▶ ezDAC

By Claudio Negro

The author presents an easy-to-build—and good-sounding—upsampling digital to analog converter.

PHOTO 1: The DAC.

I had wanted to build a DAC for a long time, but other audio duties kept me from doing so. After some on-line searches, I was able to find many do-it-yourself kits, as well as some assembled DACs (mainly from Asian sellers) at such cheap prices that I was tempted to give them a try. However, soldering and building DIY projects acts as a kind of meditation for me, recharging my mind. So, I definitely wanted to assemble a DAC rather than buy a ready-to-play one.

I first needed to decide between oversampling or nonoversampling topology. Some audiophiles believe upsampling is the wrong way to go, but in the end, it is a philosophical decision. Anyway, I chose upsampling.

My next question was: Which DAC chip to employ? I had the chance to listen to the Accuphase DP57 CD player, which I liked very much and which uses the TI PCM1796 (www.ti.com), so I decided on either this family of chips or the AD1853 (www.analog.com), which is used in another Accuphase player. Both those Analog Devices and Texas Instruments DACs have differential current output, leaving full freedom in choosing the current to voltage conversion (I/V) circuit.

After much web surfing, I ended up with two DAC options: the Analog Devices 1853 evaluation board (now replaced by the EB1955), which, at the time, came at a cheap price. The second option was to buy the ezDAC PCB by Evan Zamir. Because I wanted to gain some experience with SMD components soldering and to be free to choose the components to be used, I decided on the ezDAC (**Photo 1**).

Evan is a professor of mechanical engineering at Georgia Tech University, but most of all he is a DIY audio enthusiast who decided to produce a small number of PCBs just for fun and passion, without any commercial gain. So I contacted him and ordered the PCB, plus some spare components. I waited a long time to receive the box, due to postal delay, but when it finally arrived I was impressed by the quality of the board. You can find more information on Evan's website: www.ezdiyaudio.com.

The PCB I used is version 1.0, although the upgraded v. 1.5 is available. These boards are similar, with the newer one including some jumper-able power rails (which allow easier modifications to the regulator section) and the addition of solder mask-silkscreen layers. The ezDAC architecture is shown in **Fig. 1**.

The S/PDIF digital input enters a 1:1 pulse transformer, which offers some galvanic isolation to the noise present in the input signal. The quality of the transformer is very important here. The DIY audio community recommends the used model: the Newava S22083 (www.newava.com) alias Schott 22083. Making a good pulse transformer is an art, because some compromises exist; one parameter that has a big impact on the performance is the *leakage inductance*, the lower the better.

