Direct Digital Amplification (DDX®)

The Evolution of Digital Amplification

Tempo Semiconductor

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1. DDX® Technology Overview

The world today is inundated with portable multimedia devices. From PC's to cellular telephones, tablets to MP3 playback devices, nearly every individual carries one or more of these devices on a daily basis. The need to present the end-user with a satisfying experience has become a true differentiator among these products. As such, battery life and great visual and audio capabilities have become increasingly important. The designer of today's multimedia devices will face an enormous challenge in choosing the correct components that provide the precise blend of performance, quality, battery life, and cost. When choosing audio components, most designers will, and should, look immediately to a Class-D amplifier to provide power to their speaker solutions. Class-D amplification provides enormous advantages over older analog topologies, particularly in battery powered devices. However, what if Class-D could be improved?

Direct Digital Amplification (DDX®) is a patented, all-digital, high-efficiency amplifier technology designed and developed to meet the needs of today's high-performance, battery-powered multimedia applications. DDX is similar to a standard Class-D digital amplifier in that the amplifier provides digital output to the load (speaker) but improves upon this topology by providing a unique, three-state modulation (Damped Ternary) which allows DDX to achieve better efficiency, reduced EMI/RFI, and improved sonic characteristics.

2. Comparison of Amplifier Topologies

There are two main forms of amplifier topologies used in today's portable multimedia devices – Class-A/B and Class-D. The easiest way to explain the differences of these amplifiers is to compare them to voltage regulators. A Class-A/B is similar to a linear dropout regulator, while a Class-D amplifier is similar to a switching regulator. Let's take a closer look:

a. Class-A/B Amplifiers

The Class-A/B amplifier is the most common audio amplifier type in existence and is the standard by which all other amplifiers are judged. Also called a push-pull amplifier, this device uses two amplifying devices (usually transistors) in the power output stage. One amplifying device will drive the high-side of the output waveform (pushing the load) while the second amplifying device will drive the low-side of the output waveform (pulling the load). However, in order to avoid high levels of distortion, there is a crossover point at which both output devices will be on simultaneously (Figure 1). This cross-over point is controlled by setting a bias current, but it also contributes to the inherent inefficiencies of the amplifier design. Typical Class-A/B amplifiers are only about 65-75% efficient with a full-scale sine wave output and only 20-30% efficient at half-power.

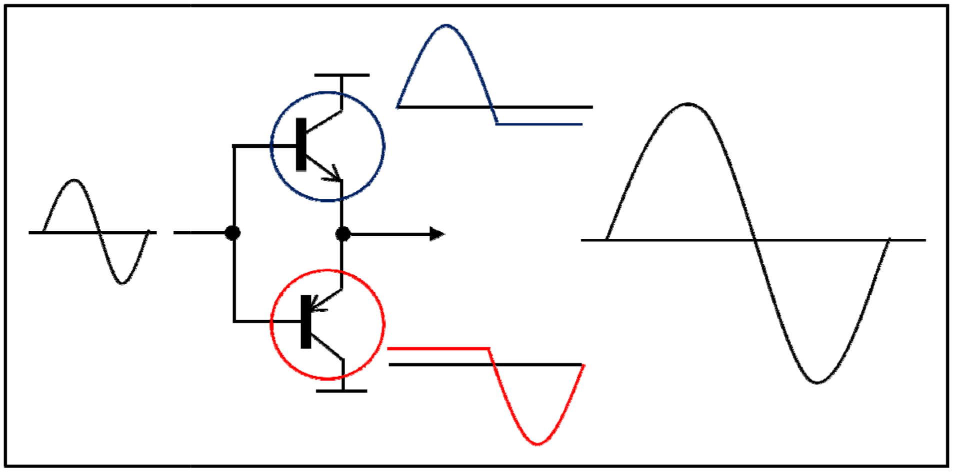

Figure 1 - Basic Class-AB Amplifier Topology

b. Class-D Amplifiers

Class-D Amplifiers employ a completely different strategy in terms of amplifying the source signal. Instead of relying on amplifying devices operating in their linear region, a Class-D amplifier will turn the output stages completely on and off in a very rapid fashion, creating output pulses. As mentioned previously, the theory of operation is similar to that of a switching voltage regulator. The switching frequency is well above the range of human hearing and is therefore inaudible. However, when averaged over time, the output of these pulses is equivalent to the amplified form of the input signal. Figure 2 shows an example of a Class-D amplifier output.

