The Mystery of the Current Mode Amplifier

(Or “The Journey of the Non-Voltage Amplifier”)

Part 1 this month, Part 2 next month.

This is a rather tricky subject to talk about. Most of us don't have too much trouble about getting our heads around a voltage source representing an audio signal. But using current rather than voltage is far less intuitive.

Let us discuss the Voltage amplifier first. These are said to be *voltage source* amplifiers and pretty much 99% of the amplifiers you have heard are *voltage source* amplifiers. We shall just call them Voltage amps and later *current source* amplifiers as Current amps.

But back to Voltage amps: Have you ever seen an oscilloscope displaying a sine wave – they are fairly easy to understand. Looking at a sine wave on the scope and you understand clearly that is how sound moves through air by moving forward and backwards.

Indeed put a sine wave through an amplifier to a speaker and then put a microphone near the speaker and connect microphone to an oscilloscope, and what will you see on the scope? You see a nice sine wave, just as you would have expected of course. The air moves as we see on the scope, forward and backwards. It is intuitively easy to understand. More accurately, the exact motion is shown in the vertical scale volts which represent the amplitude motion of the cone and the frequency is the lateral scale in time, as that is what comes out of the microphone and what the scope sees.

Same goes for the output of the amplifier, it is in volts versus time, where time is really another way of saying frequency.

But this voltage must also produce current when fed into a speaker. The exact current is a function of the load, so 4 Ohm demands twice as much current as 8 Ohm which in turn demands twice the current of 16 Ohm and so on.

So a speaker requires both voltage and current, it is just a matter of delivery. Are you going to deliver volts and the current will follow *or* are you going to deliver current and then the voltage will follow. The first is the Voltage amplifier delivery and the most common. The other is the very much less common Current amplifier delivery.

Back to Voltage amp: Since the current changes with load, the volts of our Voltage amplifier must be very steady and solid; the current is then demanded by the load, the speaker and must not wilt as the current changes with load. Therefore the Voltage amplifier must have *very low impedance* or at least many times lower than the load or speaker. If the output impedance is not very low, the amplifier’s output will wilt or sag and compress the volts.

How low should the output impedance be for a Voltage amp? Well, the technical answer textbook wise is to be low enough not to cause more than 1dB insertion loss. You said what? Yes it sounds wordy but is actually quite simple. The load must not cause the amplifier's output to sag more than 1dB, it's that simple.

In real life, as a rule of thumb, this means the output impedance should be no more than around one-tenth the load impedance. Thus if a speaker is an 8 Ohm load, the output impedance of the amplifier should not be more than around one-tenth of that or 0.8 Ohm.

But what about Current amps, how do they work? Try to get your head around this, the Current amp works in exact reverse. Whereas Voltage amps needs *low* output impedance, the Current amp needs to have *high* output impedance. Indeed needs to have many times higher that the load and ideally infinitely times higher. In practice, if you use an 8 Ohm speaker, the output impedance needs to be many times that.

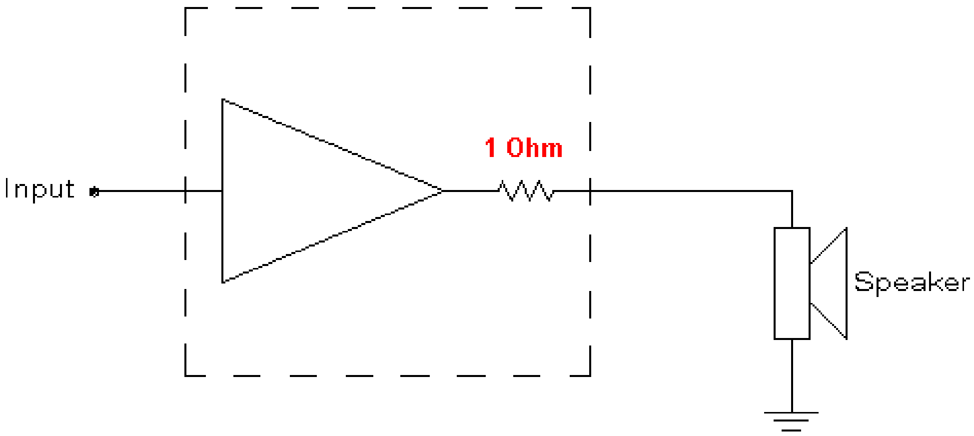
Where a Voltage amp should sag as little as possible, the Current amp's current needs to be stiff and let the voltage across the loudspeaker's terminal develop naturally, according to Ohm's Law, as the current changes. The current goes up, and then the voltage the speaker sees goes up and vice versa when current goes down. In theory the same voltage and current will develop as before. So a Current amp achieves the same as the Voltage amp, albeit in a different way, *if* the speaker's load was a passive resistor. But that little if is a big IF! But in real life this is a very different story.

