Bel Canto Design eVo Digital Power Processing Amplifier

Introduction

Analog audio power amplifiers rely on balancing the inherent linearity of a device or circuit architecture with factors related to efficiency, cost and power output capability. Today virtually all high-performance power amplifiers are inherently analog in nature and the tradeoffs related to power, fidelity and sonic performance have led to few real advances towards an inherently better solution. Recent developments in digital signal processing and MOS power switches have provided the means to produce a significant advance in audio power amplification. The Bel Canto Design eVo digital power amplifier architecture provides a new combined level of measured and sonic excellence. This is achieved with unprecedented value and applicability in present and future audio and audio/video systems.

The Power Output Stage

Analog audio power amplifiers, whether tube or solid state, fall under a few categories:

1) Single-ended class A
2) Push-pull class A
3) Push-pull class AB

All of these architectures have inherent advantages and disadvantages:

> Single-ended class A is the oldest amplifier architecture and has advantages in simplicity of operation, inherent linearity and stability of bias point and thermal characteristics. The down side is efficiency around 25% which leads to low power levels and high cost.
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> Push-pull class A is slightly more efficient than single-ended class A but requires more complicated bias circuitry and complementary output devices, it is also potentially less linear than the simple single-ended architecture.
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> The push-pull class AB architecture has advantages in efficiency and cost at the expense of complications related to inherent linearity of operation, stability related to thermal modulation and the ultimate cost of efficiency that is still less than 50%.

All of these analog output stages are further complicated by the requirements for analog pre-drivers, protection circuits and feedback that is needed to reach acceptable levels of performance. Tube output stages typically require a coupling transformer to match the low impedance of a loudspeaker to the high impedance of a tube circuit. These complicating factors increase the difficulty of reducing the sonic signature of a given amplifier design.

Considerable effort has been focussed over the years on optimizing designs in all of the above categories. These efforts have resulted in a high overall level of measured performance, however, work in reviving the oldest and simplest of analog amplifiers, the Single-ended Triode, has revealed that the sonic signature of even the best modern solid-state amplifier is often too obtrusive.

Bel Canto Design has searched for an amplifier architecture that provides the sonic superiority of an SE triode amplifier with the value, power, and reliability of a solid state amplifier. Our searches have led us to a new amplifier architecture that combines a switching output stage with a digital signal processor to reach new levels of sonic performance and value.

The eVo Digital Output Stage and Digital Power Processor

The Bel Canto Design eVo digital output stage is of unique simplicity. The output uses 2 N-channel MOSFET switches which are switched between the power supply rails. These switches turn on and off within 30 billions of a second and provide an on resistance path to the supply of less than 65 thousands of an ohm. These switches switch alternately between the supplies at a rate that averages over 600 thousand cycles per second (600 kHz). When no audio signal is present the ratio between the time at the positive supply and the negative is balanced to provide no audio frequency output. The switching stage is isolated from the loudspeaker by a single Inductor/Capacitor (LC) filter that removes energy above 80 kHz.

Furthermore, the digital power processor adds small levels of high frequency dither to insure that an inherently linear output stage characteristic is maintained from very low to very high output levels. The audio frequency information modulates the output stage by changing the time relationship between the positive and negative supply rails. The critical timing information is controlled by the digital power processor and the effective switching frequency is changed over a 200 kHz to 1500 kHz range.This spreads the digital energy created by the amplifier over a wide bandwidth, similar to spread spectrum technology, greatly reducing the energy at any one frequency. This permits using a simple 80Khz LC filter to remove the digital energy and maintains low cost and excellent phase response. Feedback around the output switches is taken from the common node of the output switches before the LC filter and fed back to the digital power processor. This feedback is used to insure that any variations in the switching speed of each output device are compensated for, optimizing the linearity of the output stage.

The eVo output stage does not suffer from the distortion mechanisms of analog output stages; crossover distortion, thermal bias wander and transconductance variations. The audio information is carried in the complex modulation of dithered switching edges. The digital processor controls the modulation of the output switches. The typical compromises between output stage efficiency, complexity and linearity and cost no longer apply. The eVo output stage is over 90% efficient, uses only 2 N type output devices and maintains extremely high linearity and low output impedance for good power delivery and control of the loudspeaker. The digital power processor insures that high frequency energy and audio band performance are excellent without the problems of older class-D type switching architectures. Important measures of amplifier performance such as Total Harmonic Distortion, Noise and most importantly Inter Modulation Distortion levels are extremely low across the audio band at all power levels.

