TNT 1541A - DIY zero-oversampling DAC

The elder brother of our Convertus...

[Italian version]

Product: TNT 1541
Company: **not for sale**, TNT-Audio **free** DIY design
Approx. cost: 200$/Euro (just components)
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The TNT Convertus has been one of my favorite designs. It was probably one of the first DAC DIY projects published in Italy, and attracted a lot of attention (well, given the size of the market, obviously...).

A few changes have been made to the original Convertus design, but I never had the time to test another DAC: it would have required a complete overhaul of the project, including a new PSU.

Anyway, rumours about the outstanding quality of another DAC chip have loudly continued - the DAC in question, the TDA1541A, has a slight problem: it is no longer in production.

As I wanted to present an easy to build DAC, this was a condition I was not willing to accept, but after building it, I realized that the design includes a few interesting elements that can be applied to any other dac type. Even though the DAC is now rather difficult to find, especially in the selected versions, it is still available, and in the end the situation is no worse than that of a few well known NOS tubes....

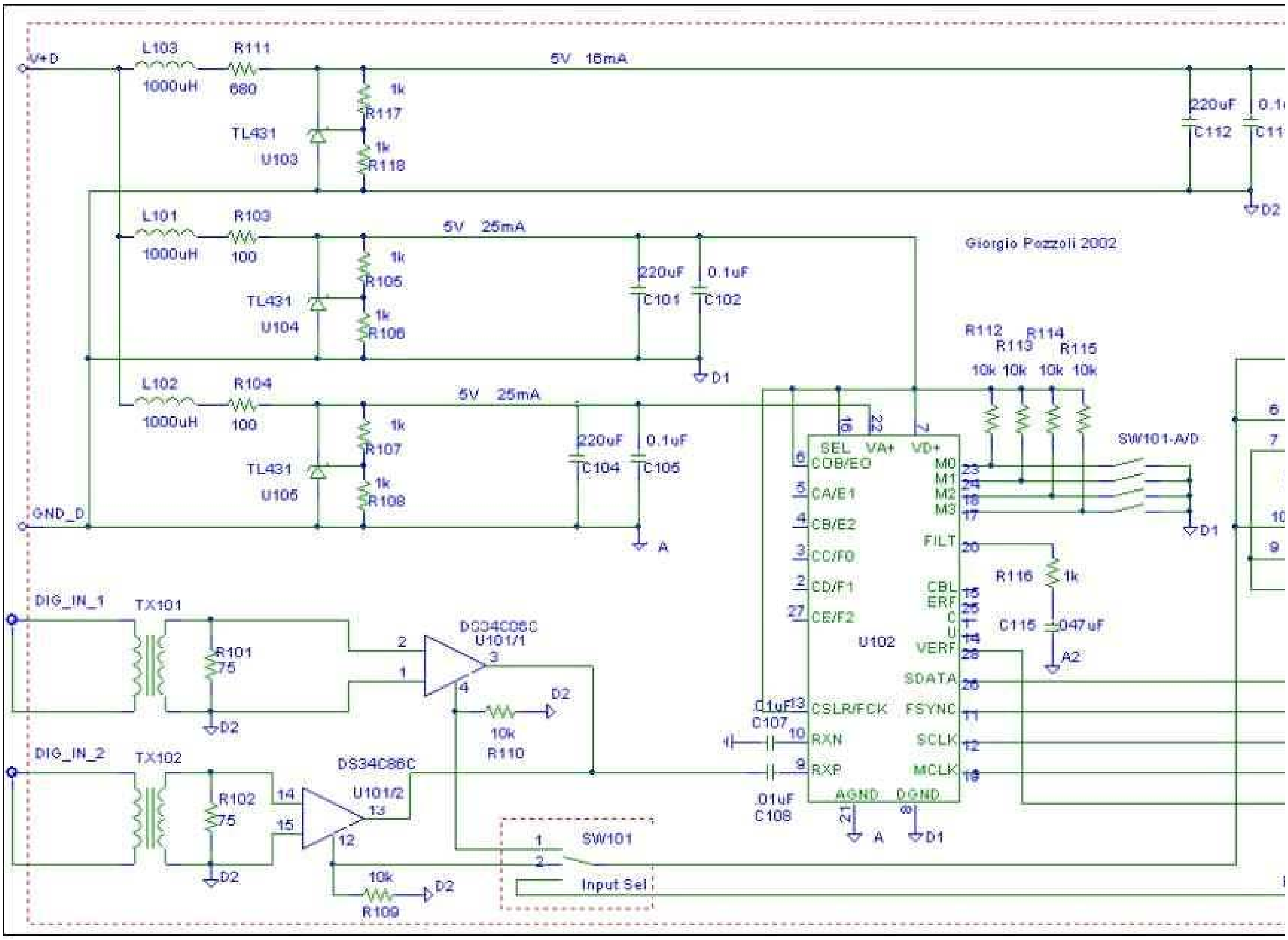
So here is the DAC.

One more note. I will not go back in detail over all the circuitry I have already described in the Convertus, Convertus decima and Convertus Decima Digital articles. Please read them through before reading the present one.

The receiver circuit

For the receiver I used a CS8412. At the time I'm writing this article it is still present in the RS catalogue in a DIL package. The CS8414, the current generation, seems to work a little better, but is not available in DIL format: if you dare working with a surface mount chip, it can be a valid pin to pin substitute.