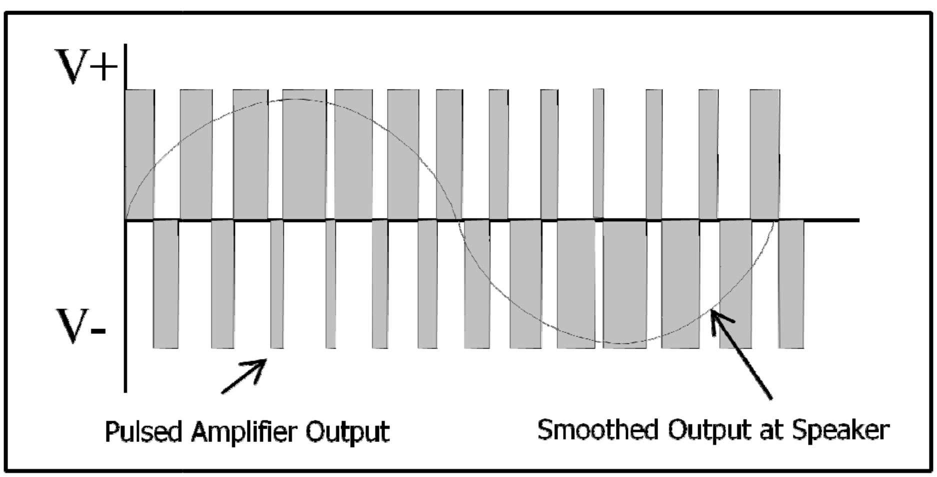

Figure 2 - Class-D Amplifier Ouput

The advantages of a Class-D amplifier output stage include greatly improved efficiency, cooling and power supply requirements are reduced, and smaller board space requirements. The typical efficiency of a Class-D amplifier can reach 85- 90% at full-scale output. However, because of the the switching nature of the Class-D design, unwanted carrier band energy will exist at and above the switching frequency of the amplifier. Minimizing this electromagnetic interference (EMI) is one of the key design issues faced when implementing a Class-D amplifier design.

c. DDX® Amplifiers

Similar to Class-D amplifiers, the DDX amplifier topology also employs a switching output. However, DDX implements a unique damped ternary modulation to address the inefficiencies seen in typical Class-D amplifiers while also reducing EMI by producing less carrier band energy.

To better understand DDX, let's examine the three different drive states of a DDX amplifier output waveform of a DDX amplifier:

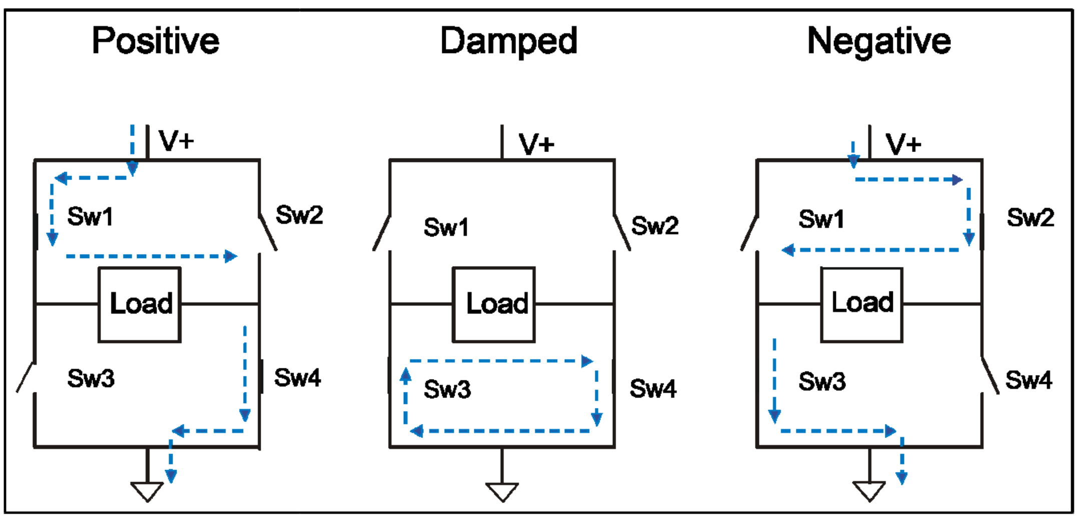

Figure 3 - DDX® Amplifier Drive States

As shown in Figure 2, binary systems generate a small output signal produced by the cancellation of two large signals. Thus, even for low-level signals (i.e. where music usually resides) binary class-D modulation continuously provides energy to the filter and the load.

