

inguz amplifier

2005-10-06	highZ/lowZ output taps
2005-10-03	tweak component values for 4Ω and more gain; add rear photo
2005-09-29	add "background" and "references" and finish photos
2005-09-27	first version; rough exterior & some internals pictures



This is a high-performance audio power amplifier using the LM3886. Its home is to bi-amp my Linn Keosa floorstanding loudspeakers (using their passive crossover, but separate amplifier channels for top and mid/bass) with [SqueezeBox2](#) as source. There's no preamp; volume control is digital, internal to the SB2. The high output impedance means this amplifier should work really well with single-driver full-range speakers too.

Input: 2 channels.
Output: 4 channels (Left-A, Left-B, Right-A, Right-B) >25 watts per channel.
Gain: 21dB into 4 ohms.
Enclosure: approx 8½ x 11 x 3 inches, copper, brass, acrylic and mahogany.
Weight: approx 40lbs.

Background

In the couple of months since I bought a Squeezebox, my previous system – Linn Axis, Rega Planet, Nakamichi DR3, Rega Brio – have been largely unused. So they need to move upstairs, and the Brio be replaced with a simple power amplifier.

A friend introduced me to DIYAudio.com, and things kinda snowballed from there. Hours and hours of reading and learning. It's been a slippery slope, as you will see by the "References" section at the end of this document.

The end result: I wanted to build an amplifier. It ought to have some of the "arts and crafts" aesthetic, be built fairly easily with my very limited skills and resources, and sound great.

So, the inguz amplifier. Total cost: somewhere below \$150, plus many hours uncounted. It looks good and sounds good; if I can resist the temptation to keep tweaking, it should last for years.

Amplifier

The amplifier is a single stage; the only active element is the LM3886 chip.

LM3886 is configured in a modified (unbalanced) "Howland current pump" to provide output impedance approximating 4 ohms, with the output impedance being reasonably constant across the audio range (primarily resistive). Using an unbalanced bridge achieves good stability with easily available components; there's no need for closely-matched resistors beyond 1% tolerance.

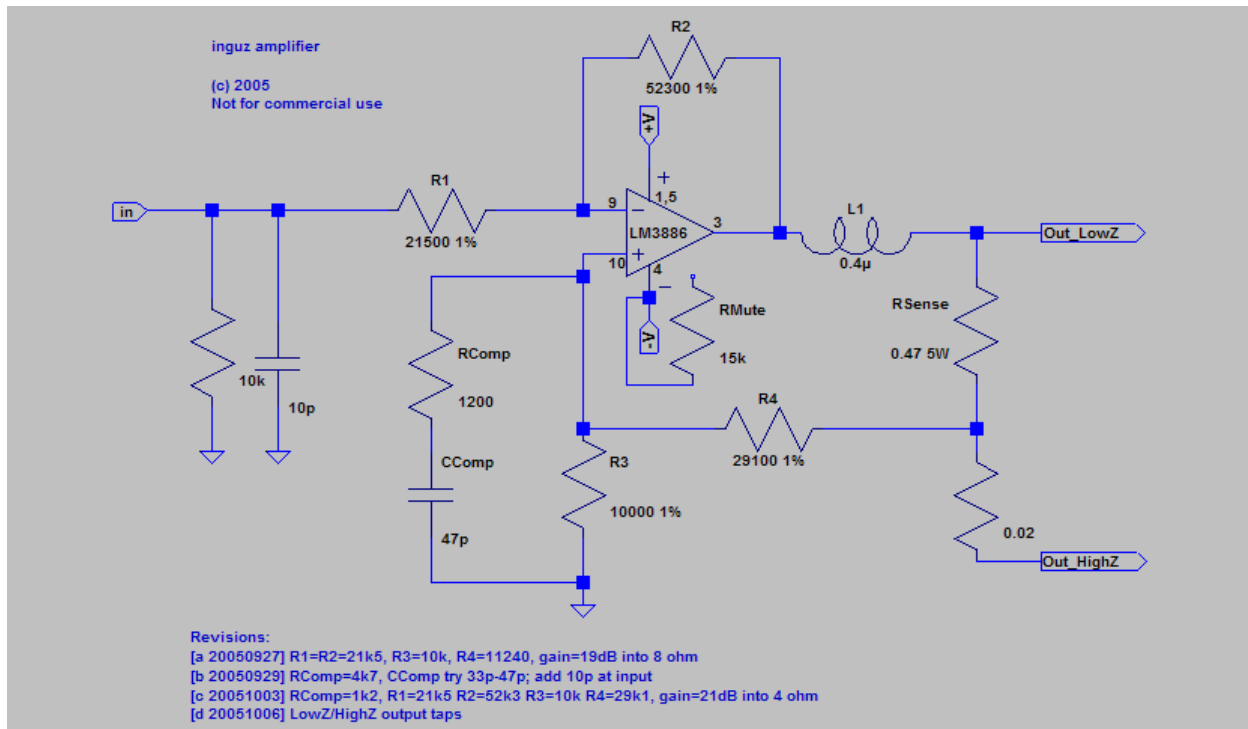
One interesting feature of this circuit is that you can take a choice of two outputs: a high output impedance (similar to many tube amplifiers) or a near-zero output impedance ("voltage drive", much more typical of solid-state amplifiers). Currently I'm experimenting with both: high-Z to drive the top end of my loudspeakers, and low-Z to drive the bass/mid. There's plenty of room for experimentation.