In order to be able to select any output configuration, the mode pins are controlled by a quadruple microswitch... this lets me select any possible output configuration with ease. Mode 3 is to be used (M0=1, M1=1, M2=0, M3=0), unless you do not wish to implement the digital decimation circuit. In that case, you must select mode 1 (I2S compatible, all signals output).



As you see, there is wide use of local regulation. A large number of TL431s are used on the different boards to decouple all power supplies. This is a precision, programmable, low cost voltage reference that is used (in this application) as shunt voltage regulator. In this configuration it has a dynamic output impedance of 0.1ohm up to 100KHz... Not a very original idea, anyway: I think there are at least two other DAC projects available on the net using the same feature in exactly the same position.

More interesting are the digital inputs. In fact, two inputs are shown on the schematic, but you can add as many as you want, provided that you check the power supply regulation is up to the job.

Each input connection is completely de-coupled using a high frequency transformer. I used a ferrite toroid from RS Components as a core, part number 212-0831, and just wound up both primary and secondary coils with five turns of insulated copper solid core wire (the one used for normal power transformers secondary coils). Unfortunately the original ferrite toroid is no longer available; try finding something similar of small dimensions.

The digital input socket can be either RCA or BNC. I always use BNC, which can specified for a precise 75ohm impedance, but this sometimes creates problems (or requires an adapter to be used...). In either case they must be female sockets, insulated from the panel.

The digital input signal comes out of the secondary of the transformer and is taken to a digital receiver, a DS34C86. This chip contains two differential line receivers and two drivers. The drivers have no use for us, at least for the moment. The receivers work according to the RS-422 electrical standard, which is very similar to S/PDIF electrical standard.

A very interesting aspect of the chip is that the receiver has a three-state output: this means that its output can be disabled, and in this situation presents a very high impedance. The technique is obviously used in buses, where more than one device can get control of the bus depending on the situation.

In our case it allows us to have several different receivers with output in parallel on the same digital line, provided that only one receiver output is enabled at any time. This is achieved by using a simple switch (SW101). If you plan to add more inputs, a rotary switch is recommended.

It is now clear why it is so easy to add other digital inputs: it is just necessary to add one more receiver chip and connect its output to the common output line and its selection input to the input selector.

Note how the receiver outputs are coupled to the 8412 input via a capacitor.

The output signal EN_SPDIF_IN is for future development (guess what for?).