Because the Newava is hard to find in Europe, while US DIYers can find it at Digi-Key (www.digikey.com), I investigated some possible substitutes, finding the Umec UT14013 and the C&D 76601/3 as valid candidates, though with different PIN dispositions. I tried to buy them from a local distributor and reseller, with no success. So I e-mailed the manufacturers asking for a sample, explaining to them my project and a follow-up article, but getting the same result: zero. So, unfortunately, I can't provide a pulse transformer comparison. Last minute note: While writing this article, I checked my usual components resellers again, and discovered that Farnell (www.farnell.com) now carries the Murata 76601/3, rebranded model of the C&D
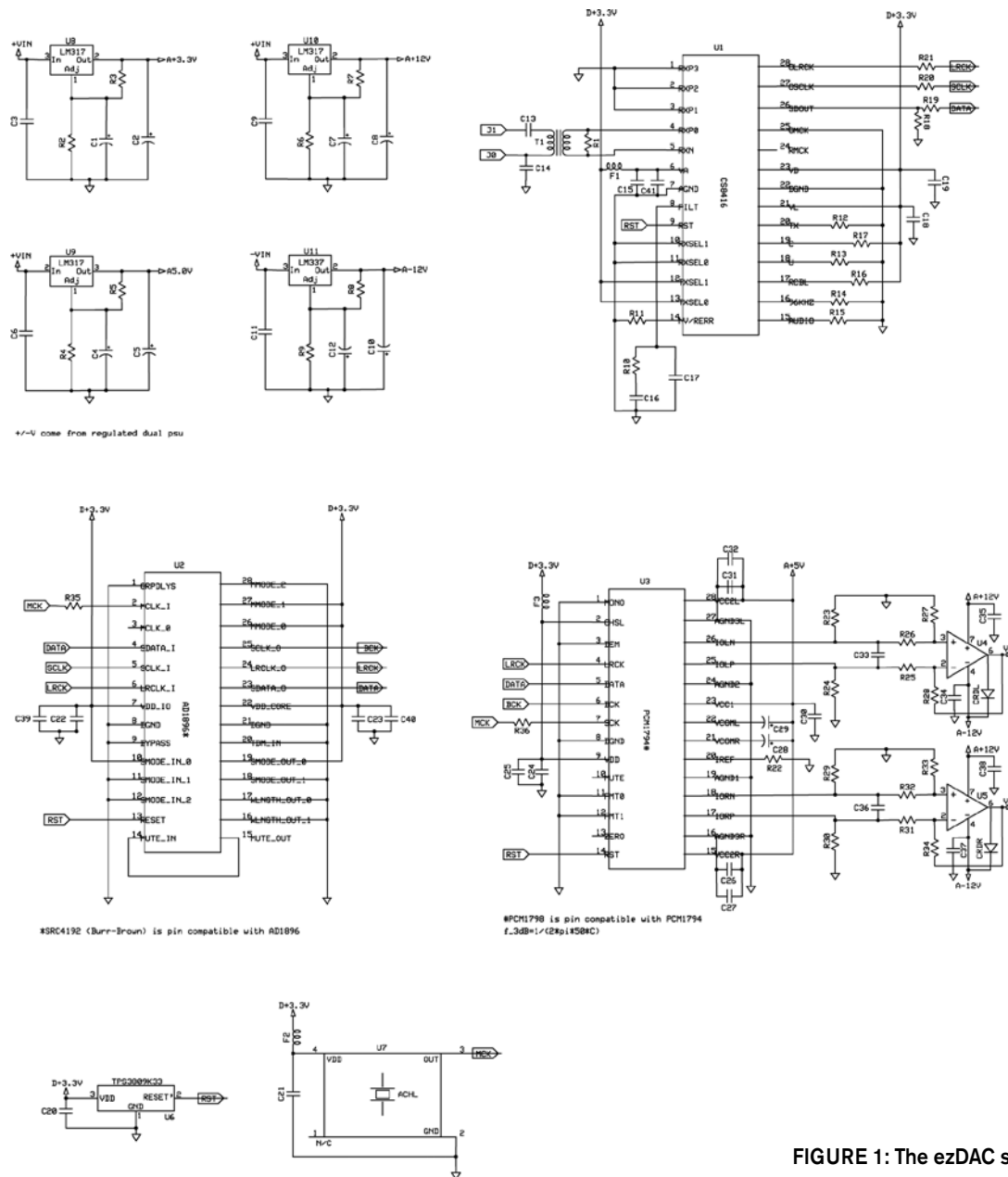
FIGURE 1: The ezDAC schematic.

one. I added this to my "things to do" list.

The receiving stage consists of the Cirrus Logic CS8416 (www.cirrus.com), a widely used chip, followed by the asynchronous sample rate converter (ASRC), which samples the input signal to 96kHz. You can choose between the AD1896 or the Texas Instruments SRC4192 as ASRC. An external crystal oscillator generates the clock for the ASRC and the DAC, bypassing the CS8416 clock recovery.

The conversion stage is performed by the Texas Instruments PCM1794 or the PCM1798, two of the best-sounding DAC chips on the market. The PCM1798 is cheaper, but it is a little bit noisier and outputs less current than its bigger brother. As I said before, the

PCM1794/8 outputs current, so the needed I/V conversion is done using a simple resistor on each signal leg.

The analog output stage converts the differential signal, coming from the I/V stage, to unbalance and to amplify it. To do this job the AD8610 is used, but any other PIN-compatible integrated IC can be used, such as the National LME49710 (www.national.com) or the TI OPA134. A high-quality capacitor, placed on the signal path, applies a mild filtering.