The sense component is fine with 10% tolerance; it consists of a power resistor and hand-wound air-core inductor. The inductor keeps output impedance up at high frequencies as the open-loop gain of the LM3886 decreases. It also helps roll off HF gain slightly, although the other compensation components are more important for loop stability. To roll your own inductor: 13 turns, over a 6mm diameter nylon tube, then wrapped with heat-shrink.

Input impedance may drop somewhat if load impedance is high. Preferably the source should be capable of driving low impedance (<1K), especially if you leave some of the channels' outputs disconnected. A buffer stage before the main amplifier would be useful if your source can't meet this requirement.

Bridging – connecting A and B channel outputs directly together for increased power – should be naturally supported with a high-output-impedance design. I include a small series resistance for additional reliability (but mostly just because I had these gold-cased Dales sitting around, and they look mighty fine); 0.02 ohms is probably too low, try 0.1 instead. If you hear a rushing noise with bridged channels, it means one or both the channels are oscillating! Do NOT bridge the "low-Z" output taps!

Stability should be OK with the components below. If you have oscillation, try adding a small capacitor (10pF or so) across R2.



Note that output impedance of your source should be included in the R1 value when making calculations (see spreadsheet at http://www.cabezal.com/~inguz/amp/inguz_amplifier.xls).

Component values in the diagram give output impedance 4 ohms and gain 21dB at the "Out_HighZ" tap, when driven from a source with output impedance 200 ohms (the Squeezebox). The "Out_LowZ" tap gives near zero output impedance and 26dB gain; to reduce gain in "voltage mode" to 21db, add 4k7 in series with the 29100 feedback resistor.

I built this amp with point-to-point wiring, but a PCB would have been easier (and doubtless more forgiving of missteps from fat fingers and hot irons).