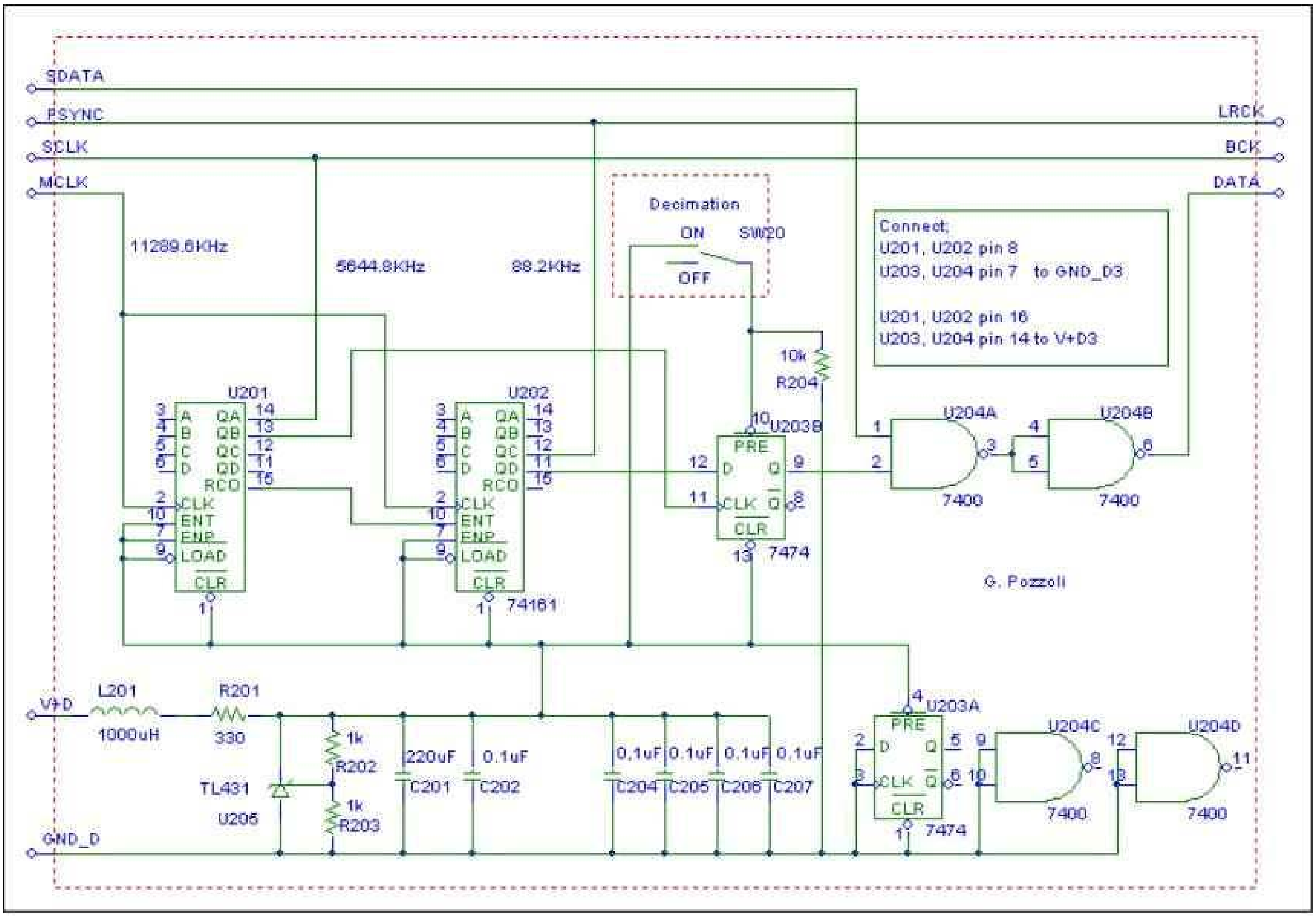
The decimation circuit

I am not going to describe this module in detail, as it has been already described in the article about the Convertus Decima Digital.

If you want to avoid implementing it, you must simply select CS8412 mode 1 through the multiple microswitch SW101/A-D and just connect FSYNC to LRCK, SCLK to BCK, SDATA to DATA.

As there is switch SW201 that allows to enable or disable decimation, I strongly suggest to test it. If you don't like the results, you can simply bypass the decimation module.

I must admit that while decimation improves the sound of the Convertus in a significant way, the TDA1541A treats high frequencies with such care and detail that decimation can be considered optional.



C204, C205, C206, C207 are bypass capacitors placed as near as possible to U201, U202, U203, U204 respectively, and connected between the power supply and ground pins of each IC.

The DAC circuit

Even the DAC circuit is not anything special. The DAC, configured as in the schematic, directly supports the I2S interface, so connection to the receiver is really straightforward, apart from the decimation circuit.

The DAC chip requires three voltages: +5V, -5V, -15V. As you see there are three separate voltage regulators on board. They should be placed as near as possible to the corresponding DAC chip pin.

In this area all components should be of the highest possible quality: polypropylene capacitors must be used, especially for the 14 capacitors to be connected to the DAC chip and the I/V conversion resistors (R310, R311).

Some explanation is perhaps required for DAC chip quality levels. From old Philips documentation ("Semiconductors for Digital Audio", Designer's Guide, August 1997) it appears that there are four versions of TDA1541A; from the datasheet of February 1991, it appears that the selection was based on the highest linearity attainable, but only 3 selections are defined. I have also included TDA1543 info in the table just as a reference (in referring to Convertus take into account that a quad DAC increases SNR by 6dB).

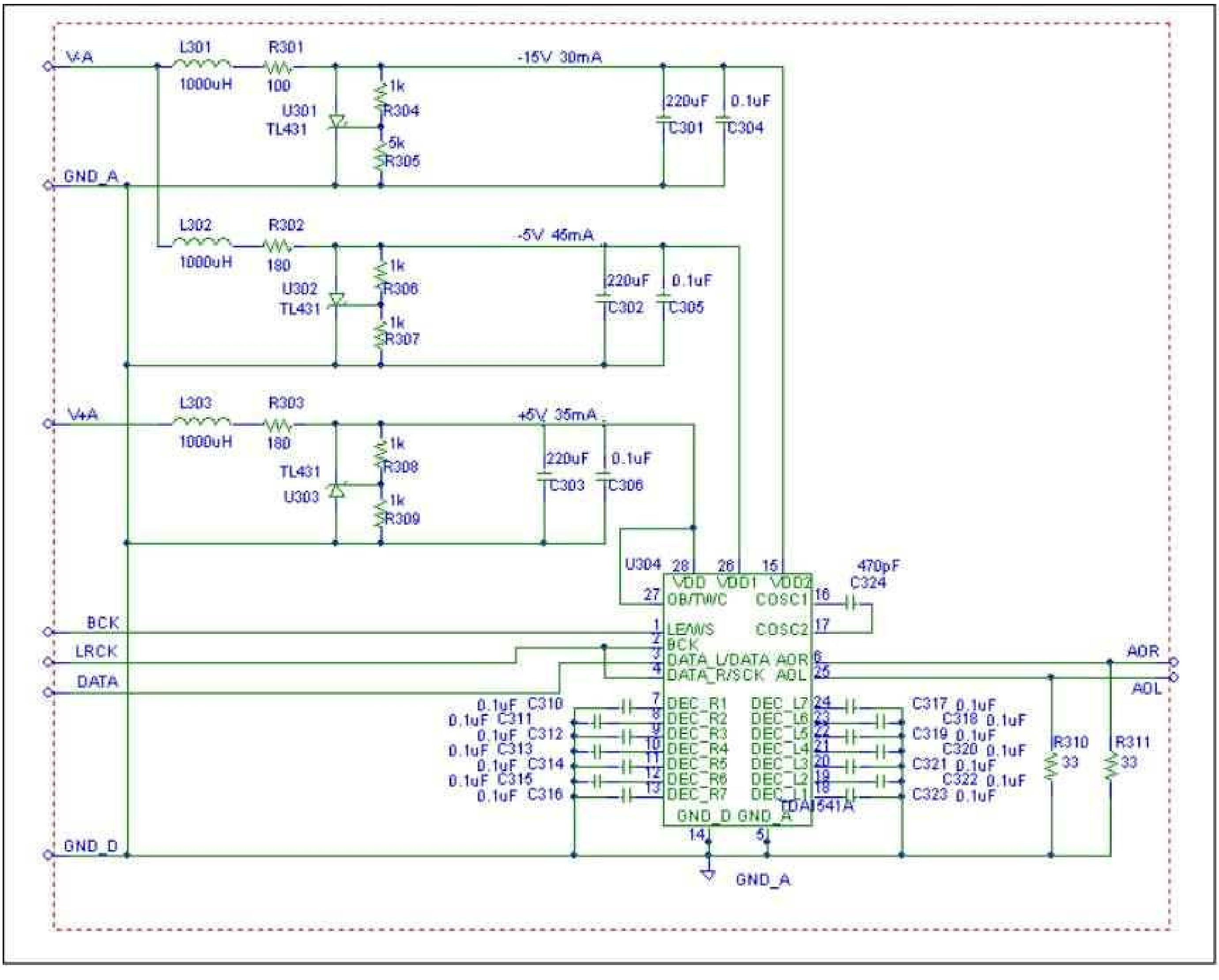
Type	Description	Data Format	Typ. THD+N at 0dB *	Typ. THD+N at -60dB *	Typ. SNR	Typ. Output Current	Channel Separation	Max dif e
			dB(%)	dB(%)	dB	mA	dB	
TDA1541A	high-performance 16- bit DAC	I 2 S, up to 8f s	-95(0.0018)	-42(0.79)	112	4.0	98	bit 1-16 E
TDA1541A / R1	high-performance 16- bit DAC	I 2 S, up to 8f s	-95(0.0018)	-43(0.7)	112	4.0	98	bit 1-16 E
TDA1541A / S1	single crown 16- bit DAC	I 2 S, up to 8f s	-95(0.001)	-47(0.4)	112	4.0	98	bit 1-7 Ed bit 8-15 E bit 16 EdL
TDA1541A / S2	double crown 16- bit DAC	I 2 S, up to 8f s	-97(0.002)	-47(0.4)	112	4.0	98	I
TDA1543(T)	economy 16- bit DAC	I 2 S, up to 4f	-75(0.018)	-33(2.2)	96	2.3	90	I