eVo Digital Power Processor versus Class D

Traditional switching amplifiers have used what is termed a Class D architecture. This architecture uses a Pulse Width Modulation algorithm to control the output stage switches. These algorithms are generated with relatively simple analog processing and a crude digital to analog conversion mechanism based on a fixed frequency triangle wave. Traditional analog feedback is then used to reduce the distortion produced by the analog processing and output switch

imperfections to acceptable levels. This approach has numerous drawbacks and can produce unacceptable levels of THD and IMD. The fixed frequency of operation also requires extreme measures in designing the output filter to insure that switching noise is low enough. This can result in frequency response changes between 4 and 8 ohm loudspeaker loads and large phase deviations at high frequencies.

The eVo architecture insures extremely linear phase response, low levels of IM distortion and has a THD performance which consists of low levels of low-order harmonics in a very natural descending progression, much like a single-ended amplifier produces. However, the distortion levels of the eVo amplifier are typically 10 to 100 times lower than a SE triode amplifier. The sonic signature of the eVo amplifier is virtually gone, leaving the musical message intact.

Analog Signal Processing

All analog signal processing in the Bel Canto eVo architecture occurs at small signal levels using 15 volt and 5 volt analog circuits. These stages are powered by low noise regulated supplies and use the latest audio grade amplifiers, resistors and capacitors. The analog input is received using a true instrumentation amplifier to allow ideal processing of both single-ended and balanced input signals. The eVo architecture confines the analog processing to small signal where analog processing is best, noise is reduced and analog distortion mechanisms are minimized. This also insures that the eVo amplifier can be used within today's analog based system architectures without extra expense or performance compromise.

The Digital Power Processor contains both CMOS analog and digital processing to convert the analog input signals to a digital bit stream for processing and driving the output stage switches. High voltage DMOS drivers then drive the output switches for controlled switching speed of less than 30 nS. The slew-rate of the output stage is over 6000 Volts per microsecond, more than 10 times faster than any analog power amplifier. No feedback is taken from the analog output of the power amplifier after the LC filter. The output filter uses a low distortion high performance gapped toroidal iron-core inductor and low-loss capacitor.

Overload and Protection Circuitry

The Digital Power Processor also provides unique advantages in the overload and protection circuitry of the eVo amplifier. The eVo amplifier uses the digital signal processor to sense amplifier clipping. If clipping is sensed high frequency dither is added to insure that the clipping performance is soft and does not produce the extreme high harmonics that solid state amplifiers suffer from. These harmonics can result in unpleasant sonic consequences, producing buzzy or harsh sounds when driven into clipping. The soft clipping characteristic of the eVo amplifier mimics the soft tube overload characteristic, preventing the harshness that most solid state amplifiers suffer from. This soft clipping does not cause any compromise in the performance of the amplifier at levels below clipping. Typical, analog-based, soft clipping circuits in solid state amplifiers achieve the soft clipping characteristics at the expense of distortion performance below clipping. This is not the case with the eVo amplifier.

In the same way, the sonic compromises of typical protection circuits are avoided by using the digital processor to sense excessive DC current in the output stage and shut the amplifier down. The eVo amplifier also senses failure modes in the amplifier that could damage a loudspeaker and disconnects the speaker to prevent loudspeaker damage. This is all accomplished outside of the signal path, with no compromise to the sonic performance of the amplifier.

The unique combination of features within the Bel Canto eVo Digital Power Processing Amplifier:

High efficiency output stage: >90%

This high efficiency is critical to the performance and reliability inherent in this technology. The output stage efficiency is over 90%, meaning that if 100 watts are used by the amplifier over 90 watts are going into the loudspeakers. Even efficient class AB linear amplifiers rarely exceed 50% efficiency, meaning that over 50% of the energy is lost as wasteful heat. The result of this lack in efficiency is heavy and expensive heat sinks and a much larger power supply transformer for equal performance. How this compares in the case of the Bel Canto Digital Amplifier is much more music to the loudspeaker and reduced costs for custom parts.

Low distortion operation without overall analog feedback: <0.01% THD/IMD

The Bel Canto Digital Amplifier produces very low and natural progression of harmonic and inter-modulation distortion products. This is achieved without the waste heat and expense of a linear design and without traditional overall analog feedback mechanisms.

Simple and elegant output stage using only two, rugged, N-channel output devices.

