TeddyPardo
HIGH END AUDIO

TeddyDAC

Digital to Analogue Converter - white paper

Teddy Pardo

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Introduction

This document describes the TeddyDAC, a high-end digital-to-analogue converter for audio systems with digital sources such as CD/DVD players, streamers, media centers, or computers.

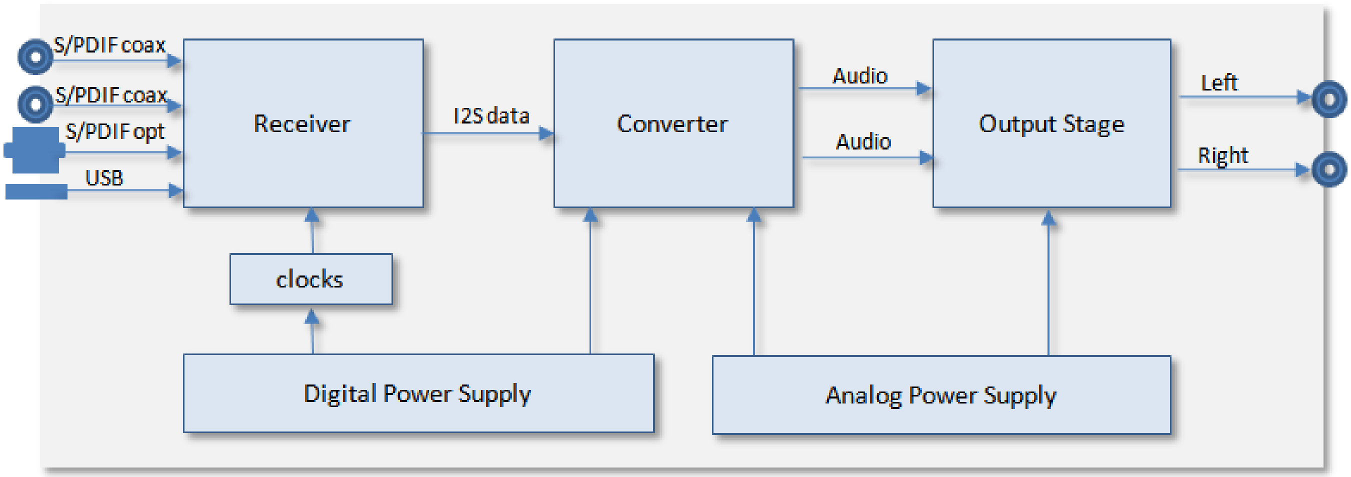
About the TeddyDAC

The introduction of digital audio in the 1980's promised "Perfect Sound Forever" and created the notion that "digital audio can be transported faultlessly between devices and without loss". Reality is different and engineers have since become deeply aware of the impact of jitter and other distortions in digital sound systems.

The goal in designing theTeddyDAC was to reproduce the most accurate, realistic and natural sound, free of digital artifacts and to achieve an "analogue" sound signature that appeals even to the most demanding LP and vacuum tube amplifier owners.

To achieve this goal, a unique approach was taken, based on the understanding that the power supply is a major, if not *the* most critical, ingredient of the design.

The TeddyDAC is the result of experience gained through years of designing, building and modifying audio products, covering the complete range of phono stages, amplifiers, CD players, speakers and power supplies. This experience led to the introduction of the TeddyCap in 2006, the TeddyReg low-noise voltage regulator in 2007, the SuperTeddyReg in 2009 and now, the TeddyDAC.



Design Highlights

The TeddyDAC deploys what many consider as the best sounding DAC chipset available today: the Wolfson Micro WM8741 DAC chip and WM8804 digital receiver. This combination, though used in many DACs and CD players, receives special attention within the TeddyDAC, with some unique design features:

- Ultra-clean power supply, thanks to the SuperTeddyReg voltage regulator.
- Highly accurate, 1.1 pico-second jitter clocks.
- Discrete component output filter, based on a single ended zero feedback buffer stage.

The TeddyDac is based on a shortest-audio-path design concept which, as described later in this document, is achieved thanks to the contribution of the acclaimed SuperTeddyReg voltage regulators.