* A-weighting

The best version of TDA1541A is obviously the double crown, which was used only on really high-end converters. And this happened not centuries ago: in 1998 it was still the best Philips converter available and in fact when the Marantz CD-7 cd-player was produced, it was chosen for that specific reason, according to Marantz documentation.

I have not been able to find any double crown, and I have used a single crown instead. I also used during first tests a normal version (no crown) just to spare the better ones. There is more refinement and detail in the single crown, but the difference is not so huge as when comparing the quad TDA1543 of Convertus with a single TDA1541A.

Given the huge costs the single crown has reached these days, I do not dare imagine the cost of a double crown, assuming it is possible to find one. Anyway, should you by chance have any spare double crown, please e-mail me...



The C310-323 capacitors must be very high quality polypropylene capacitors (in choosing them, take into account that normally film and metal sheet capacitors are better than metallized film ones) and should be placed as near to the corresponding pin as possible. A package as small (thin) as possible is therefore required.

Also C304,C306,C308 are very high quality polypropylene capacitors, and must be placed as near as possible to the corresponding power supply pin. C301, C302, C303 are OS-CON capacitors placed as near as possible to the previous ones.

For R310-R311, the I/V conversion resistors, I used Holcos. Given the fact there are only two, and their importance in defining the resulting sound is expectedly high, you could experiment with more expensive varieties.

The output circuit

TDA1543, according to Kusunoki, is the only DAC able to drive directly a load up to a normal line output level, and hence the only one not requiring any output stage with gain.

In the case of TDA1541A such a stage is mandatory. I have used a very simple solid state differential stage followed by an emitter follower, in order to achieve the required gain (around 22dB) with a very low output impedance.

There is however a peculiarity: note the position of R421/423. These introduce a small of amount of feedback. In general I agree that the less input/output feedback the better, but here the case is different: this is positive feedback, reducing the stability margin of the stage but increasing its speed. The difference in sound with these resistors in place is really notable: far higher push, impact and apparent speed - a really lively sound.

A few other designs use twin TDA1541As to increase dynamics: I do not really think it is necessary, unless you are a real lover of high dynamics. That said, in our solution, it requires only four more resistors...