The power supply section consists of four voltage regulator chips. The variable LM3x7 type is preferred over the fixed one for its better *ripple rejection*. Some modifications are possible in this section as follows:

The basic configuration needs to connect an external filtered ±15V DC supply to the ezDAC, with the onboard regulators converting the voltage to 3.3, 5, ±12V DC. The second step—the one I utilize—is made by using a separate power supply to feed the digital and analog sections of the ezDAC, leaving the onboard regulators to do their jobs. The resulting improvement in the use of different transformers and filtering for the analog and digital supply is noticeable, so I highly recommend it. To make it possible, you need to cut a board trace as indicated by the black arrow in **Photo 2**. With the PCB version 1.5 you don't need to cut anything, because a jumper is present for the purpose. The third possi-

bility is to completely bypass the onboard regulators by providing a clean, low impedance source of regulated power: for example, you could employ Jung's super regulator (*AE* 4/2000).

EZDAC CONSTRUCTION

As usual, the first components to be soldered are the smallest, in this case, the surface-mount ones, preferably starting from the center of the board. Using tweezers, a magnifying lens and some flux, and applying a small amount of solder on one of the two pads I first placed the SMD resistors and capacitors over the pads and heated the already soldered pad. Once done, I applied (with the tweezers) a small amount of pressure on the part and re-heated the pad to be sure that the component was flat against the PCB. Finally, I soldered the other side of the part. I checked the nearby traces with the ohmmeter to be sure everything was properly connected.

The surface-mount chips are a step forward in difficulty, especially the PCM1794 and the AD1896 that have a SSOP package. I prefer to put a small amount of solder on two opposing corner pads, then place the IC over the pads and heat one of the pads with solder, adjusting the component so that it lines up with all the pads. Then I soldered the second pad applying some pressure so that the chip was flat and aligned. With this done, I soldered the remaining pads.

I inspected the work—with a magnifying lens and the ohmmeter—to ensure there weren't any unwanted shorts and for the proper pin-pad connection. This is the most time-consuming part of construction, but ensures an almost trouble-free first power-on of the DAC. I found it very helpful to utilize some flux (be sure to remove the residues because some kinds of flux are corrosive) and a solder with 2% of silver. For those who believe silver solder makes better-sounding devices, the real aim of the silver is to facilitate the soldering of SMT parts, because these components come with silver-plated leads. I used the Sn96.5/Ag3.5 eutectic alloy.

After finishing with the surface-mount parts, it's time for the standard through-hole ones, starting with the resistors, followed by the capacitors, the quartz, and the pulse transformer, and ending with the four voltage regulators. You are free

PHOTO 2: The ezDAC completed PCB; the arrow indicates the cut trace to separate the analog/digital supply.
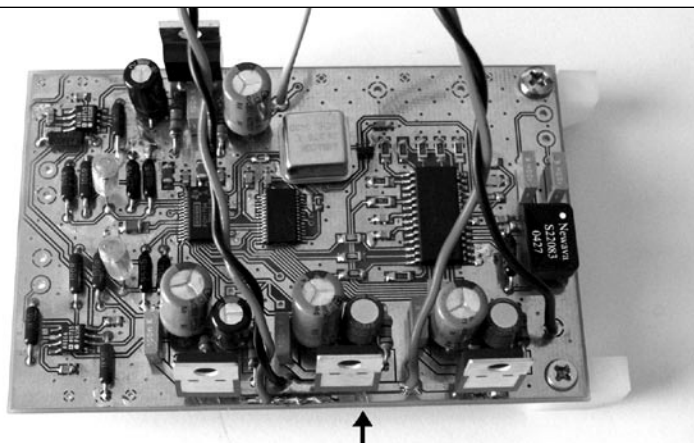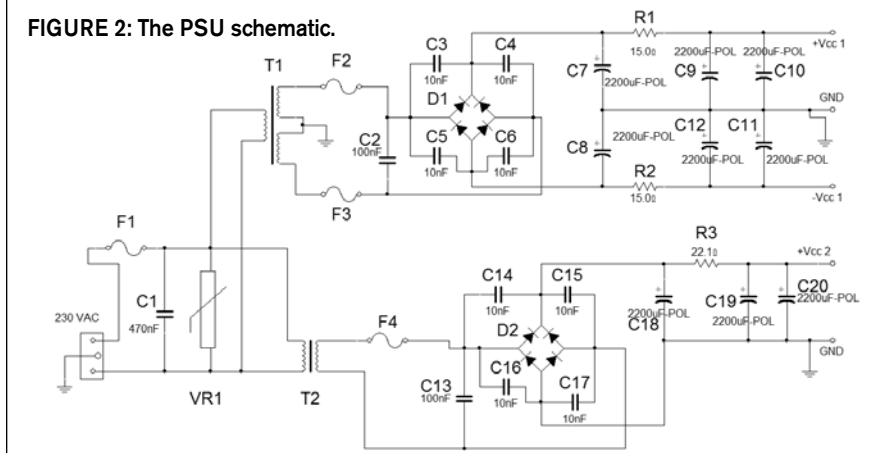

FIGURE 2: The PSU schematic.

to choose the most exotic parts, if the dimensions and application are correct. For example, I was careful with the ±12V DC regulators adjusting resistors (R6-7, R8-9) which I matched to get the same voltage output. For the adjustment pin bypass capacitors, I used low ESR (Equivalent Series Resistance) ones such as the Sanyo SH and the Panasonic FC, while the output caps (C2, C5, C8, C10) are generic with a significant ESR, because this resistance is used as a filter to prevent resonance. Finally, I preferred a polystyrene capacitor in the signal path (C33-36). The finished ezDAC board is seen in **Photo 2**.

THE POWER SUPPLY

The schematic of the power supply I used is in **Fig. 2**. The 230V AC is filtered by a varistor, for surge suppression, and by an X2 class capacitor for RFI (Radio Frequency Interference). The MOV (metal oxide varistor) is a pretty useful component, because it protects the power supply from quick transient voltages by absorbing those dangerous pulses.

It comes in a variety of clamping voltages, with 275V AC the common value used in Europe, and 150V AC in the US. Its case is button style, ranging from 5

to 20mm diameter, with the bigger one capable of absorbing more energy. The main disadvantage of the MOV is that when it fails, due to a too long overvoltage, it doesn't show up, leaving the user in doubt whether or not it is protecting. Moreover, in extreme situations, the varistor can ignite, as reported by the *National Fire Protection Association*, producing a dangerous situation.

My suggestion is to use the Littlefuse TMOV, which integrates a thermally activated fuse, designed to open in case of overheating, thus preventing it from catching fire and failing. When the temperature goes down again, the TMOV reactivates itself. Littlefuse produces an even more advanced type, named iTMOV, which allows you to monitor the functionality of the varistor through an LED. Mouser (www.mouser.com), Digi-Key, and Farnell carry these Littlefuse varistors.

Two transformers are utilized to supply the analog and digital section; when choosing the secondary output keep in mind that the LM3x7 regulators need an input voltage at least 2V DC higher than the desired output to work properly. I placed a film capacitor between
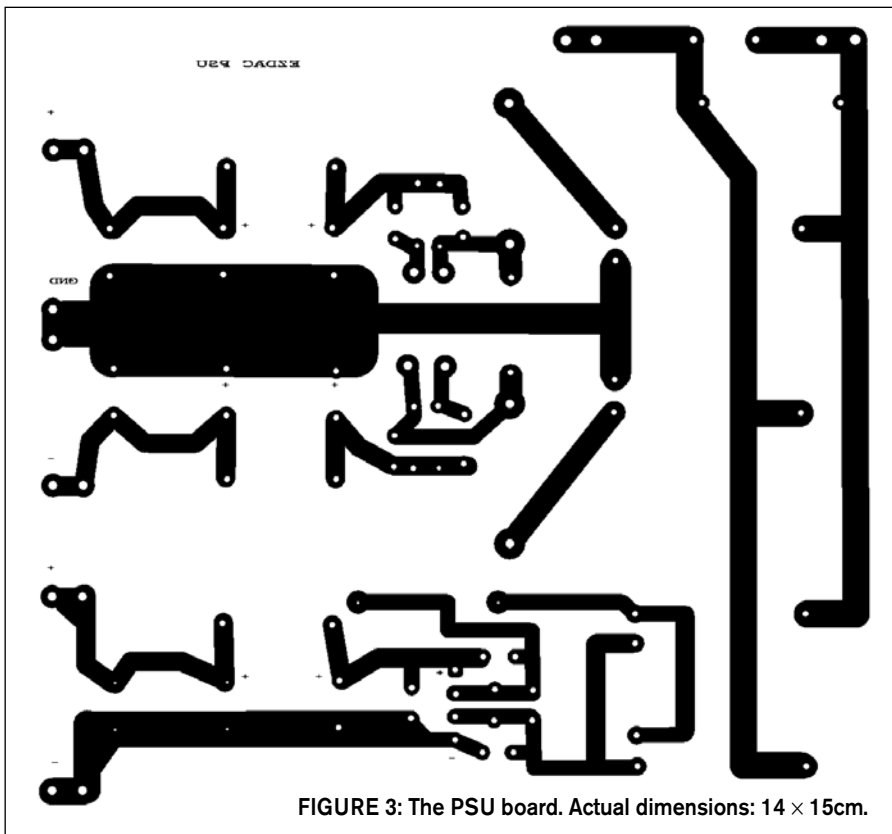
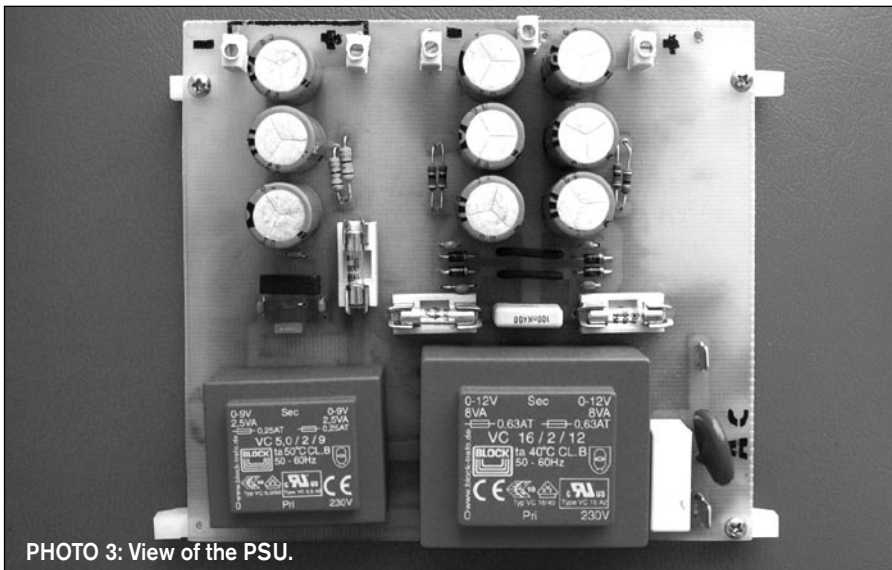FIGURE 3: The PSU board. Actual dimensions: 14 × 15cm.

PHOTO 3: View of the PSU.

TABLE 1

REFERENCE	DESCRIPTION	RS-Comp. PN	Farnell PN
R1, R2	Res 15Ω, 2W, 1%	214-1715	9474943
R3	Res 22Ω, 2W, 1%	214-1737	9475109
F1	fuse, 0.5A, 250V, fast	541-4347	1271612
F2-4	fuse, 0.3A, 250V, fast	541-4325	1123182
VR1	MOV, 275V AC		4804697
D1	diodes, 1N4937, 600V, 1A	652-7365	4502358
D2	diode bridge, 100V, 2A, case D44	629-6077	2416189
C1	cap X2 class, 470nF, 275V, P22.5	208-8030	1198299
C2	film cap 100nF, 100V, P15	298-0368	9752820
C3-6, 14-17	ceramic cap, X7R, 10nF, 100V, P5	211-5081	1200397
C7-12, 18-20	elec. cap, 2200µF, 25V. diam. 16mm, P7.5	628-3914	8813027
C13	film cap 100nF, 100V, P5	108-2700	1572134
T1	power transformer, 220/12-0-12V AC, 8VA	347-2688	
T2	power transformer, 220/9V AC, 5VA	347-2537	
3 PCB fuse holder	5 × 20mm, P23	417-098	1162740
PCB terminal block		548-7250	
PCB male faston	6.3mm	534-834	

the transformer secondary and the bridge rectifier, which reduces the voltage transient due to the diodes switching. Each bridge diode is bypassed by a ceramic cap (X7R type), whose function is to minimize diode noise.

The filtering section is made by paralleling three 2200µF electrolytic capacitors, or 6600µF per rail. Using multiple caps instead of a single one helps to reduce the total ESR. The resistors R1-2-3 form an RC circuit to further improve the filtering capabilities of the power supply (I used two resistors in parallel because I already had them). The PCB copper side is depicted in **Fig. 3**, while the completed supply is illustrated in **Photo 3**. The used components are listed in **Table 1**: the parts suppliers are Farnell (www.farnell.com) and RS-Components (www.rs-components.com).

ASSEMBLING THE DAC

The case is the GX287 by HIFI-2000 (www.hifi2000.it), an Italian producer that sells abroad, too. The model I used has aluminum sides that can be used to dissipate the regulator heat. Using the inner cave and some screws, I blocked a clip that pushes the three LM317s to the case side, through an aluminum oxide insulator (Fischer Elektronik AOS247), which I preferred in order to get some distance between the PCB and the panel. The dissipation capacity of the case is overkill, with the 3.3V DC regulator (the one that has the hardest job) always cool after many hours of use.

Photo 4 shows the DAC blocked to the case. I then took care of the power supply. Because there are some rails that carry the line voltage, I painted the PCB with transparent paint to achieve some electric isolation.

Moreover, I glued a white plastic sheet to the case bottom. I found both the plastic sheet and the screw clip (used to block the regulators) in an old computer PSU, which I cannibalized for useful components. Once both the PCBs were fixed to the case, I connected the power cables first and the signal cable after. For S/PDIF cable I utilized the coaxial RG179, which has an impedance of 75Ω as required by the Sony Philips Digital Interconnect Format.

The completed DAC and its back panel are shown in **Photos 5-6**. Note

that I didn't use any power switch, nor an IEC power connector, but feel free to install them if you like.

MEASUREMENT PERFORMANCE
The output DC offset is 2 and 5.5mV for the right and left channel, respectively. The frequency response is represented in **Fig. 4**, showing an almost perfectly flat line in the audio band, with the -3dB frequency located over 40kHz. The channel matching was 0.06dB.

Figure 5 is the spectrum distribution of a 1kHz tone. The harmonics are mainly of the odd type, but of very low value (the third harmonic is at about -120dB). The 200Hz tone, and its harmonics, belongs to the measurement chain, and is present in all the shown spectrums.

The intermodulation spectrum is what you can see in **Fig. 6**, relative to a 19 + 20kHz tone. The resulting IMD is very low, with the tones products staying at an insignificant -102dB or lower.

SUMMING UP
I am happy with the results obtained by this little DAC, which sounds pretty good. I compared the ezDAC to a cheap DVD player and medium-priced CD player, and the audible differences were like night and day, in favor of my last project. The total cost was about 140 euro, which sounds good to me in this time of world economy potential recess.   *aX*

PHOTO 4: The ezDAC board blocked to the case lateral panel.

FIGURE 4: The DAC frequency response.

PHOTO 5: Top view of the finished DAC.

FIGURE 5: Distortion spectrum: 1kHz tone, at -70dBV.

PHOTO 6: Back panel view.

FIGURE 6: Intermodulation spectrum: 19 + 20kHz tones, at -5dBV.