In real life we can also basically say that amplifiers with an output impedance of 1 Ohm or less are Voltage amplifiers. The Current amp is typically 30 Ohm or more for 4 Ohm speakers and even higher for 8 Ohm. I have noted that Nelson Pass has said near 50 Ohm for 8 Ohm speakers is sufficient. The higher the impedance of the speaker the higher the output impedance needs to be for Current amp delivery.

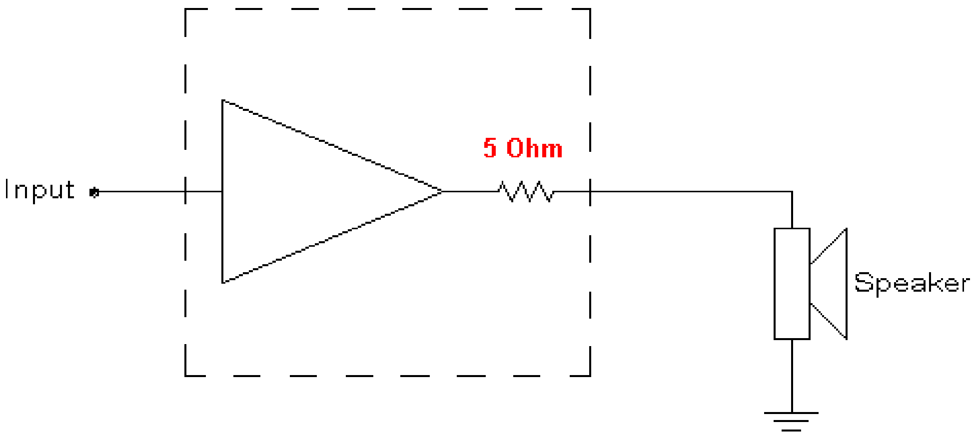
I am not trying to confuse you, but to complete the picture we must realize that there are not just two kinds of amplifiers, Voltage and Current, but that there is also a *third* one – and it sits in between the other two, it is the Unity Coupling amp.

Basically here are the three types of amplifiers that drive speakers:

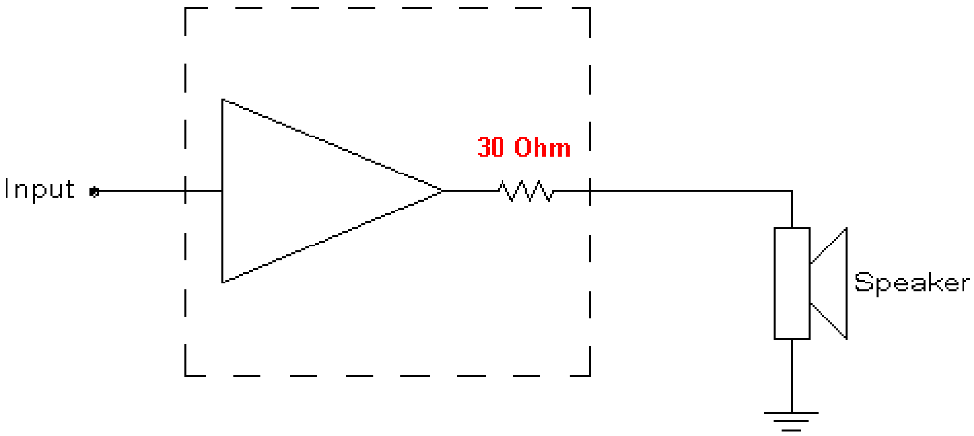
1. The Voltage Amp - the output impedance is much lower than the loudspeaker.



2. Unity Coupling Amp - the output impedance is similar to that of the speaker.



3. The Current Amp - the output impedance is many times that of the loudspeaker.



Here 30 Ohm for Current amp is the very minimum. Can you see there is a pattern? The type of amplifier is directly referenced to that of its output impedance. It changes, indeed *determines* the way the amplifier delivers power to the speakers.

But again we see that the above are simply practicable values as if we were to be exact textbook, the Voltage amp would have *zero* output impedance, the Current amp would have *infinitely high* output impedance and the Unity Coupling amp would match the exact impedance of the speaker. In the real world, the above values are what we need to be comfortable with and what's more, they seem to work.

Now the most technical statement I will make here; the amplifier with zero output impedance will by nature *regulate Volts,* whereas the amplifier with infinitely high output impedances *regulates Amps* (current) by nature. But since those ideals are not totally achievable or even hard to get close too, the high versus low impedances gives us an insight to how well they do their assigned jobs. But also keep in mind that Unity Coupling is in fact a compromise between the two camps, one that also works well, then that helps us keep things in the right perspective: That is non-Voltage amps have an inherent advantage. So really the minimum output impedance should be that of the speaker *or* higher. It should not even approach 1 Ohm or lower.

The Advantages of non-Voltage Amplifiers

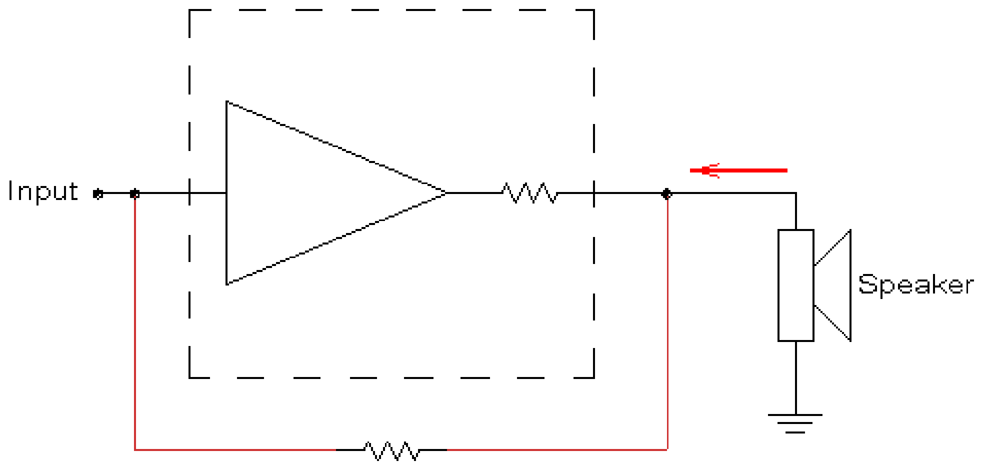
There does seem to be one benefit that over-rides all other. It is *insensitivity* to the load's reactive forces.

Speakers don't care whether the amp delivers current or voltage *if* the speaker were an entirely non-reactive resistive load. Alas this is not the case, speakers are violently reactive devices. They react to anything and everything that is in its proximity. Would you believe that if you were standing near a speaker and suddenly coughed, that speaker would react and also tell the amplifier it is connected to that something happened. This is not theory, it is fact.

But with non-Voltage amps the amp itself becomes much more immune to the speaker's reactive load. If the amplifier uses feedback, it likely becomes even more of an issue. Let's look at that in more detail.

