has most of the features of pro gear but operates at the -10dBv level.

Interconnecting the two kinds of equipment can be a headache, but it is a common problem, particularly in electronic music. The usual solution in a studio is to convert everything to match the level of the majority of equipment. The decision to convert all low level gear to +4dBm balanced line is an expensive one, as that requires buffer amplifiers or transformers for all the affected inputs and outputs, but a pro studio is an expensive item anyway. Converting a few +4dBm devices to consumer levels is fairly simple. The output level can be unbalanced and lowered with a 15 cent part, and most pro gear is designed with enough input gain to make up the difference with no modification at all. Unbalanced patch bays are satisfactory if total wire length is kept under twenty feet or so.

Line level signals must be shielded.

A new signal level is becoming established for **synthesizer outputs**. Some digital instruments seem to be designed so that their maximum output is -10dBv. The typical output of an interesting voice will be maximum only briefly; a VU type measurement of the output would be around -20dBv. These instruments must have their outputs amplified if they are to be used in +4Dbm studios, and can even benefit from a buffer when used with low level gear.

Grounding

An electronic device responds to changes in current flowing through the input circuitry, which implies that a changing voltage is applied across the input terminals. In a balanced system, the voltage at one terminal mirrors the other; for example, if the voltage on the hot lead rises from 0 to + 4 volts, the voltage on the return lead would fall from 0 to -4 volts. Current flows equally in the hot and return leads and relative differences in reference voltage from one device to another are unimportant.

In an unbalanced system, the voltage on one lead changes while the voltage on the other remains steady; the hot lead would rise from 0 to +8 volts and the return would stay at 0 volts to produce the same result as the previous example. In this system, it is important that 0 volts be properly defined at both ends of the wire. If the two devices disagree as to what zero means, current will flow along the shield, often at 60 hz AC. This current will induce hum into the hot lead. The techniques used to establish a reliable zero volt level are lumped together as "grounding" and often seem to involve as much witchcraft as engineering.

Wires

Hi-fi enthusiasts talk a lot about the effects of the wire that is used to interconnect audio equipment. As with many things audiophiles are concerned with, this is a case of valid basic principles followed to extremes. Herewith; a rational point of view:

The prime concerns for microphone cables are flexibility and durability. The main difference between a cheap cable and an expensive one is the effectiveness of the shield. The connectors are expensive enough that no one has thought to gold plate them.

Balanced line cables are identical to mic cables. High impedance unbalanced connections are somewhat sensitive to the kind of wire used. With shielded wire, there is some capacitive coupling between the center conductor and the shield. Capacitive coupling acts as a low impedance path for signals of high frequency. Since current follows the path of least impedance, a capacitive cable connected to a high impedance input will show a low pass characteristic; in other words, some high frequency energy will be shorted out. The actual frequency at which this is apparent depends on the material the cable is made of, the length of cable, and the actual input impedance of the device. In my experience, with typical equipment and ordinary cable, the problem develops with runs longer than twenty feet. The only exception is with phono inputs, which with their extremely high impedance are sensitive to cables longer than three feet. There is no point in gold plating a phono plug unless it is connected to a gold plated jack[4]. (The gold is supposed to prevent the buildup of resistive corrosion. This can happen with nickel plated connectors if they are in a warm humid place, but the corrosion is removed each time the plug is inserted. Anyway, it is the jack that corrodes, not the plug.)

In speaker wires the important issue is resistance of the wire itself. With circuit elements connected in series, the voltage across each is proportional to the impedance of each. If a speaker impedance is eight ohms, and the wire impedance is two ohms, twenty percent of the power of the amplifier will be used up in the wire. The resistance of a piece of wire depends on its length and thickness, or **gauge**[5]. A six foot chunk of #22 "speaker wire" sold by Radio Shack measures 0.3 ohms, so you probably should not use it for very long runs (I never use the stuff). Ordinary #18 lamp cord ("zip cord") is less than a third as resistive, and I routinely use it for runs of up to twenty feet or so. For very long runs, I use #14 electrical cable and count on some power loss. You can buy huge cables with very low loss over fairly long runs, but the cost of the cable is more than the cost of the wattage you are wasting. You should never use shielded cable for speaker leads.

Digital Wire

Digital audio signals are commonly carried by two main kinds of connection, which differ in the format of the data as well in electrical characteristics and types of connector. AES/EBU is the transmission standard used with professional gear. It uses balanced cable with XLR connectors. You can routinely run cables for 100 meters without fuss. Most consumer grade equipment (and a lot of pro gear as an option) follows the SP/DIF standard, invented by Sony. Phono connectors are used, with video quality coaxial cable.

Optical cable is sometimes used for digital audio. The cable used is an inexpendisve plastic kind, so it's limited in length to 1 meter. AES and SP/DIF wiring can be reasonably long, but to really get down the street, you need a glass optical system with special translator boxes.

In any digital interconnection, extra care must be taken with the quality of the connections. The high bit rate involved makes the signal behave like a video signal. A bad solder joint or corroded terminal can cause the signal to be reflected back down the wire (signals can go both ways in wire, just a sound can go both ways in air). This causes ghosts in video signals, and data errors in digital signals.

Source: http://www.co-bw.com/Audio_Connections.htm