Meticulous attention to detail in the selection and quality of components and in jitter-reduction design has resulted in a DAC that achieves the most accurate and natural sound reproduction possible.

Architecture

The TeddyDAC has four major blocks: the receiver, the converter, the output stage, and the power supplies. These are described below.

Receiver

The receiver converts the digital input (S/PDIF or USB) to a data stream in I2S format and, in addition, it is in charge of jitter handling (de-jittering).

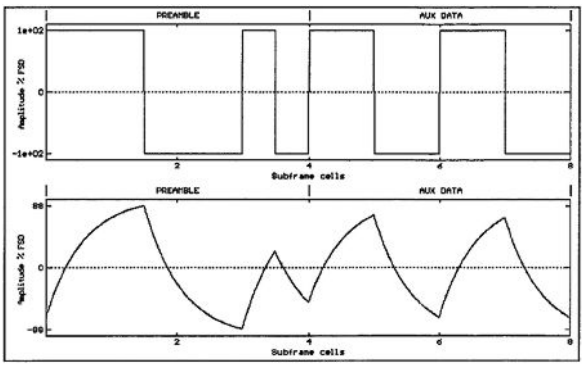
Digital to analogue converters reconstruct an analogue signal from digital samples that were recorded at regularly spaced time intervals. The signal reconstruction is achieved by converting these samples to voltage values according to these time intervals. The clock which determines the time intervals and is used to reconstruct the signal should, therefore, be identical to the clock used to record the samples.

The irregularities and deviations of a clock from a theoretical 100% precise clock are called *jitter*. If the clock which is used to reconstruct the signal has jitter, that is, it differs from the clock used at the recording studio, the reconstructed analogue signal will differ from the original signal.

Most digital hi-fi components feature a digital interface for interconnecting other components.

This interface is based on the Sony/Philips Digital Interface (S/PDIF), which uses a single physical channel (either electrical or optical) to transmit data, clock and frame synchronization signals.[1]

The figure below shows the signal in its original form and when transmitted through S/PDIF (source: Stereophile [5]):



A receiver needs to extract the data from this combined signal, convert it to I2S data stream, and transmit it to the converter along with the clock.

As the S/PDIF signal seen by a receiver is not a perfect square wave, additional jitter is introduced due to the inability of a receiver to determine the exact transition timing.

The TeddyDAC uses the Wolfson Microelectronics WM8804 receiver which, in order to avoid jitter induced distortion, uses a local clock instead of reconstructing the clock from the S/PDIF signal. Most commercial products use the built-in 50 pico-second jitter oscillator of the WM8804, the TeddyDAC uses an external ultra precise 1.1 pico-second jitter clock.

Using an independent clock means, of course, that the digital source and the DAC receiver are not using the same clock which can potentially lead to over-run or under-run synchronization errors. The WM8804 overcomes this problem by buffering the data in solid state memory and reading the data from this buffer using the receiver's clock. Thus, the precision of the receiver's clock becomes the major factor in the receiver's de-jittering capabilities.

The use of an ultra-precise clock, running as close as possible to the frequency of the recording studio clock, in conjunction with the WM8804 synchronization mechanism, guarantees the lowest possible jitter distortion and the highest fidelity to the original signal.

In addition to S/PDIF, the TeddyDAC features a USB-audio input which uses another 1.1ps jitter clock oscillator.

Converter

The *Converter* converts the I2S digital data stream into an analogue audio signal. The converter includes the digital filter which has an important impact on the sound signature.

The Wolfson WM8741 features an ultra high performance Multi-bit Sigma-Delta architecture and 125dB SNR. It uses digital filters with reduced pre-ringing and minimal group delay, resulting in reduced transient distortion and better imaging capability. Pre-ringing corresponds to hearing the effect of the sound source before the originating sound reaches the listener. Research shows that pre-ringing makes a large contribution to distortion caused by digital to analogue converters [3][4].

In terms of sound quality this translates into a more natural sound, free of the so called *digital* sound signature.

Output Stage

The *output stage* filters the high frequency noise, a by-product of the digital to analogue conversion.

[1] Integrated CD players internally use I2S, which has dedicated clock signals used to convert each sample.