Because of the high efficiency of the output stage there are only 2 N-channel switching devices in the output stage, even though they can deliver over 60 amps and several hundred watts into the loudspeaker. This results in a very elegant power stage with none of the matching and biasing problems of class A and AB linear amplifiers.

No Crossover Distortion mechanism.

The switching operation of the output stage conveys the analog information through the movement in time of the dithered edge of a switching waveform. This edge moves between the power supply rails in less than 30 billions of a second. The placement of this edge in time defines the accuracy of the amplifier and this movement in time does not result in any small signal non-linearities. There simply is no small signal distortion mechanism to overcome as in push pull solid state or tube class AB amplifiers. The result of this is remarkable low-level resolution and a naturally sweet and extended sound quality that transcends older technologies in efficiency, measured and sonic quality.

No thermal distortion mechanism or bias point wander.

One of the least understood and difficult distortion mechanisms in solid state amplifiers is a result of the change in the power device's performance with temperature. This can cause problems related to bias point instability and a change in the amplifier's distortion characteristics with signal. The Bel Canto Digital Amplifier is not subject to any of these distortions because the output stage has no bias current, and because the output stage runs very cool. Again, as with crossover distortion, there is inherently no way for this amplifier to suffer from thermal distortion or bias point wander. The result is stability in operation heard as rock steady imaging and solid, dynamic bass performance.

All analog processing is done at small signal, preamp-like levels with regulated supplies.

All analog processing stages are performed using the latest generation integrated devices and custom audio grade resistors. These stages are powered by isolated, high performance regulated supplies with audio grade bypass capacitors. Great care is taken to insure star grounding of the audio signals and supply paths. None of the power electronics share these supplies. This imparts performance that could only be approached in a linear amplifier with extreme cost using high power regulators for all stages including the output stage. The result, sonically, is a remarkably solid, stable and dynamic sound stage.

High power processing is done using DSP and only two output power switches per channel.

Sophisticated Digital Signal Processing is used to control the two output power switches in each channel. The placement of the switching edge is controlled to a high level of accuracy by the algorithms embedded in this custom DSP engine, the Digital Power Processor. Feedback from the digital portion of the output stage is used to 'learn' the switching speed of the output devices and to optimize the DSP for each device's characteristics. This insures that each amplifier is operating at peak performance at all times.

High frequency energy is spread over a broad spectrum from 200 kHz to 1.5 MHz.

A simple 80 kHz LC filter is all that is needed to reject the high frequency energy. This works efficiently because the digital switching energy is spread over a broad band so that it remains low at any given frequency. Much like a Delta-Sigma converter or the DSD process this simplifies the filtering needed to achieve high performance and insures that phase and frequency response is optimized and high frequency information is preserved.

Sophisticated protection circuits insure reliable and safe operation.

The DSP engine handles the protection routines. These are implemented in a way to insure that the audio signal is never compromised by the protection mechanisms. There is protection against over-current from output shorts, over voltage in the power supply and DC offset at the output because of an amplifier fault. The amplifier is protected from misconnection and the loudspeaker is protected from amplifier faults. The result is solid reliability with no sonic penalty.

Dual channel boards operate in anti-phase to reduce low frequency power supply modulation for tighter bass and regulated supply-like performance.

This is a very subtle mode of operating which effectively increases the performance of the power supply, again improving the supply performance to levels which would have required an expensive, high power regulator to achieve.

True differential input stage allows quietest operation and easy bridging delivering up to 4X power.

We have implemented a true instrumentation amplifier input stage to insure optimum performance within any system in either single-ended RCA or balanced XLR connection and when in bridged, mono, operation.

No AC coupling capacitors in the signal path.

Starting with the position that the best coupling capacitor is no coupling capacitor we have removed the need with a DC servo to insure constant, low DC offset even in the presence of DC signal from a preamplifier.

High efficiency allows _ transformer size for a given level of performance, i.e. 500 Watt transformer performs like a 1000 Watt transformer in linear amplifiers.

We can bring very high levels of performance for a given price level.

Sophisticated dual-zone star grounding and double-sided ground plane fill combine with ground bounce correction to maintain the quietest ground system reference possible.

These sophisticated techniques allow all of the resolution and dynamic range inherent in the technology to be reached. The resultant sonic wealth brings the music to life as in few other amplifiers.

The first Watt is as linear as the last Watt…

The inherently linear dithered operation of the switching output stage transcends the normal expectations of sonic quality, efficiency and cost.

The Bottom Line:

The Bel Canto eVo Digital Power Processing Amplifier represents a significant eVolutionary advance in audio amplification.