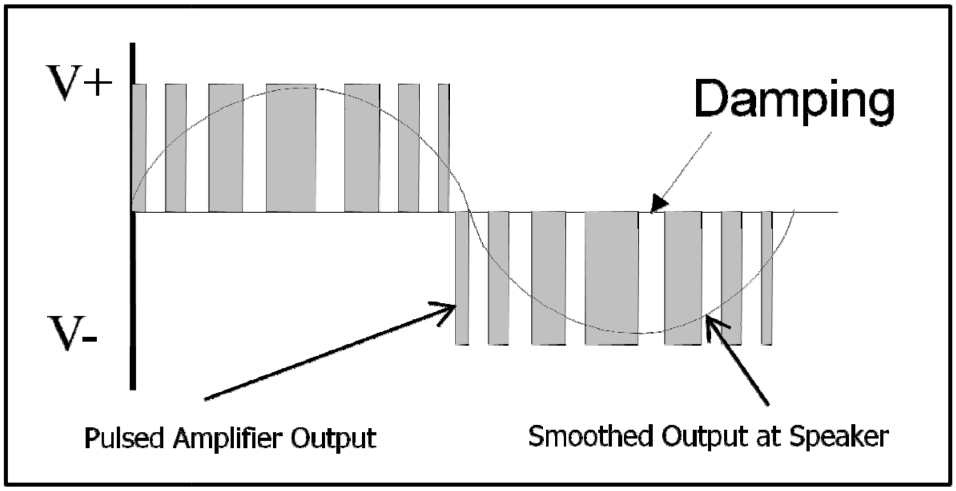

Figure 4 - DDX® Amplifier Output

In contrast, damped ternary operation (shown in Figure 4) only supplies the energy necessary to produce a signal. When no signal is required, the load is connected to ground, providing damping to the loudspeaker – hence the name damped ternary.

3. Advantages of DDX® Designs

The damped ternary operation of DDX amplifiers provides several advantages over standard Class-D implementations. From examining the differences between how signals are reproduced (Figures 2 and 4), the first advantage is obvious.

a. Reduced EMI/RFI

Because DDX is only delivering energy to the load when required to produce a signal, there is a significant drop in carrier band energy compared to traditional Class-D amplifier designs. In tests performed with the same hardware using the same filter, damped ternary's carrier energy was measured to be 16dB lower than standard binary switching (Figure 5). This reduction in energy enables some applications to eliminate the need for an output filter, resulting in a lower system cost and reduced PCB board space requirements.

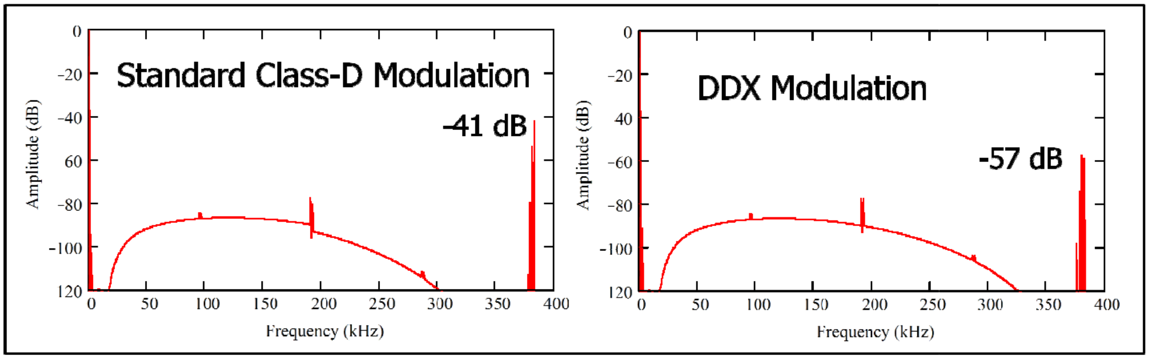

Figure 5 - Measured EMI/RFI Comparison

To further understand how this is possible, Figure 6 shows a comparison of the filtered PWM output of a standard Class-D as compared to the output from a DDX solution. Note how the standard Class-D output exhibits constant ripple amplitude throughout the entire waveform while the DDX output reduces the ripple amplitude, particularly at lower amplitudes.