Power supply

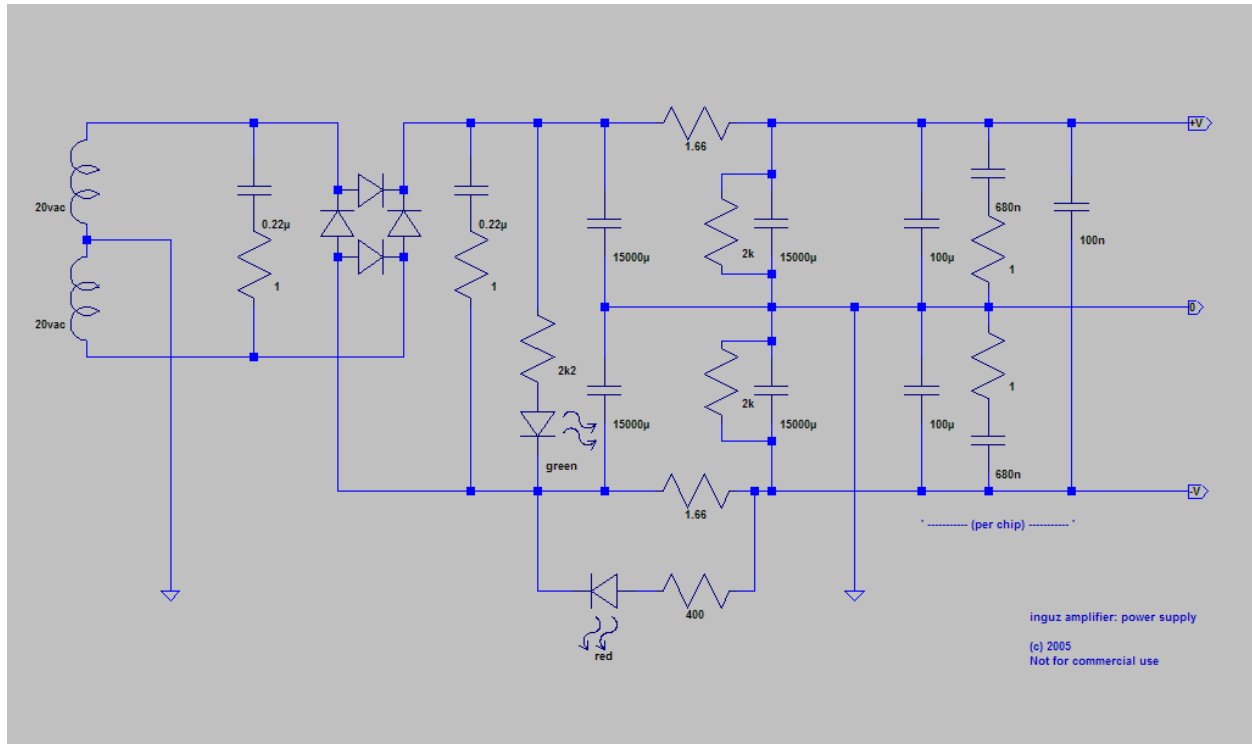
The power supply uses a large (approx 500VA) toroidal transformer with 20-0-20 volt secondary windings at 120v input, a single high-current bridge rectifier, and 30000uF filter capacitance per rail. The single positive and negative rails drive all four amplifier channels; this is not a "monobloc" power supply. Components were chosen simply due to availability.

Mains fuse is 3A slow-blow. (There's quite a large current inrush at switch-on). I didn't include fast-blow fuses on the DC rails; the LM3886 chip includes some protection, so DC fuses will probably only save your transformer if you have a short somewhere in the wiring.

A C-L-C filter would have been nice, but my enclosure is quite crowded already, so there's no room for large choke inductances. Instead I use a C-R-C design compromise, which provides reasonably good ripple rejection. Somehow I squeezed in four 15000uF/63v caps; it would have been easier if the chips were chassis-mounted, but that would have disrupted the clean sides of the enclosure. (Next time, I'd try to parallel several low-profile 4700uF/63v capacitors instead of the larger 15000uF/63v here).

Additionally, each chip has local decoupling of 100uF electrolytic || (680nF polyester + 1R) || 100nF ceramic, per rail to ground and 100nF from V+ to V-. Don't skimp on the decoupling capacitors, and put the ceramics as close to the pins as possible.

Since I had a nice green/orange dual LED to hand, I wired it so the green shows power and the orange should light up if too much current is being drawn (overload, or something badly wrong in the internals).



Enclosure

The enclosure has five sides of copper, with the back (connector panel) being acrylic. The corner supports are mahogany. Materials were chosen for aesthetics and availability.

