68W
Hi-Performance Power Amplifier

Based on LM3886

by Born2BeWired for e-Gizmo

I guess I really took a long absence in audio related work. I became so out of touch with the developments that when I first took a look at the data sheet of recent high fidelity audio power amplifier IC devices, I was for a moment in a state of disbelief.

I am actually looking at the datasheet of LM3886 power amp IC- this is not even a new power amplifier IC, it has been around for about 10 years. But it is the one highly recommended by friends who spend most of their life doing professional and DIY audio. Checking the datasheets, they have reasons to be sanguine about this chip. I was instantly captivated by its published performance specifications that will rival even those of discrete designs.

Driven by curiosity, I found myself engrossed in doing the PCB layout for the LM3886 for a quick evaluation.

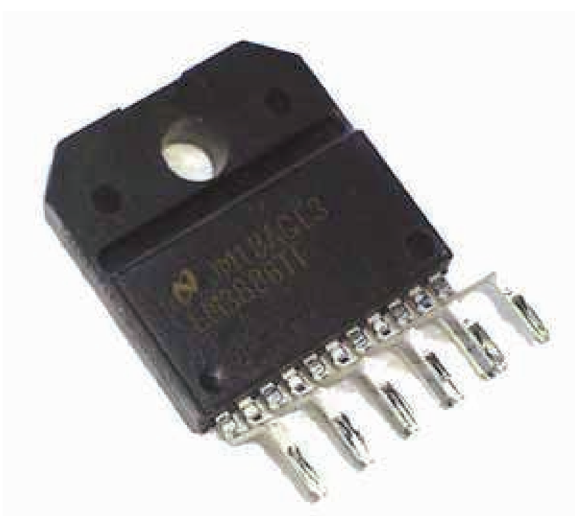

Figure 1. The LM3886 Overture Audio Power Amplifier is a high performance IC amplifier chip capable of delivering 68W (average output power) high-end quality music and sound reproduction.

Measured Performance Summary

Load:	4 ohm Resistive
Supply Voltage:	+/-29VDC
Idle Current:	+50/-50mA
Power Output	
@ 1% THD	68W sine average (RMS)
@10% THD	100W sine average (RMS)
Sensitivity:	-7.7dbV (0.816Vrms)
Output Offset:	-4.5mV (No load)
THD + Noise:	0.0028% (1)
S/N :	104dB (2)
Freq Response:	16Hz- >160kHz
Residual Noise:	490uV (2)
Damping Factor @ 100Hz:	180
Output Impedance @ 100Hz:	0.0222 ohms
Input Impedance @ 1kHz:	0.62912/0.62855

(1) Filter : 400Hz-80KHz
(2) Filter : 400Hz-30KHz
(3) @1kHz 45W Output

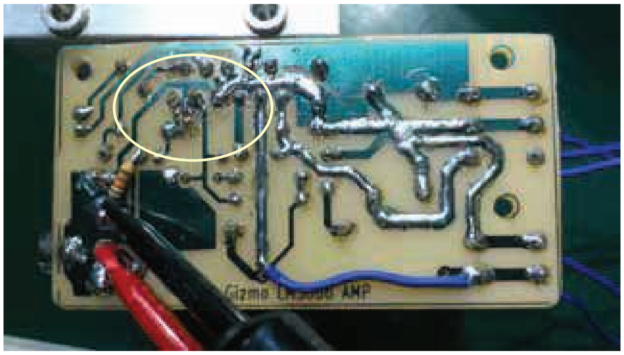

Figure 2. The LM3886 prototype built on a hand made PCB initially showed a higher than expected THD+N of 0.012%. That what appeared to be a subtle modification in the layout (the jumper wire encircled within the ellipse) resulted in THD+N improving to 0.0068%!

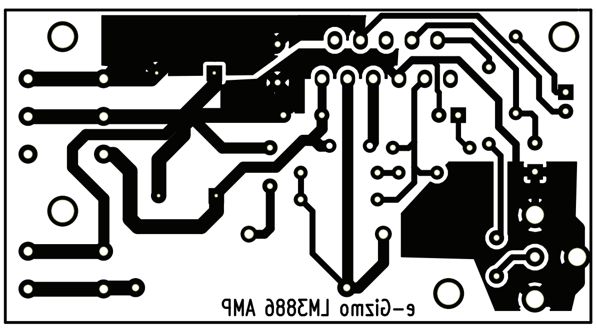

Figure 3a. This is the initial PCB copper pattern used in the prototype.