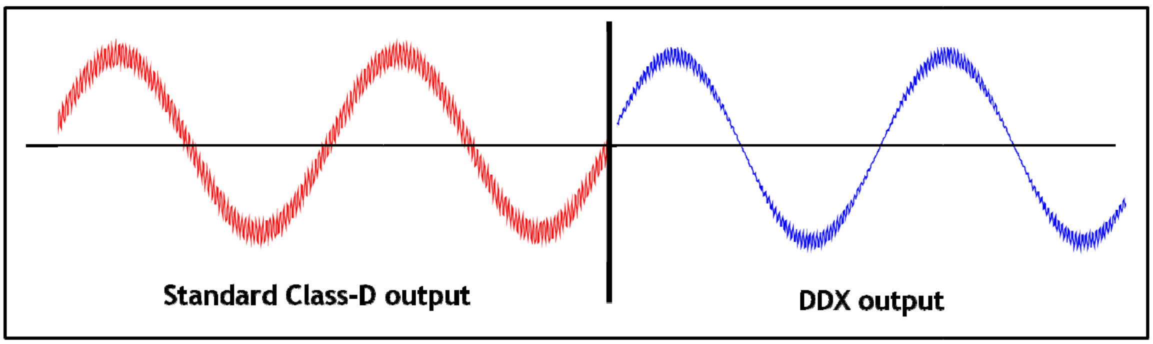

Figure 6 - Comparison of Filtered PWM Outputs

b. Signal to Noise Ratio

DDX provides an excellent signal to noise ratio due to its digital design. With standard analog input amplifier designs there is always an input signal present that is amplified through the power stage. With a DDX enabled CODEC, a zero digital input signal will transition the output to a damped state, grounding the load. This results in an almost infinite SNR. Since this transition from the damped state to a small signal is inherent to DDX modulation, it does not have the “pop and click” problems associated with analog designs.

c. Power Supply Rejection

Conventional amplifiers require a high power supply rejection ratio because at small signal levels power supply variations can produce audible distortion. DDX modulation, operating in an open loop mode, has inherent power supply rejection that makes most errors inaudible. This is because most of the time the load is connected to ground (i.e. in the damped state) and not to the power supply. In fact, this rejection characteristic provides the most benefit where power supply variations are most audible during the reproduction of low level signals.

d. Increased Efficiency

Perhaps the greatest benefit DDX provides to the designer of today's battery powered multimedia devices is an increase in efficiency, particularly during music playback. Figures 4 and 6 have already shown how DDX provides a reduction in carrier band energy emissions, but they also indicate how DDX can improve the efficiency of a battery powered device. Figure 7 shows the normalized efficiency curves of a typical Class-A/B amplifier, a standard Class-D amplifier, and a DDX amplifier across the power band. The chart assumes that all amplifiers are maintained in a region where THD+N is 1% or less.