Base and top: 8½ x 11 x 0.1875" copper plate.
Front and sides: 2½" x 0.25" copper bar.
Rear: ½" acrylic solid surface.

Copper is a beautiful metal, although very expensive – a [local source](#) supplied cheap offcuts at approximately \$3 per pound weight. It is fairly easy to drill and cut, and conducts heat extremely well (there is no need for separate heatsink). Copper is heavy; the case alone provides most of this amplifier's weight. Clean copper tarnishes quickly in air, so a protective coating of polyurethane rub-on varnish is applied. Caution: copper is very malleable, and will bend and dent if dropped or banged.

A slice of mahogany was available, so I used it. ([Don't buy mahogany](#) – instead, rescue it from antique furniture!). Other hardwoods are readily available. Oak would be nice. Surface treatment is Danish oil. (In the end I cheated, so as not to stress the wood: the legs don't actually hold the amp, in the pix you can see rubber feet underneath too.)

Acrylic solid surface ("Staron", available from kitchen/bathroom suppliers) is very strong, quite heat resistant, and easily worked; it can be drilled, sawn and sanded with woodworking tools. Besides use for the back panel, I also use it for insulating supports inside the amplifier. A half-inch panel thickness does require recesses for mounting most panel connectors. Again, suitable stock was already to hand.

Fixings use brass 6x32 and 8x32 bolts. Insulating supports use nylon 6x32 bolts. Sides are joined using 1/2" x 3/8" copper bar, drilled and tapped 8/32.

References

For build quality, I was definitely inspired by Peter Daniel's work, and the wonderful GainClone assortment in BrianGT's gallery.

<http://www.6moons.com/audioreviews/audiosector/patek.html>

<http://www.briangt.com/gallery/nigc>

On the subject of amplifier output impedance: although current-driven amplifiers (Hawksford, Pass) are interesting, I don't think they're practical in my environment. Instead I became convinced that non-zero but non-reactive ZOut should make for a "good" loudspeaker interface. There's a giant DIYAudio thread covering many aspects of this and the "back-EMF" issue. Alan Blumlein's ancient patent 421546 on power supply design was an interesting perspective (since I think the same concerns apply to audio amplifiers), as well as another Blumlein patent 425553 on the control of output impedance through feedback. Both these are completely readable and relevant seventy years on.

http://www.essex.ac.uk/ese/research/audio_lab/malcolmspubdocs/J12%20Distortion%20reduction%20MC%20current%20drive.pdf

<http://www.diyaudio.com/forums/showthread.php?s=&threadid=57995>

<http://www.6moons.com/audioreviews/firstwatt/firstwatt.html>

<http://www.doramusic.com/patents/421546.htm>

<http://www.doramusic.com/patents/425553.htm>

Mauro Penasa's "MyRef" design amazed me; although I didn't really understand his circuit, it provided the motivation to create an "interesting" chip-amp. Also, this was my introduction to the Improved Howland Current Pump.

<http://www.diyaudio.com/forums/showthread.php?s=&threadid=54571>

My final circuit is similar to this line-driver from Jerry Steele, with his compensation and gain calculations too:

<http://www.elecdesign.com/Articles/Print.cfm?AD=1&ArticleID=4529>

http://eportal.apexmicrotech.com/mainsite/pdf/apex_10_92.pdf

Error correction fascinates me, from the Quad 405 (sitting in my basement still, waiting for a day in the light, but now transformerless...), through Malcolm Hawksford's voluminous contributions, to Aubrey Sandman's strange solution of simply doubling open-loop gain. But having chosen a Howland-based circuit, and not wanting to include a simple buffer nor the complexity of an error-correcting bridge, I settled on a single-chip amplifier.

<http://home.jps.net/~shiloh/currentdumping.pdf>

http://www.essex.ac.uk/ese/research/audio_lab/malcolmspubdocs/J4%20Distortion%20correction%20Circuits.pdf

<http://www.lsionline.co.uk/lsi/features/techfocus/article.asp?ID=-19LOCH>

What next? A super-symmetry version of the current circuit? A "Class H" chipamp? A spirally-loaded loudspeaker? Who knows...