How do amplifiers become Voltage amps? The question is a fair one as they are not usually such by nature. Indeed Voltage amplifiers mostly need to be forced to behave that way. How? It is usually by the application of feedback, and a fair bit of it. Negative feedback lowers the output impedance of any amplifier's output. So it is no mystery that Voltage amps are usually also… *feedback* amps.

When a feedback amplifier drives a reactive load, the output of the Voltage amplifier sees another input. The output of the amplifier becomes an input for the negative feedback, but also an input to the reactive loads of the speaker. Ouch!



The input is that red line that goes back to the actual input of the amp. It is controlled by the bottom series resistor. Can we now see that the output that goes to the speaker's terminal now has become another input? Note too that the actual *internal* output impedance has been bypassed and its effect has been overridden. On a mathematical level the feedback *shrinks* the value of that series resistor we see above that represents the output impedance. That internal resistance or output impedance is no longer able to buffer the reactive behaviour away from the amplifier. To use a common vernacular, the desired insensitivity goes up the spout.

Peculiarly, if we were to examine the actual output impedance before the application of feedback, then it may well be measured in several Ohms and hence become a Unity Coupling amplifier before the onset of feedback.

Indeed the natural behaviour of amplifiers is often not that of a Voltage amplifier at all (they mostly behave that way as result of what is a trick). In fact I rarely think it is achieved in a proper way. Certainly tube amps naturally tend to be Unity Coupling and can also be tweaked to behave as Current amps and this is done so by designers like David Berning, Gary Pimm, Steve Bench and I am sure a few others. Solid State amplifiers can be made into modulated *current source* and they truly are Current amplifiers with extremely high output impedance. One such is made by Nelson Pass.

Perhaps the only real Voltage amps that are solid state are very much heavy duty Class A (they run a *lot* of current and huge heat) without negative feedback and that can achieve 1 Ohm or lower. But these are rare beasts. But if any of the above amps starts to apply negative feedback they will go down the road to behave like Voltage amps and that *real* output impedance is no longer able to buffer reactive loads.

Hence the low output impedance of Voltage amp is not *real*, but the output impedances of non-Voltage amps *are*.

Next month we will publish Part 2. The above does not touch on what problems are encountered with amplifiers with high output impedances. Yes, they may be more immune to the speaker's reactive load, but now the problem becomes the fact that speakers do not have flat impedance and that the amplifier's frequency response becomes modulated by the impedance curve of the speaker. For this reason the speakers we use with Unity Coupling and Current amplifiers needs to be chosen, or designed, carefully. But when that is tackled, some remarkable performances can be had – even if they employ less than common methods. So next month we will deal with those issues. We will also discuss the experiment(s) we shall try at ASoN's August meeting. Hopefully, we will be presenting a new speaker for the first time, one that has designed to work specifically with non-Voltage amplifiers.

In the mean time, here is a test that many of you can try right now:

I have some nice Dale 4-5 Ohm resistors that I would be willing to sacrifice, for some of you to try going down this road. Simply put them in series with your speakers. This will force your Voltage amp to behave like a Unity Coupling amplifier.

The down side is that you will loose some of your amplifier's rated power and also increase some interaction between the amp and speakers. But you will also improve markedly the amplifier's ability to reject the speaker's reactive load. It is worth a try. Give me a call and I will pop some suitable resistors in the post.

BTW, if you are listening to 300B Single-Ended-Triode amp, then you may not be aware that you are already listening to a Unity Coupling amp. Indeed most classic SE tube amps do not use feedback and thus behave as non-Voltage amps. Also, the JLTi EL34 amplifier that won the huge amplifier shoot-out we did over two month's meetings; that too were *not* a Voltage amp, but a Unity Coupling tube amp. It used no feedback.

But if you use solid state amp, then try force it into Unity Coupling mode. Give me a call on 02-96074650 or 0412-203382 and chat about it, maybe even arrange for me to send you just two parts that can be tried. You have nothing to loose.

Be sure to read Part 2 next month and also the August ASoN meeting where we will be running demonstrations and compare all three modes of amplification.

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