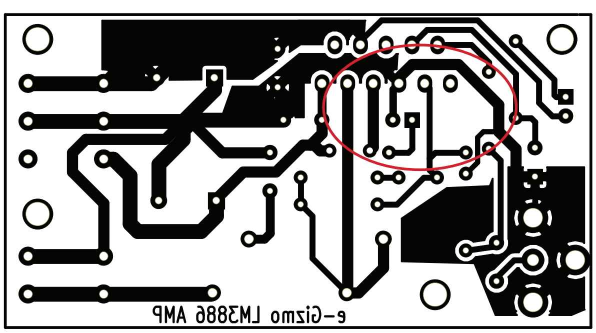

Figure 3b. Production PCB layout. The layout changes enclosed within the ellipse bring the THD+N down to 0.0028%. Can you spot the difference?

THE PCB LAYOUT

With my first test PCB layout ready, I hooked up the LM3886 amplifier on a +/-30V laboratory power supply with the amplifier output loaded with a 4-ohm dummy load. I let the amplifier run for a few minutes at different output level, poking at something every now and then, my kind of a getting-to-know ritual. When it was time for me to check the THD level at 1kHz, my VP-7720A Audio Analyzer showed a THD+N figure of 0.012%, not a bad figure, but a bit higher than what the datasheet says. I let the amplifier run at an output level just below clipping for about half an hour and checked again the THD+N reading- it remained at 0.012%.

This took my focus back on the most probable culprit - the PCB layout. After a detailed review of the layout, I found a subtle routing path error that may have contributed to the higher than expected THD+N figure. Its is the copper path that route the ground return of the feedback circuit. I hand modified the trace using cut and solder method, and tested again the LM3886 - THD+N is down to 0.0068% after this simple modification. That two times improvement, but still about twice worse than what the datasheet says it should be.

Nevertheless, I figured I can now rework the PCB layout. A new PCB layout with all improvements put into place was sent to a PCB fab house. The new PCB was delivered a couple of weeks later, from which I quickly assembled another set. Measured THD+N with the new PCB : 0.0028%. SNR gave an equally impressive figure of 104dB. Now I am both impressed and happy!

ABOUT THE CIRCUIT

In the final PCB layout, I included the usual components that may be needed to keep the LM3886 stable. But as it turned out, the LM3886 does not want these components. Adding them in the LM3886 circuit just made it more unstable, opposite to what was expected and desired. Hence the circuit in its final form as shown in Fig. 4 looked sparse and unremarkable. All components marked with asterisk (*) are not used.

R3 and R4 feedback components determine the voltage gain of the amplifier. With the given values, gain is about 1+ (20k/1k) = 21. C7 blocking capacitor ensures gain is experienced by AC signals only. We don't want any steady DC appearing at our amplifier output; it is C7 job to ensure this.

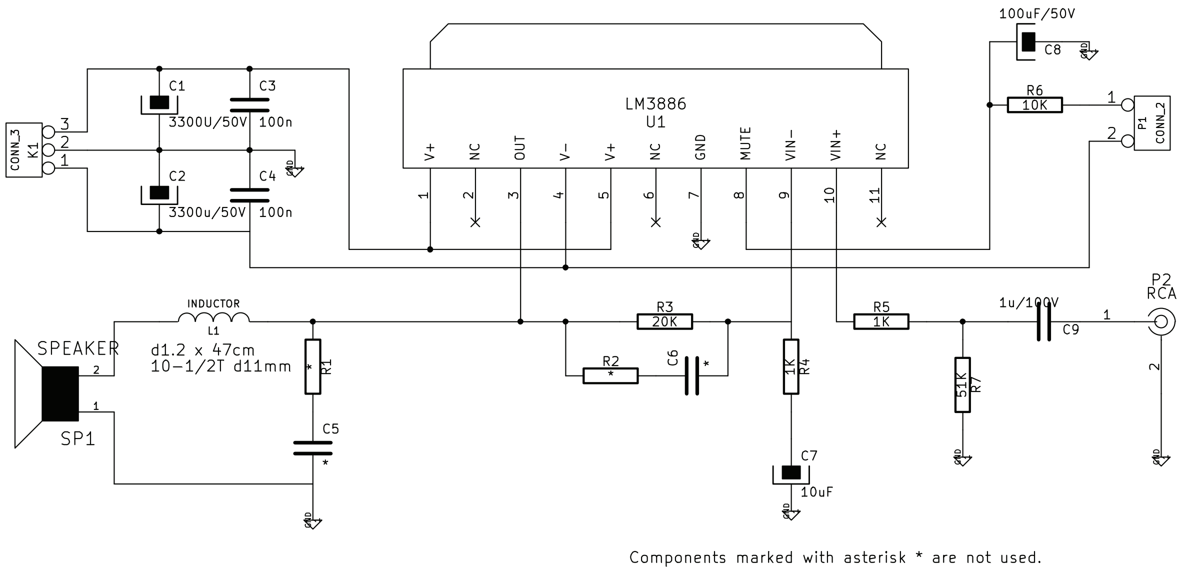

Figure 4. The complete schematic of the LM3886 based amplifier. Components marked with asterisk (*) were omitted when final evaluation testing showed them actually contributing more to instability, opposite to what is desired.

C9 works in a similar manner. It prevents DC voltage that may be present at the P2 input from appearing across the LM3886 input. R7 keeps the amplifier input firmly attached to DC ground, while R5 helps the LM3886 to maintain stability whatever the input signal may be doing.

L1 is fairly standard for power amplifier circuits, it keeps the output from oscillating whenever the speaker load shows its capacitive effect.

P1 is the mute input. It should be shorted with a jumper if not used. R6 and C6 keeps the amplifier muted for a short period when powering up to minimize pop noise.

C1-C4 are the on board power supply decoupling of the amplifier. Although the LM3886 have these capacitors on board, they are not intended to replace the filter capacitors that should also be present on your power supply circuit.

BILL OF MATERIALS

C1,C2	3300uF/50V
C3,C4	0.1uF/250V Polyester Film
C7	10uF/50V Electrolytic
C8	470uF/50V Electrolytic
C9	1uF/100V Polyester Film
K1	Teilbar Connector 3Way
SP1	Teilbar Connector 2Way
L1	Inductor (See Text)
P2	RCA Jack
R3	20K Resistor 1/4W
R4,R5	1K Resistor 1/4W
R6	10K Resistor 1/4W
R7	51K Resistor 1/4W
U1	LM3886TF
PCB	80-052812-1

Note: Heat Sink is required for U1.

Figure 5. The LM3886 IC U1 must be soldered so that it is standing close to 90 degrees relative to the PCB surface. The rear tab of the IC will line up with the edge of the PCB. This will minimize undue stress when you mount U1 later in a heat sink.

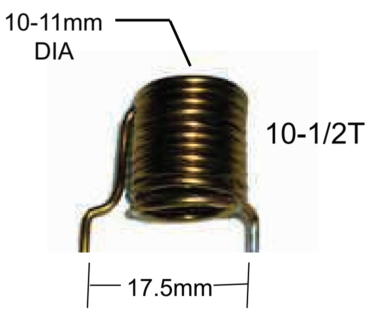

Figure 6. L1 can be formed by winding 10-1/2 turns of d1.0mm magnet wire on a 10-11mm diameter form.

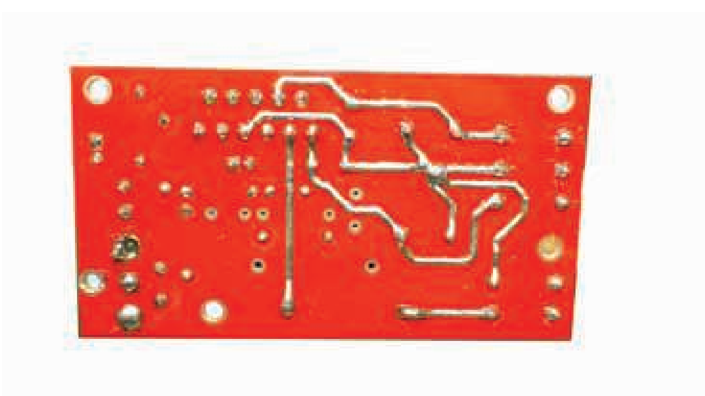

Figure 7. The PCB copper pattern has certain paths not covered with solder mask. These are the high current carrying conductors. You should apply generous amount of solder along these paths to augment their current carrying capacity.

ASSEMBLY HINTS

The whole kit contains just a handful of components and can be assembled by anyone with good soldering skill in less than an hour of assembly time.

As you mount and solder U1, keep in mind the LM3886 will have to be mounted later on a heat sink of your choice. Hence, make sure the IC is soldered upright 90 degrees relative to the surface of the PCB. A little slack on U1 pins will be a good idea- do not insert U1 pins all the way in. The rear tab surface of U1 should more or less line up with the edge of the PCB after the soldering is done.

Included in the kit is a 47cm d1.0mm magnet wire for L1. You need to find a 10-11mm diameter form to wind and make L1 out of it. Scrape 4-5mm insulation on both ends and wind 10-1/2 turn around the form. Cut the excess length and form the leads so that they are about 17.5 mm separated. See Fig. 6 for more details.

USING THE LM3886 AMPLIFIER KIT

The LM3886 kit is a high performance amplifier kit that can rival the performance of equivalent high end commercial amplifiers if built properly. In order to keep it performing it to its full potential, there are few basic wiring rules which you must carefully adhere to. This is discussed in greater detail in my blog "Freedom from Hum, Noise, and Distortion", originally published in www.elab.ph. A reproduction copy is also available through the following link:

http://www.e-gizmo.com/KIT/appnotes/Audio/FreedomFromHum.pdf

Spare some time to read this blog before assembly wiring your amplifier kit.

The LM3886 can drive 4-8 ohm speaker load. Of course, you get only half the available power with an 8-ohm load. You can somewhat compensate for this by using a slightly higher power supply voltage. For example, raising the power supply voltage to +/- 35VDC will allow LM3886 to deliver 50W average output power with an 8-ohm load.

Heat sink is required for the LM3886. Heat sink is not included in the kit to allow you to pick the size and shape that will fit inside your enclosure. The LM3886 tab is insulated, it does not need a mica or silicone insulator, but a heat sink compound must be liberally applied on both the LM3886 tab and heat sink surface during mounting to ensure good heat transfer.

How much heat sink is required depends largely on your enclosure. A crowded enclosure will almost always require a larger heat sink. The LM3886 datasheet discussed in details the determination of heat sink size. In practice, you will know if the heat sink is insufficient- the LM3886 shuts down repeatedly when playing at high volume levels. If you can't fit in a larger heat sink inside or outside of your enclosure, force convection cooling using a fan may present an alternative. Be warned though that forced air cooling may result in audible and annoying air current and fan noise, defeating the 104dB SNR your amplifier so remarkably achieved.

The LM3886 amplifier kit input can be driven directly from personal music player outputs with great results, such as iPods. You can use the built-in equalization functions of these players if you want to tweak the tonal properties of the sound.

If you want to equip your LM3886 amplifier with its own preamplifier and tone control circuit, e-Gizmo Digital Control Preamplifier kit is well suited for the purpose. A pure analog preamplifier and tone control kit is currently being planned for development, and may become available pretty soon.

LISTENING TESTS

This is one particular subject I am every bit reluctant to discuss with anyone. This is because of its highly subjective nature, not to mention the fact that my ears are not made for this. To be honest, I myself don't pay much attention with discussions of this nature. I tend to give more weight to performance parameters that can be measured. But people are expecting a topic of this sort to be included when discussing amplifiers. So, for the fun of it, I will give it a shot. Promise, I will make this as short as it needs to be. Remember, what matters most is your personal judgment. If you like what you are hearing, enjoy it to its fullest. Don't let anyone else opinion rob you of that pleasure.

I hooked up a pair of finished LM3886 PCBA to a pair of old Yamaha NS-153 loudspeakers and used an Apple Ipod as my program source. I played an old slow rock classic "Hotel California" by the Eagles. This was how it sounded to me:

Sound clarity is outstanding. Mids and highs came out very clearly. Bass played out solid and not boomy at all. OK, OK, I myself is not so sure about the meaning of the things I just mentioned. But in my honest opinion, I liked very much the way it reproduced the music. Of course, I know for a fact that every hobbyists would swear theirs is the best sounding one ever, very much like a mother to her child (being the prettiest in the whole world). And so to bring in a fair measure objectiveness, I invited several my colleague who occasionally pops in and out of the testing area to listen and tell me what they think. All of them expressed a genuine approval, with some of them even returning with their personal player to try out their favorite music with the setup.

MEASURED PERFORMANCE

Test Conditions:

Date: June 26,2012
Ambient Temp: 26-28C
RH: 75%

Load: 4 ohm Resistive Dummy Load
Supply Voltage: +/-29VDC

Instruments Used:
Panasonic VP-7720A Audio Analyzer
Philips PM3394 Oscilloscope (Audio Analyzer Monitor)
HP35665A Dynamic Signal Analyzer
HP3401A 6-1/2 Digit DMM
Tektronix TDS784D DSO
Fluke 197 DMM

Idle Current:
+50/-50mA
Power Output
@ 1% THD 68W sine average (RMS)
@10% THD 100W sine average (RMS)
Sensitivity/Gain:
-7.7dbV (0.816Vrms) / 26.6dB
Output Offset:
-4.5mV (No load)
THD + Noise @ 1KHz :
0.0028% (1)
S/N :
104dB (2)
Freq Response:
16Hz- >160kHz
Slew Rate:
11V/us
Residual Noise:
490uV (2)
Damping Factor @ 100Hz:
180
Output Impedance @ 100Hz:
0.0222 ohms
Input Impedance @ 1kHz:
0.62912/0.62855

(1) Filter : 400Hz-80KHz
(2) Filter : 400Hz-30KHz
(3) @1kHz 45W Output

THD+N vs Frequency

Freq	THD+N (%)		
100Hz	0.012	2000	0.0042
200Hz	0.008	3000	0.0046
300Hz	0.0085	4000	0.0048
400	0.0045	5000	0.0054
500	0.0045	6000	0.006
600	0.0044	7000	0.007
700	0.0042	8000	0.0082
800	0.0032	9000	0.0095
900	0.003	10k	0.011
1000	0.0028	20k	0.026
Freq	**THD+N(%)**		

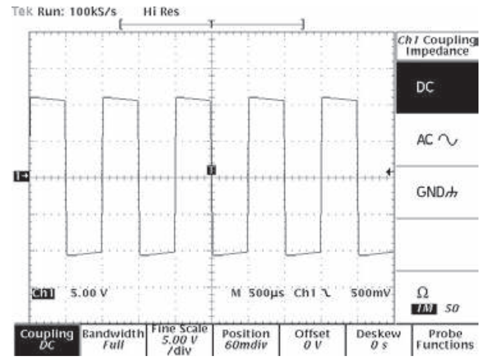

Figure 10. LM3886 1 KHz square wave clean response. No ringing is detected, but then, keep in mind the test load is purely resistive.

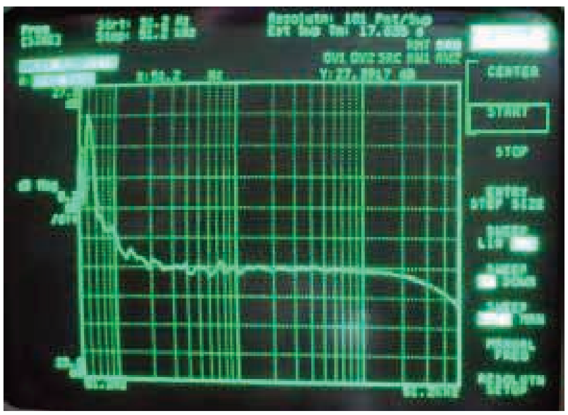

Figure 8. Photo of LM3886 Kit Magnitude response curve as plotted by HP35665a. A 1dB peaking occurs at around 60Hz. Gain is measured at 26.6dB with +/- 0.2dB flatness from 100Hz to 50KHz.

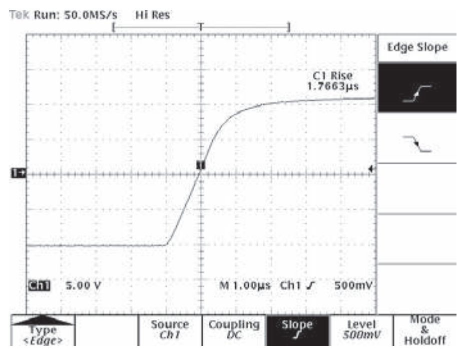

Figure 11. LM3886 rise time is pegged at 1.7 us. The amplifier slew rate can be derived from this plot as around 11V/us.

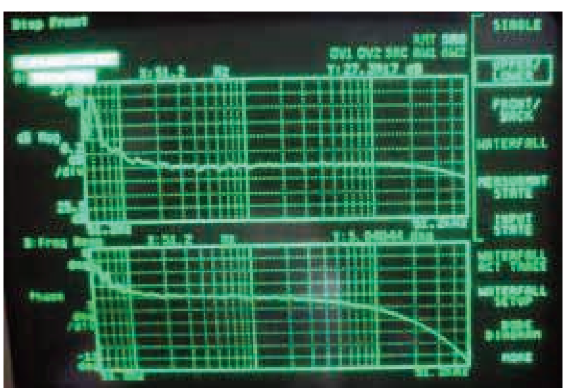

Figure 9. Gain and Phase response. The HP35665a was not actually built for audio test response; hence it has a limited upper frequency range of up to 51.2KHz only, not enough to cover the whole bandwidth of LM3886. The lower plot shows the phase response as beginning to roll at -2 degrees at 20 KHz, shifting to -12degrees at 51.2 KHz.

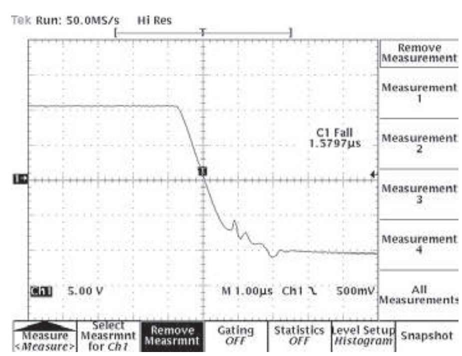

Figure 12. The switching fall time is nearly equal to the rise time. Ringing comes into view at this fast horizontal sweep rate.

PCB ARTWORK

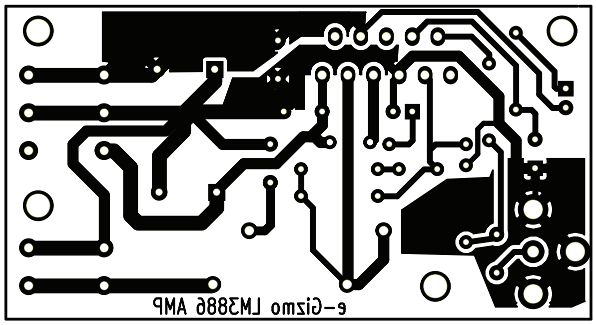

Figure 13. PCB Copper pattern viewed from component side. This pattern is drawn to 1:1 scale.

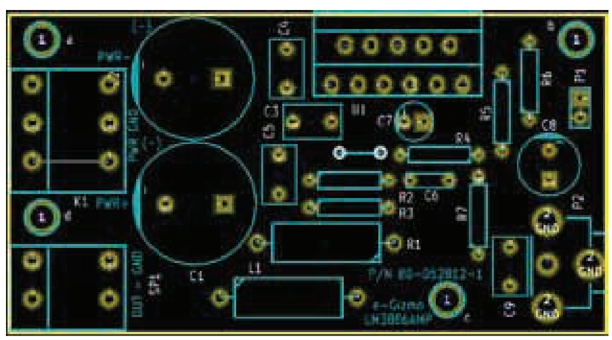

Figure 14. LM3886 Kit component layout.