Traditional digital to analogue converters use operational amplifiers[2]. Operational amplifiers are typically designed with multiple gain-stages and feedback, catering to lower harmonic distortions and increased Power Supply Rejection Ratio (PSRR). This however creates a longer signal path, resulting in a less natural sound, often characterized as *solid-state* sound.

The TeddyDAC analogue stage is based on a zero-feedback unity-gain buffer stage, using discrete components. The key components used are Junction-gate Field Effect (JFET) Transistors.

This minimalistic configuration results in very high-speed, low transient distortion and harmonic behavior characteristic of vacuum tubes.

Despite these advantages, such unity gain buffer stages are rarely used by other designers because they can suffer from low Power Supply Rejection Ratio (PSRR). The TeddyDAC's use of SuperTeddyRegs, however, results in an extremely low noise-floor, allowing for true high-resolution signal without a need for gain and feedback circuits.

Power Supply

The TeddyDAC *power supply* provides a critical contribution to the improved sound quality. It occupies about two thirds of the printed circuit board surface and supplies clean DC power to all other blocks of the TeddyDAC.

The benefits that a well-implemented power supply can bring to audio products have been discussed countless times. Power supplies found in typical audio products deliver a DC voltage contaminated with mains ripple and noise at all audible frequencies, produced during the AC to DC conversion. This noise is the reason for the famous "veil" associated with these products.

In fact, the high resolution offered by many digital to analogue converters is rendered unusable by the noise levels of their power supplies. As an example, a DAC with 24 bit resolution represents 16,777,216 levels below the full scale (full scale = all `1`s, also labelled as 0dB-FS). This means that the lowest signal represented is about one tenth of a Micro-Volt. But an average power supply keeps noise levels around 1 tenth of a Mili-Volt, yielding an effective resolution of only 14 bits – even less than the original Red Book specifications written 30 years ago…

In 1995 Walt Jung, then of Analogue Devices, published a series of articles that showed the effect of power-supplies on audio performance. Nevertheless, audio manufacturers still utilize low-cost 3-terminal regulators (e.g. LM78xx) in their products. These regulators suffer from significant noise levels, mainly in the high audio frequencies. Even with the use of high-end linear regulators such as the LM317 or the Walt Jung Super Regulator, products still suffer from non-negligible noise levels.

Low-cost digital to analogue converters use Switch Mode Power Supplies. These suffer from an even higher level of noise, especially in high frequencies.

The SuperTeddyReg[1][2] voltage regulator was conceived out of the frustration experienced with different variants of linear regulators due to their inability to filter out mains-borne ripple noise. It is important to note that linear-regulators not only fail to filter mains noise totally but also add their own noise, caused by their internal operational amplifiers and feedback loop.

The SuperTeddyReg is a dual-stage, fully discrete voltage regulator with zero negative feedback, making it a major departure from the typical concept of linear, feedback-based regulators. The SuperTeddyReg has probably

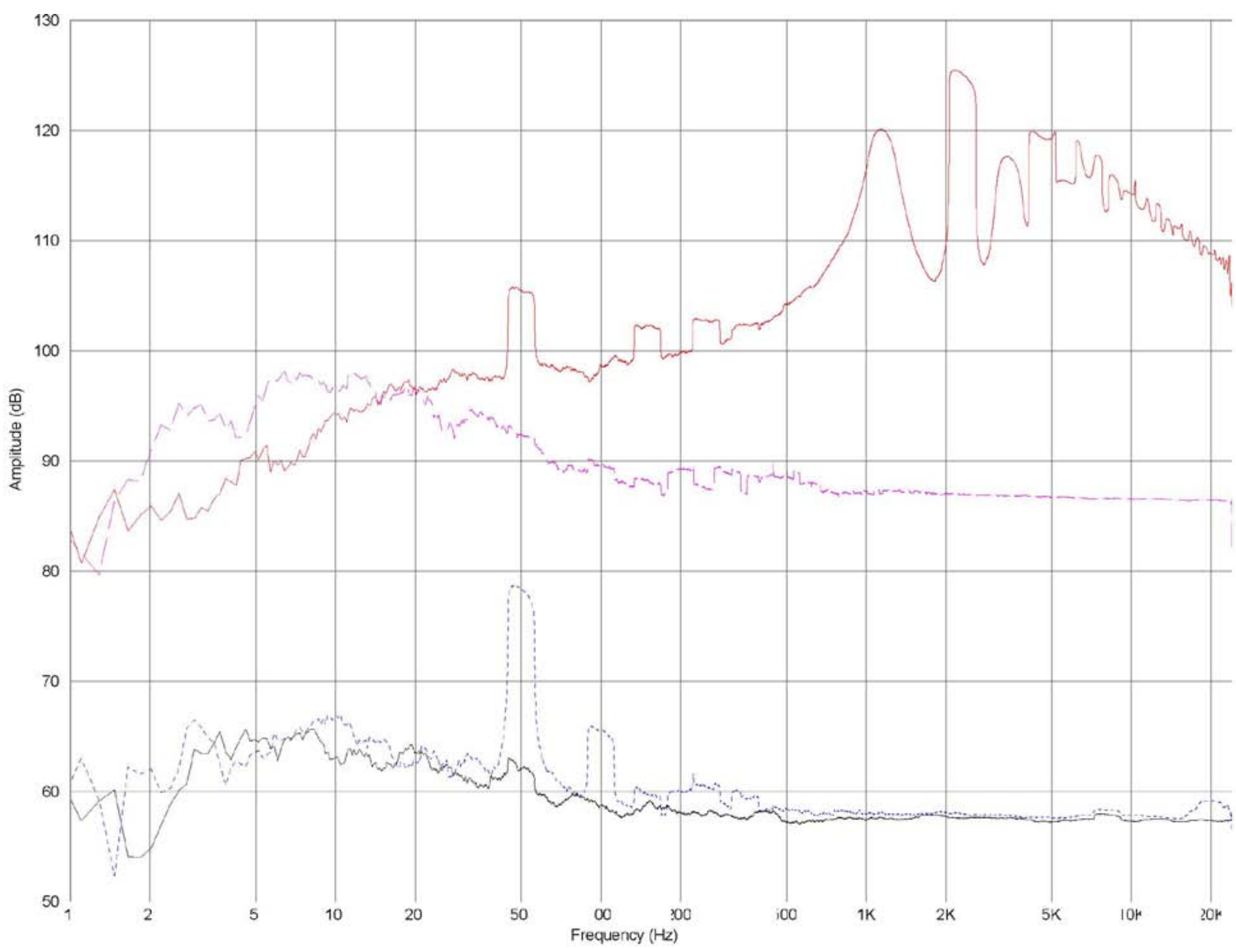
[2] Low-cost digital to analogue converters often don't use an output filter stage at all.

the lowest noise level of all known regulators today.

Shown below is the noise spectrum comparison between the SuperTeddyReg (blue dotted line), a Switch Mode Power Supply (red line) and a high-end power supply costing $2500, based on a LM317 (violet dashed line). The black line is the 0V reference. It can clearly be seen that the noise level of the SuperTeddyReg is much lower than other power supplies and very close to the 0V reference.

The TeddyDAC employs no less than ten SuperTeddyRegs. Analogue and digital blocks are fed from separate transformer secondary windings, providing maximum isolation between their power supply blocks.

The result is an absolutely black background, clear and detailed sound in all frequencies, excellent soundstage and natural- sounding voices.



Construction

The TeddyDAC is built using the best available components today: selected Toshiba low noise JFET transistors, Polystyrene capacitors in the analogue filter, Tantalum and PPS capacitors in the SuperTeddyRegs and Acrylic and Tantalum coupling capacitors.

All components are mounted on a four layer FR4 PCB with separate grounds for the digital and analogue sections. Signal routing was optimized to guarantee the shortest paths for critical signals. Noisy components such as the clock oscillators are placed on isolated ground islands to avoid ground plane noise.

Many audiophiles today prefer compact cases over large, full size cases (wife acceptance factor…). One of the design goals, and a big challenge, was to fit the TeddyDAC into a compact case, of the same size as the TeddyCap power supplies. Whenever possible the design uses Surface Mount Technology (SMT), which also reduces conductor inductance and improves performance.

The TeddyDAC uses a large toroidal transformer and over 200 components placed on a 6.5 x 4.5" PCB. Even full size DACs are typically built with far fewer components.

Digital Sources

Thanks to its high de-jittering capabilities, the TeddyDAC can produce surprisingly good sound quality even from moderate digital sources such as low cost DVD players.

It is important to note, however, that information on music CDs is stored using a different format from data CDs. Information on data CDs is read using error correction algorithms, guaranteeing that every bit is correctly extracted (computer programs will not work otherwise). Music CDs are stored differently. The player has to extract in real-time as much data as it can, otherwise it inserts interpolated samples. Although the TeddyDAC is very effective in jitter handling, better results will be obtained using better transports, as they can extract more information from the CD, and have lower jitter.

Music streamers, computers, or CD/DVD players playing lossless music file formats (such as FLAC) use data files rather than music file formats and can potentially provide the ultimate sound quality. Sound quality depends, however, on the ripping process and the condition of the original CD, that is, how the data was extracted from the original music CD. Ripping software such as Exact Audio Copy (EAC) will help extract the maximum from the original audio CD.

Using USB

Like with every USB DAC, although any player software can be used, for best results it is recommended to configure your computer with an appropriate driver (e.g. ASIO). Foobar player and the asio4all USB driver were tested and provide excellent results.

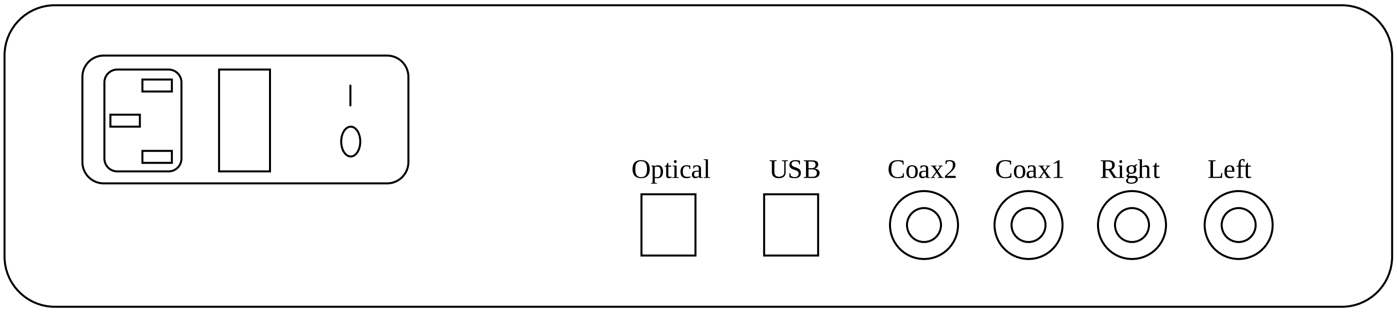
In Conclusion

With the TeddyDAC human voices sound as they sound in real life, orchestral music sounds detailed and three dimensional, just like in concert halls. The TeddyDAC contributes to many enjoyable listening hours without fatigue.

References

1. *The SuperTeddyReg:* http://teddypardo.com/Articles/SuperTeddyReg.html
2. *Power supplies under the hood:* http://teddypardo.com/products/PSU-detailed.html
3. *An Ultra High Performance DAC with Controlled Time-Domain Response:* http://www.wolfsonmicro.com/uploads/doc

uments/en/Ultra_High_Performance_DAC_whitepaper.pdf
4. *Ringing in the ears:* http://www.testreports.co.uk/music/hifi/basket/add.asp?Stock_ID=1562
5. *Bits is bits:* http://stereophile.com/features/396bits/index.html



TeddyDAC back Panel

Specifications

Inputs*:*

- 2 x Coax (RCA)
- 1 x Optical
- 1 x USB

Output*:*

RCA
Balanced XLR (optional)

Output level:

2V RMS

Dimensions (HxWxD):

6.2 x 17 x 25 cm (2.4 x 6.7 x 9.8")

Weight:

2.2 Kg (4.8 lbs)

Voltage:

110-120V or 220-240V