<http://www.passdiy.com/pdf/zen-v6.pdf>

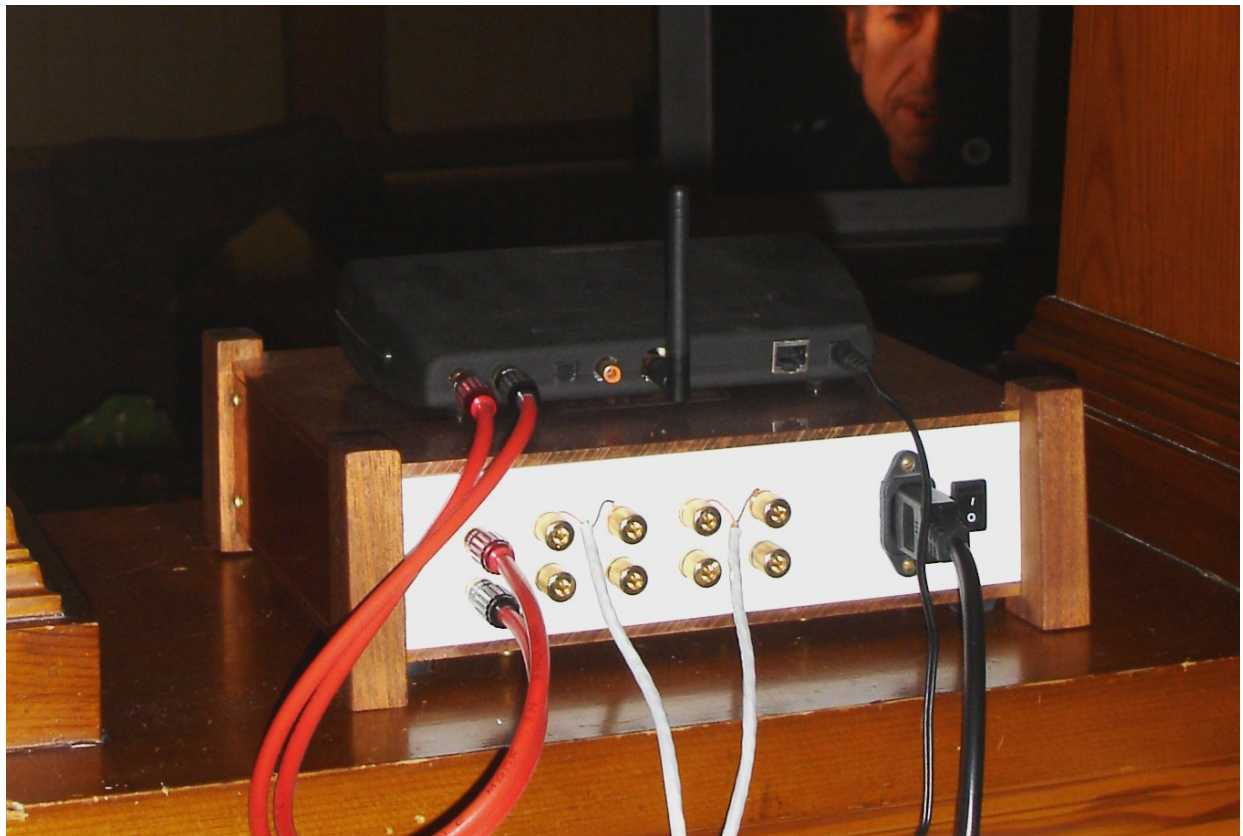
<http://www.diyaudio.com/forums/showthread.php?s=&threadid=36398>

<http://www3.ocn.ne.jp/~hanbei/eng-whyspiral.htm/>

<http://www.6moons.com/audioreviews/cornu/cornu.html>

Pictures

Rear:



The internals:

