

# Bel Canto e.One Amplifier Architecture

## Introduction

Analog audio power amplifiers rely on balancing the inherent linearity of a device or circuit 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 architecture and MOS power switches have provided the means to produce a significant advance in audio power amplification. The Bel Canto e.One Analog Switching ICEpower amplifier architecture provides extremely high levels of measured and sonic excellence.

## 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.

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.

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.

## **The e.One ICEpower Analog Switching Output Stage**

The e.One switching output stage is of unique simplicity. The output uses 2 Nchannel MOSFET switches per phase (4 devices in a balanced/bridged output). These power devices are switched between the power supply rails. They turn on and off within 30 billions of a second and provide an on resistance path to the supply of less than 30 thousands of an ohm. These switches switch alternately between the supplies at a rate that averages 500 thousand cycles per second (500 kHz). These 4 power devices can deliver many hundreds of watts of power to the loudspeaker. The elegance of this output stage is unmatched by any traditional power amp architectures.

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. Multiple nested feedback loops insure low distortion, while the extremely high speed of the control and power circuitry prevents any problems like slew limiting or TIM that plagues traditional linear amplifiers.

The audio signal controls the output stage by changing the timing of the switching edges. The critical timing information is controlled by the feedback loop processing and the effective switching frequency is changed over a 200 kHz to 1500 kHz range.

The e.One output stage does not suffer from the distortion mechanisms of analog output stages; crossover distortion, thermal bias wander and multiple device variations. The typical compromises between output stage efficiency, complexity, linearity and cost no longer apply. The e.One output stage is over 90% efficient, uses only 4 N type output devices and maintains extremely high linearity and low output impedance for good power delivery and control of the loudspeaker.

Important measures of amplifier performance such as Total Harmonic Distortion, Noise and Transient Inter Modulation Distortion (TIM) levels are extremely low across the audio band at all power levels.

## **e.One ICEpower Architecture versus Class D**

Traditional switching amplifiers have used what is termed Class D architecture. This uses a Pulse Width Modulation algorithm to control the output stage switches. This is generated with relatively simple analog processing and a crude digital to analog conversion based on a fixed frequency triangle wave. Traditional analog feedback is used to reduce the distortion produced by the analog processing to acceptable levels. This approach has numerous drawbacks and can produce high levels of THD and IMD. The fixed frequency of operation also requires extreme care in designing the output filter to insure that switching noise is low enough. Changes in frequency response based on the loudspeaker load and phase deviation at high frequencies result.

The e.One ICEpower architecture has linear phase response, low levels of TIM distortion and THD performance consisting of low levels of low-order harmonics in a natural descending progression, much like many tube amplifiers and better solid state linear amplifiers.

## **Overload and Protection Circuitry**

The ICEpower architecture also provides unique advantages in the overload and protection Provided by the e.One amplifier. The soft clipping characteristic of the e.One amplifier mimics the soft tube overload characteristic, preventing the harshness that occur with many solid state amplifiers. This soft clipping does not cause any compromise in the performance at levels below clipping.

The sonic compromises of typical protection circuits are avoided by using the switching processor to sense excessive DC current in the output stage and shut the amplifier down.

## **The compelling combination of features found in the Bel Canto e.One ICEpower 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 wasteful power supply for equal performance.

### **Low noise/low distortion: <0.005% THD/IMD, 120dB dynamic range**

The Bel Canto e.One 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. Every nuance of the recorded message is clearly reproduced.

### **Simple and elegant output stage using only 4 N-channel output devices**

Because of the high efficiency of the output stage there are only 4 N-channel switching devices in the output stage, even though they can deliver up to 45 amps and many hundreds of 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 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.

### **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 e.One Amplifier is not subject to these distortions because the output stage has very little bias current, and runs cool. The result is stability in operation heard as rock steady imaging and solid, dynamic sound reproduction.

### **Efficient Integrated Regulated Switching Power Supply**

Each amplifier channel in an e.One amplifier has its own dedicated switching power supply. This supply provides steady power rails for the amplifier and rids the supply of the line-frequency related harmonic content that muddies the sound from the unregulated supplies used in traditional linear amplifiers. The result is rock solid bass performance and unprecedented mid-band clarity that are hallmarks of the e.One amplifiers.

### **The first Watt is as linear as the last Watt...**

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