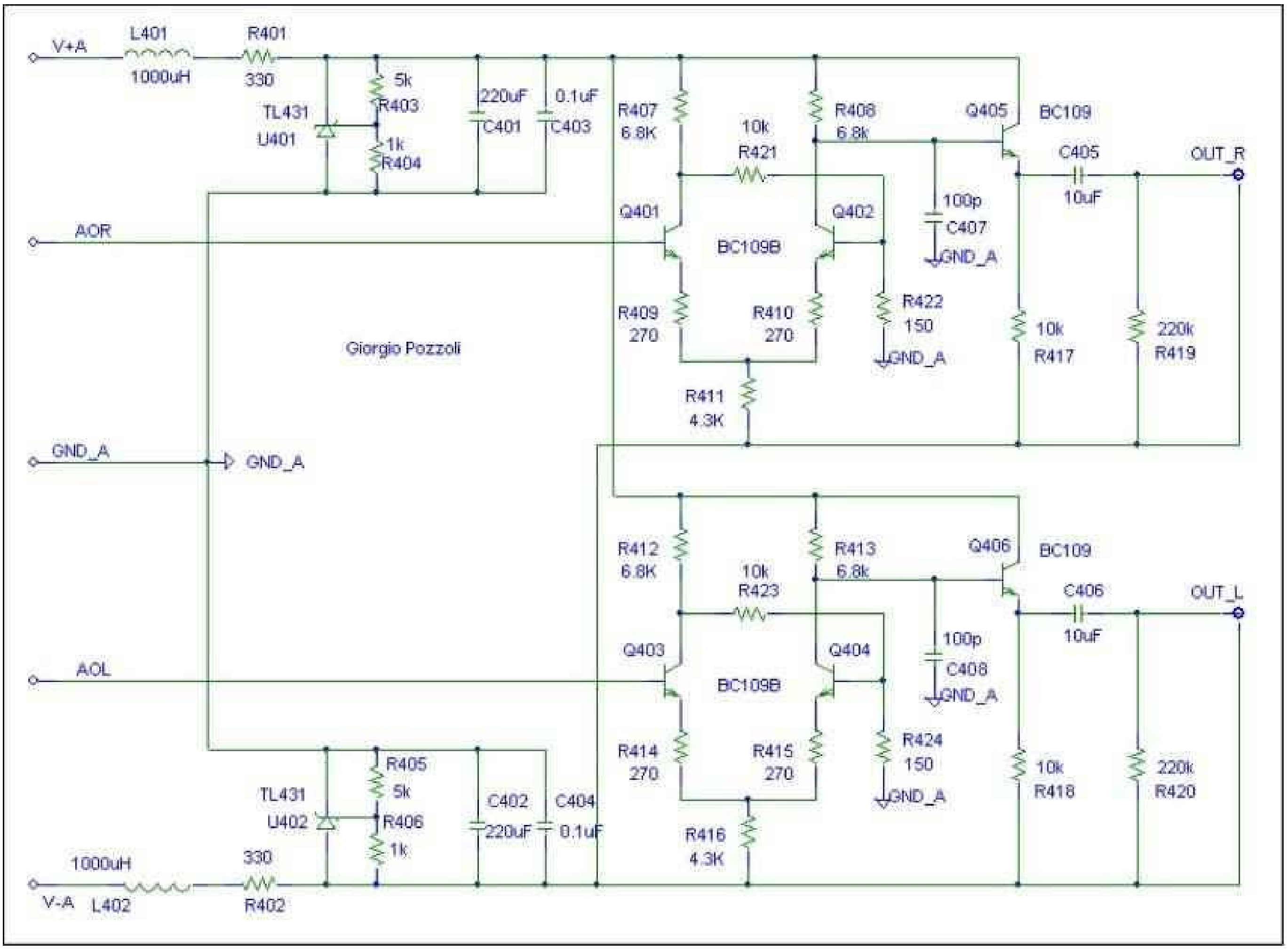
The circuit is perfectly stable and has a good deal of local feedback, which helps in giving rather low distortion in spite of the simplicity of the circuit (0.05% at 20kHz at full output level from simulations: direct measurements are not so easy due to characteristics of the zero-oversampled signal...).

Here the highest quality components are again mandatory. In the prototype all resistors are Holcos, all capacitors are polypropylene or OS-CON electrolytic ones. Matching transistors for the same gain and possibly lowest noise cannot do any harm, but I didn't bother and no trouble has arisen.

There is also a low pass filter, composed simply by C407/408 and the collector resistors of the differential couple. This causes only a tiny drop at 20kHz, but also a reduced drop at higher frequencies: in one word, the output is (very) dirty. In compensation, the phase shift due to the output filter is very, very low.

The output is AC coupled via a very high quality polypropylene capacitor. Use the best film capacitor you can think of, and afford...

I definitely suggest avoiding paper in oil capacitors here, as the sound (for my taste) already has enough passion, sparkle and glitter without paper in oil caps!



The circuit has been built on the same board as the DAC, as near as possible to the I/V conversion resistors to reduce the risk of interference.

The power supplies

Given the high number of local regulators, I decided to limit the number of power supplies to two - one for digital components (receiver and decimation circuits), and one for the analogue side. If you wish, you can mount a larger number, dividing their usage between the different modules.

All power supplies are regulated using a simple capacitance multiplier circuit, using either an N- or a P-channel MOSFET depending on the polarity.

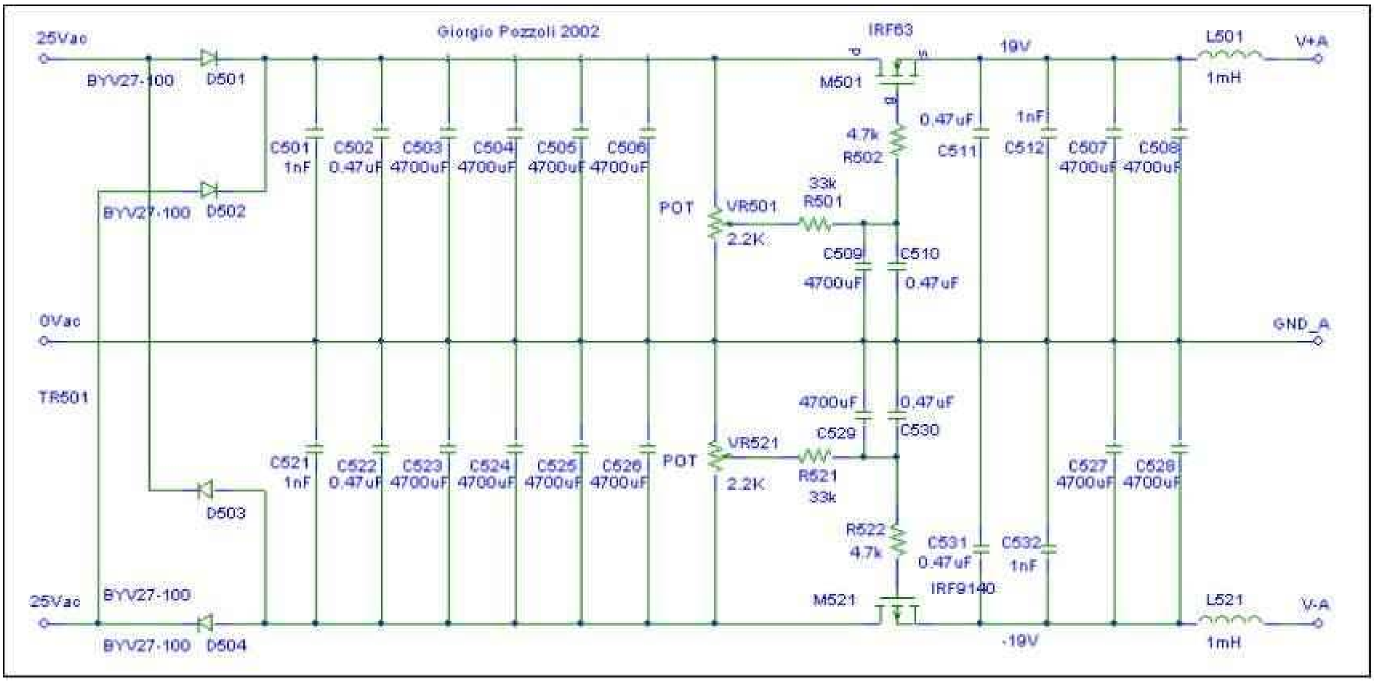
Do not underestimate the importance of the pre-regulator: without it, significant mains ripple filtered through to the output, so it is definitely mandatory.

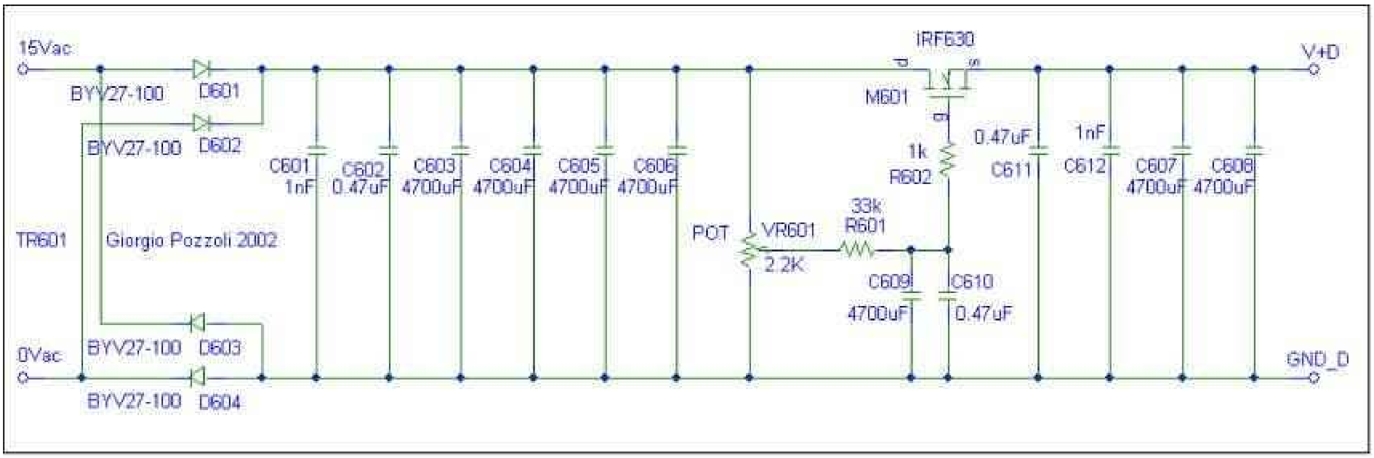
I used a large number of power supply capacitors in parallel in both PSUs. To an extent, the more the better, but don't be excessive.

The diodes are ultrafast rectifiers, with a 25ns recovery time; this reduces spikes and switching disturbances. You could even use the SBYV27 series, which has a recovery time of 15nsec.

Given the distance from the audio circuits, I do not think it is the case of using special capacitors here: standard industrial quality should be enough.

Important note: all the MOSFETs must be mounted on small heat sinks.





The implementation

All the circuits are mounted on single sided printed circuit boards. As usual, the copper side is used as the ground plane and all the components are mounted on this side. Have a look at the assembly instructions for more information.

The internal connections, between the boards and from these to the RCA connectors) are in rather thin, solid-core, silver plated copper wire. When the connections are longer, I used insulated solid-core wire from some UTP Category 5 network cable.

Follow the the order of the schematics exactly in wiring the input pins. As already said the input jacks are isolated from the back panel, and also the output sockets are insulated. All ground leads meet only in one point in each board. Follow the instructions and schematics carefully.

The sound

I am not going to review the unit at all. I am not so arrogant as to pretend to be able to be objective (yes I know, I have some limitations...).

Even so, I understand it is important to give the reader an idea of the sound it produces. Anyway I warn you in advance to consider whatever follows a very biased and personal view...

The sound is lucid and passionate, with highs going up to heaven and further without any hint of hardness. The bass is deep, solid when necessary, controlled and at the same time warm and rounded - you are sometimes surprised to hear a bass line where normally one would only know a bass was playing.

From the imaging point of view, it is precise; the soundstage is naturally deep.

A comparison with Convertus? I used as a reference the latest Convertus version with decimation, and source follower output stage. Tests were made with decimation both active and inactive. All that I can say is the 1541A is in another league. The sound is far, far more lucid, smooth, to such an extent that this seems to be a tonal abberation compared to Convertus, with the highs taking priority. But then the bass comes in - neat, deep, and you feel it is correct this way.

When you come back to Convertus you really miss the smoothness and detail, the softness of 1541A. There is only one area in which Convertus seems to be slightly better, and it is punch: but this is probably down to the laid back and rough high frequencies in Convertus, which as said seems to highlight the bass.

Conclusion

This is not a simple project to build. As said, there are also problems in finding the TDA1541A. You can find the normal version for around 25 EUR, but the cost for the selected version **is** an issue.

Anyway, the result is so good that I really think you should at least give it a try. If you have a Convertus, you can just mount a board with the DAC and output stage, and give it a test. I am pretty sure that if you don't like the result, you'll be able to re-sell the chip for at least at the same price you bought it...

Kind of investing in chips? Well, let's say... cannot be much worse than stock, these days, no? And remember, guys: stock does not sound at all...

Parts List

Receiver

Code	**Value**	**Rating**	**Notes**
C101	220uF	25V	High Quality Electrolytic
C102	0.1uF	35V	Polypropylene
C104	220uF	25V	High Quality Electrolytic
C105	0.1uF	35V	Polypropylene
C107	0.01uF	35V	Polypropylene
C108	0.01uF	35V	Polypropylene
C111	0.1uF	35V	Polypropylene
C112	220uF	25V	High Quality Electrolytic
C115	0.047uF	35V	Polypropylene
L101	1000uF		RF Choke
L102	1000uF		RF Choke
L103	1000uF		RF Choke
R101	75	1/4W 1%	Holco
R102	75	1/4W 1%	Holco
R103	100	3.5W	Resista
R104	100	3.5W	Resista
R105	1k	1/2W 1%	Holco
R106	1k	1/2W 1%	Holco
R107	1k	1/2W 1%	Holco
R108	1k	1/2W 1%	Holco
R109	10k	1/4W 1%	Holco
R110	10k	1/4W 1%	Holco
R111	680	2W	Resista
R112	10k	1/4W 1%	Holco
R113	10k	1/4W 1%	Holco
R114	10k	1/4W 1%	Holco
R115	10k	1/4W 1%	Holco
R116	1k	1/2W 1%	Holco
R117	1k	1/2W 1%	Holco
R118	1k	1/2W 1%	Holco
SW101			1 way 3 positions
U101	DS34C86C		RS422 Line Driver/Receiver
U102	CS8412		Digital Receiver
U103	TL431		Precision Voltage Reference

U104	TL431		Precision Voltage Reference
U105	TL431		Precision Voltage Reference
	BNC female	75ohm	for panel, insulated, qty:2

Decimator

Code	Value	Rating	Notes
C201	220uF	25V	High Quality Electrolytic
C202	0.1uF	35V	Polypropylene
C204	0.1uF	35V	Polypropylene
C205	0.1uF	35V	Polypropylene
C206	0.1uF	35V	Polypropylene
C207	0.1uF	35V	Polypropylene
L201	1000uF		RF Choke
R201	330	1W	Resista
R202	1k	1/2W 1%	Holco
R203	1k	1/2W 1%	Holco
R204	1k	1/2W 1%	Holco
R205	1k	1/2W 1%	Holco
SW201			1 way 2 positions
U201	74HC161		Binary Counter
U202	74HC161		Binary Counter
U203	74HC74		Dual D-type Flip Flop
U204	74HC00		Quad 2-input NAND gates
U205	TL431		Precision Voltage Reference

DAC

Code	Value	Rating	Notes
C301	220uF	25V	OS-CON Electrolytic
C302	220uF	25V	OS-CON Electrolytic
C303	220uF	25V	OS-CON Electrolytic
C304	0.1uF	35V	Polypropylene
C305	0.1uF	35V	Polypropylene
C306	0.1uF	35V	Polypropylene
C310	0.1uF	35V	Polypropylene
C311	0.1uF	35V	Polypropylene
C312	0.1uF	35V	Polypropylene
C313	0.1uF	35V	Polypropylene
C314	0.1uF	35V	Polypropylene
C315	0.1uF	35V	Polypropylene
C316	0.1uF	35V	Polypropylene
C317	0.1uF	35V	Polypropylene
C318	0.1uF	35V	Polypropylene
C319	0.1uF	35V	Polypropylene
C320	0.1uF	35V	Polypropylene
C321	0.1uF	35V	Polypropylene
C322	0.1uF	35V	Polypropylene
C323	0.1uF	35V	Polypropylene
C324	470pF	35V	Polypropylene
L301	1000uF	100mA	RF Choke
L302	1000uF	100mA	RF Choke
L303	1000uF	100mA	RF Choke
R301	100	3.5W	Resista

