

## The Thorny Math of Impedance (a cautionary tale about subwoofers)

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I frequently get questions about connecting multiple amplifiers to Audio Research vacuum tube preamps. This can be a thorny issue. Virtually all the questions revolve around connecting a self-powered solid-state subwoofer along with the main 2 channel power amp. I guess we have a lot of customers who cannot use full range stereo speakers and must resort to a sub/satellite system either to get it to fit into their décor or to



get along with their family... And let's not forget those poor benighted souls who must press their 2 channel audio gear into the role of amplifying movie soundtracks. So, what's the big deal? Why can't you just connect up that Big-Ass-pant-leg-flappin' sub and scare the dog with subterranean bass? Read on...

### Preamp output impedance.

Nearly all ARC vacuum tube preamps are rated to drive a connected load (read amplifiers) of not less than 20,000 ohms (20K ohms). What does this mean? The output stage of a vacuum tube preamp has a high source impedance of (usually) several hundred ohms. Vacuum tubes, because of their inherently high internal resistance (known as impedance) compared to a transistor, are limited in their ability to supply current into a connected load. Solid state preamps, on the other hand, usually have a very low source impedance of < 100 ohms.

Now let's use a (tiny) bit of math to sort this out. When you connect more than one amplifier to a preamp, the loading on the preamp's output stage is considered in *parallel*.

That means each amplifier's input resistance (input impedance) is less than the individual load by some amount as expressed by the parallel resistance equation  $1/Z_1 + 1/Z_2 = 1/Z_{\text{total}}$ , where  $Z$  = amplifier input impedance. An easy example: 100 K ohm + 100 K ohm. Using the 1/X button on your kid's scientific calculator converts 100 K ohm to .00001. Add .00001 + .00001 = .00002. Hit the 1/X key again and you have 50,000 ohms (50K ohms). This is the *parallel* impedance the preamplifier's output stage must drive.

Now let's take a real world example to see why adding a subwoofer or second amplifier to a vacuum tube preamp is problematic. The REF5 SE is rated to drive not less than a 20K ohm load. A connected REF75 SE power amp presents the REF5 SE with a 300 K ohm input impedance. Good so far. But say we connect a typical self-powered subwoofer to the second set of main outputs on the REF5 SE. Our theoretical subwoofer has an input impedance of 20 K ohm. Well, 20 K ohm is OK, right? Not so fast, audio tweaker! We must use the parallel resistance equation above:  $1/300\text{K ohm} + 1/20\text{K ohm}$ , or  $.000003333 + .00005 = .000053333$ . Hit 1/X and you have 18,750 ohms. This is below our minimum recommended load for the REF5 SE.

It gets even worse: Many powered subwoofers have input impedances of 10K ohms. Plug this into the example above and your net *parallel* load on the REF5SE drops to 9677 ohms !

So what happens when you decrease the load driven by the preamp below its minimum specification? The extra current demand on the output stage softens dynamic impact and results in generally poorer sound as the vacuum tube output stage struggles to drive the low impedance of the *parallel* load of the two connected amplifiers. Luckily, this won't damage anything. But sound quality is why you purchased Audio Research products in the first place, right? – and we *never* want to hurt the sound quality!

Faced with the desire to add a subwoofer or second amplifier, what can you do? Check the specifications page of the manual of the amplifier or subwoofer you are interested in adding. (Audio Research provides the input impedance of our amplifiers in our owners' manuals and on our website.) Use the equation above to see if the gods of the high end smile upon you or smite you.

Good luck finding the input impedance specs on the speaker manufacturers' websites! Of six well-known subwoofer manufacturers' websites I visited, **only one** bothered to specify its sub's input impedance.

Nobody promised this was a hobby for the faint of heart...