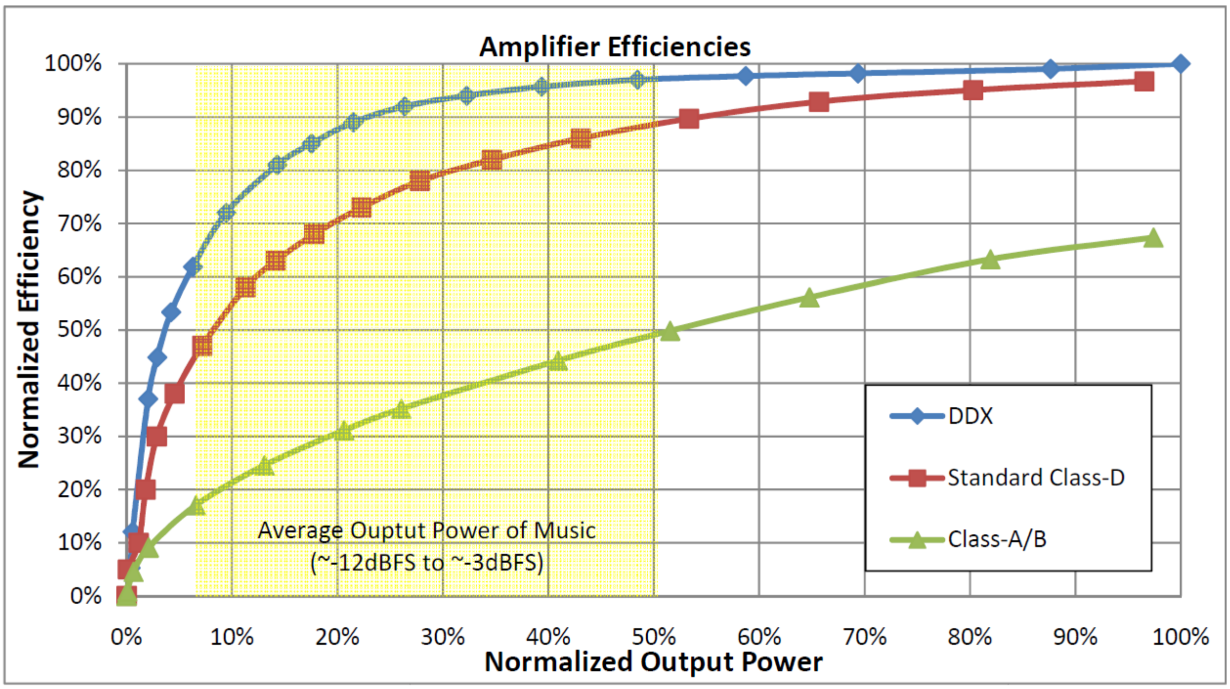

Figure 7 - Comparison of Amplifier Efficiencies

When compared to standard Class-D at full power, the designer will notice little improvement from the DDX design. In general, the maximum efficiency ratings of most Class-D amplifiers and DDX amplifiers are very similar. However, this maximum efficiency number can be misleading when applying the amplifier design in real-world applications. This is because of how an amplifier is used by the end-user. When obtaining a maximum efficiency rating, the amplifier will be used at full-power and tested when playing a 0dBFS (full-scale) sine wave. Yet end-users of the device will not be listening to a full-scale sine wave. They will listen to music, which is recorded with an average power of ~-12dBFS to ~-3dBFS, depending on the artist's, studio's, and/or mastering engineer's preference. Generally speaking, today's rock, R&B, pop, hip-hop music can reach average power levels of -5dBFS or louder while most other genres of music will maintain an average power level of -10dBFS. How this translates to amplifier efficiencies can be dramatic. A DDX amplifier is capable of providing a 15-20% increase in efficiency over a standard Class-D amplifier during music playback. This number can increase to 300% when compared to Class-AB amplifiers. Assume a designer of a 7" tablet device has a system power budget of 2 watts and the system is powered by an ideal 3800mAH, 3.7V lithium battery source. Finally, the audio solution of this system provides 1W of power to each speaker in a stereo pair at full power, and the user is playing music at an average of 20% power output for the life of the battery. Given these parameters, the user of the device would experience an additional 53 minutes of battery life when the system is powered by a Class-D amplifier as versus a Class-A/B amplifier. However, DDX can provide an additional 10 minutes of battery life over the Class-D solution!

DDX Products

DDX products are currently available from Tempo Semiconductor in two types of devices:

Audio Codecs for PC and related applications:
The Tempo Semiconductor 92HDxx family of audio codecs provide low power, high fidelity, multi-channel audio solutions with features such as integrated DDX speaker amplifier, capless headphone amplifier, and low drop out voltage regulator. Available dual High Definition Audio and I2S Interfaces can allow for docking audio support with a single codec. The integrated combo jack allows for dual-function headphone and headset detection. The integrated high-pass and band-pass filters allow for hardware EQ and speaker protection. The high integration of the 92HDxx family enables the smallest PCB footprint with the lowest system audio BOM count and cost. The 92HDxx family provides high quality HD Audio capability to notebook and business desktop PC applications.

Audio Codecs for consumer electronics and tablets:
The Tempo Semiconductor ACS422xx and ACS622xx families are the first of a new generation of audio controllers that incorporate advanced audio processing algorithums, I2C configuration, I2S interfacing, a high fidelity Audio CODEC including Headphone Outputs, a 2.5W DDX Audio Amplifier, analog inputs – all of which are required by portable consumer devices such as cellular phone handsets, portable gaming devices, digital media players, portable navigational devices, etc.

Tempo Semiconductor plans to develop a variety of new DDX enabled semiconductor products for the PC and Consumer device markets. The DDX Controller can be also readily optimized for specific applications such as voice band systems for the communications market. New digital functions (e.g. equalization) are easily integrated into the design, so customer configured designs are feasible. In addition, the DDX core can be combined with other digital audio functions to optimize silicon area, making for a cost-optimized solution suitable for many target markets.

Conclusions

DDX is a patented, all-digital, high efficiency audio amplifier architecture developed to meet the needs of today’s and tomorrow’s battery powered portable multimedia devices. DDX’s unique features allow for easy system integration and reduced power, board space, and EMI component requirements while maintaining or bettering a system’s current sonic fidelity. Please contact your Tempo Semiconductor representative for a demonstration of DDX’s capabilities.