Power

Power Calculations

Power is the ability to do work, whether it's lifting elevators or making noise. When you run current through a wire, you are transmitting power from the source to the point of use. One of the major advantages of electricity is we can do the messy business of generating power in Nevada and use it conveniently in out living room.

The Unit of power is the watt, names after James Watt of steam engine fame. The power available in an electrical circuit is

P = EI

P = power in watts

E = emf in volts

I = current in amperes.

Of course the current through a wire is controlled by the impedance- usually we know the impedance and voltage and use the derived formula

$$P = \frac{E^2}{Z}$$

It's important to notice that the power is going to change as the square of the voltage. If we are controlling current through a known resistance, this formula has the same moral.

$$P = I^2 R$$

Power Dissipation

Many electronic devices produce heat as a side effect of the their main use. For instance, resistors and transformers heat up as current passes through them. The heat isn't good for anything (quite the contrary) but we need to be aware of it so we don't try to pass enough current through something to burn it up. Most devices have a maximum power rating- to exceed this rating is risking destruction. Most resistors, for instance are rated at a quarter watt. So how much voltage can we safely apply to a 100 ohm resistor?

$$P = \frac{E^2}{R}$$

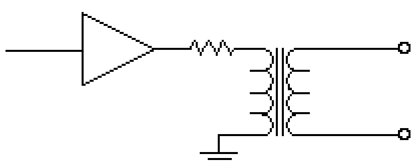
$$E = \sqrt{PR}$$

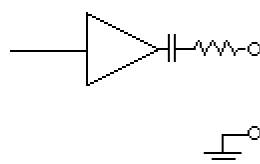
$$E = \sqrt{0.25 \times 100}$$

$$E = 5 \text{ volts}$$

Power Transfer

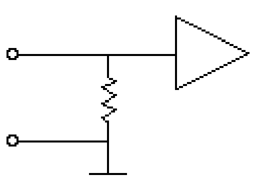
In the audio world, you still hear a lot of talk about "matching impedances". What does this mean? Any device with a real output is going to have some impedance between the signal supplying circuitry and the output jack. Here are some typical output structures:





The triangles represent amplifiers or some other source of current. There's always some combination of resistors, capacitors and /or transformers to adjust the output voltage and protect the current source from short circuits. Whatever is after the current source is going to have impedance- it's usually all lumped together and called the "source impedance".

Now here is what any input is going to look like:



Even if that is not the actual construction, as far as the source device is concerned, the next gadget down the line will present some (hopefully fixed) impedance across the output. You will remember from the essay on Ohm's law that when we hook these together, we will have a voltage divider. If the impedance of the input of the second device is low enough to load the output of the second device, the voltage at the connection will be lower than expected, and the current demand may be beyond what the source is prepared to supply. (The source could even be damaged.)

To prevent this, manufacturers specify the loading impedance their device is designed to work with. This is called "output impedance". It's not the same as the source impedance- the output impedance is the expected input impedance of the load, and will work with the source impedance (as the bottom leg of a voltage divider) to set the correct output levels.

In the old days, if a device specified an output impedance of 600 ohms, you had to connect a 600 ohm load, neither more or less. That's because up to the mid '60s or so, most equipment had output transformers as in the left hand circuit above. (Tube circuits required them.) You remember from the essay on impedance that an inductor such as the secondary coil of a transformer has a time constant dependant on the associated impedance- with some impedances, it becomes a filter. 600 ohms was an industry standard input impedance for flat signal transfer in the audio range. (There's still such a standard for video- 75 ohms, and you'd better follow it.) If you wanted to send a signal to two devices, you had to use a special distribution amplifier, because just hooking up two 600 ohm inputs to the same output gives a 300 ohm load.

It was easy to have a 600 ohm input impedance because most equipment had a transformer on the input also. However, there were pieces of gear that had higher output impedances (made for the home audio market, mostly) and if you loaded those with 600 ohms, they wouldn't work. Modern equipment avoids input transformers (they are either expensive or low fidelity, or both) and uses input circuits of higher impedances, typically 10kohms or even 50kohms. The advantage of this is you can connect to anything and you can drive several inputs without distribution amps. The outputs are still capable of driving 600 ohms (usually), but connecting a higher impedance does no harm since less current is required. If you have to connect a high impedance input to an old fashioned 600 ohm output, you should add a 600 ohm "termination resistor" across the connection. Any piece of equipment where this really matters will have such a resistor built in, with a termination switch to connect it when needed.

Microphones

Microphones still have the old distinction of high impedance vs. low impedance. That's because good microphones still have transformers in them (see the essay on connections and balanced cables) but cheap ones don't. Since a microphone produces very little current, you can't connect a high Z mic to a low Z input and expect it to work. A low Z mic will work into a high Z input, but the frequency response may be messed up.

Power Amps and Speakers

Impedance is really critical when it comes to hooking up speakers. Amplifiers are designed to provide plenty of power, but we can't afford to waste any by hooking up a higher impedance than necessary. A speaker's true impedance varies all over the place with frequency (there are coils in there), but it will have a "nominal" rating that represents the lowest it will go for any length of time. This is usually 8 ohms, although you now see a lot of 4 ohm designs in the audiophile market.

Amplifiers are designed to give their maximum safe current into 2 ohms or so, so an 8 ohm speaker represents a modest safety factor. If you connect two 8 ohm speakers in parallel, you will present 4 ohms to the amp and things will get louder with some risk. Risk of what? Well, on cheaper amps you'll blow a fuse, and on better ones a light will come on telling you the current protection has kicked in and your sound will be awful- probably severely clipped. The worst that can happen is a blown amp.

[WARNING] Clipped sound, even at moderate volume, can damage your speakers- why? Because square waves have most of their energy in the high partials. In a typical three way speaker, the woofer, which usually handles most of the power, will be rated at hundreds of watts, but the tweeter will only be rated at 20 to 50 watts. Pump in 75 watts of high frequency energy and goodbye tweeter.

If you connect two speakers in series, you present a 16 ohm load and get half the current. Since it's now driving twice as many speaker cones, you will get just as much sound, and it may even sound a bit better because the individual speakers aren't working as hard.

With a little thought, you can probably thing of a way to hook up four speakers and still present an 8 ohm load.

This discussion should also point out the necessity for using heavy guage speaker wire. 20 gauge wire has a resistance of about 0.01 ohms per foot, so you only need about 20 feet of cable to make a 5% change in impedance, wasting current and detuning the crossover coils. Better to use 18 ga at 0.006 ohms per foot or even 16 ga at 0.004 ohms.

Incidentally, there are such things as high impedance speakers. These are the little things you find in airport ceilings- hundreds of them are wired in parallel, and each speaker has a step down transformer to make that possible. The amps that run these systems are marked 70 volt output, and won't work with your speakers at all. You can use those little speakers if you take the transformers off.

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