R302	180	3.5W	Resista
R303	180	3.5W	Resista
R304	1k	1/2W 1%	Holco
R305	5k	1/2W 1%	Holco
R306	1k	1/2W 1%	Holco
R307	1k	1/2W 1%	Holco
R308	1k	1/2W 1%	Holco
R309	1k	1/2W 1%	Holco
R310	33	1/2W 1%	Holco
R311	33	1/2W 1%	Holco
U301	TL431		Precision Voltage Reference
U302	TL431		Precision Voltage Reference
U303	TL431		Precision Voltage Reference
U304	TDA1541A		High Performance DAC

Gain Stage

Code	Value	Rating	Notes
C401	220uF	25V	Electrolytic OS-CON
C402	0.1uF	35V	Polypropylene
C403	220uF	25V	Electrolytic OS-CON
C404	0.1uF	35V	Polypropylene
C405	10uF	100V	Polypropylene very high quality
C406	10uF	100V	Polypropylene very high quality
C407	100pF	35V	Polypropylene very high quality
C406	100pF	35V	Polypropylene very high quality
L401	1000uF		RF Choke
Q401	BC109B		NPN transistor
Q402	BC109B		NPN transistor
Q403	BC109B		NPN transistor
Q404	BC109B		NPN transistor
Q405	BC109B		NPN transistor
Q406	BC109B		NPN transistor
R401	330	2W	Resista
R402	330	2W	Resista
R403	5k	1/2W 1%	Holco
R404	1k	1/2W 1%	Holco
R405	5k	1/2W 1%	Holco
R406	1k	1/2W 1%	Holco
R407	6.8k	1/2W 1%	Holco
R408	6.8k	1/2W 1%	Holco
R409	270	1/2W 1%	Holco
R410	270	1/2W 1%	Holco
R411	4.3k	1/2W 1%	Holco
R412	6.8k	1/2W 1%	Holco
R413	6.8k	1/2W 1%	Holco
R414	270	1/2W 1%	Holco
R415	270	1/2W 1%	Holco
R416	4.3k	1/2W 1%	Holco
R417	10k	1/2W 1%	Holco
R418	10k	1/2W 1%	Holco
R419	220k	1/2W 1%	Holco
R420	220k	1/2W 1%	Holco
R421	10k	1/2W 1%	Holco
R422	150	1/2W 1%	Holco

R423	10k	1/2W 1%	Holco
R424	150	1/2W 1%	Holco
U401	TL431		Precision Voltage Reference
U402	TL431		Precision Voltage Reference
	RCA Pins	gold plated	for panel, insulated, qty:2

PSU A

Code	Value	Rating	Notes
C501	1nF	35V	Ceramic
C502	0.47uF	35V	Polypropylene
C503	4700uF	35V	Electrolytic
C504	4700uF	35V	Electrolytic
C505	4700uF	35V	Electrolytic
C506	4700uF	35V	Electrolytic
C507	4700uF	25V	Electrolytic
C508	4700uF	25V	Electrolytic
C509	4700uF	35V	Electrolytic
C510	0.47uF	35V	Polypropylene
C511	0.47uF	35V	Polypropylene
C512	1nF	35V	Ceramic
C521	1nF	35V	Ceramic
C522	0.47uF	35V	Polypropylene
C523	4700uF	35V	Electrolytic
C524	4700uF	35V	Electrolytic
C525	4700uF	35V	Electrolytic
C526	4700uF	35V	Electrolytic
C527	4700uF	25V	Electrolytic
C528	4700uF	25V	Electrolytic
C529	4700uF	35V	Electrolytic
C530	0.47uF	35V	Polypropylene
C531	0.47uF	35V	Polypropylene
C532	1nF	35V	Ceramic
D501	BYV27-100		Superfast Diode
D502	BYV27-100		Superfast Diode
D503	BYV27-100		Superfast Diode
D504	BYV27-100		Superfast Diode
M501	IRF630		N-channel MOSFET
M521	IRF9630		P-channel MOSFET
R501	33k	1/2W 1%	Holco
R502	4.7k	1/2W 1%	Holco
R521	33k	1/2W 1%	Holco
R522	4.7k	1/2W 1%	Holco
TR501	PSU Transformer	30VA	Prim:220V, Sec:25+25V

PSU D

Code	Value	Rating	Notes
C601	1nF	35V	Ceramic
C602	0.47uF	35V	Polypropylene
C603	4700uF	25V	Electrolytic
C604	4700uF	25V	Electrolytic
C605	4700uF	25V	Electrolytic
C606	4700uF	25V	Electrolytic
C607	4700uF	25V	Electrolytic
C608	4700uF	25V	Electrolytic
C609	4700uF	25V	Electrolytic
C610	0.47uF	35V	Polypropylene
C611	0.47uF	35V	Polypropylene
C612	1nF	35V	Ceramic

D601	BYV27-100		Superfast Diode
D602	BYV27-100		Superfast Diode
D603	BYV27-100		Superfast Diode
D604	BYV27-100		Superfast Diode
M601	IRF630		N-channel MOSFET
R601	33k	1/2W 1%	Holco
R602	1k	1/2W 1%	Holco
R603	10k	1/4W 1%	Holco
VR601	2.2k	1/2W	Trimmer potentiometer
TR601	PSU Transformer	30VA	Prim:220V, Sec:15V
	Mains Filter	with IEC Socket	with power switch and fuse

Supervisor: Tom Browne