



## **Speaker Tuning White Paper**

*Delivering Premium Audio in a High Definition World*

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### **Overview and Market Status**

Digital media has seen explosive growth in recent years, with content ranging from live TV downloads for handsets to new high definition HD-DVD and Blu-Ray players. Consumers have embraced digital media and are assembling high quality home media environments. At the heart of this experience is the Digital TV (DTV), which is also experiencing explosive growth. Early DTVs had various limitations based on the specific display technology employed. Today, display technology has matured to the point that video image quality is outstanding in nearly every case. In fact, the DTV segment is facing rapid commoditization as consumer electronics brands struggle to provide differentiation that consumers can recognize and understand.

One of the strongest development vectors in the DTV segment has been to improve the attractiveness and styling of the DTV itself. Decor and form factor are major factors affecting consumer buying decisions. The smaller and sleeker designs mean that there is little room for traditional TV speakers. Manufacturers are working hard to hide the TV speakers as they conform to these consumer style preferences. This has resulted in smaller and less capable speakers being used for the latest DTV models. In some cases, the speakers are located behind the display to hide them from view. Various sound reflectors and “waveguides” are then used to bring the sound out to the viewer. The combination of smaller speakers combined with sleek form factors mean substantially reduced TV audio quality for consumers.

In the past, video quality might have dominated the viewing experience, but today audio is now a fundamental component of the experience. The explosion of digital media sources has resulted in a broad range of readily available audio content for consumers. Ever increasing production values for broadcast television mean that many programs are now delivering Dolby® 5.1 audio. The situation is made more complex with the new high definition HD-DVD and Blu-Ray players, which each support several multi-channel audio formats on the new disks. Hollywood has reacted to the availability of high-quality audio transmission formats by increasing the richness and realism of the audio content. The range of low-frequency audio content in movies and music is astounding. Please see “Delivering Rich Media Content from Small Format Audio Speakers” for more information in the nature of modern rich media content. Multi-channel positional effects and strong rich bass tracks have added greatly to the audio experience and realism. Various experiments have consistently shown that improved audio also increases the perceived video quality, greatly enhancing the entire viewing experience. Given this fundamental link between rich realistic audio and overall viewing experience, consumers are unlikely to step back from the experience of today’s digital media. Unfortunately, physically small DTV speakers mean consumers are missing much of that experience.

The industry hope has been that consumers would install an AVR or HTiB sound system to access the immersive audio content. However, the Consumer Electronics Association (CEA) data indicates that consumers are not taking this approach. CEA surveys of consumer entertainment configurations have consistently shown that, in practice, consumers depend on the TV speakers far more than would be expected. CEA data for media rooms and other primary viewing locations show that only 66% of systems employ some type of Audio-Video

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Receiver (AVR) or Home Theater in a Box (HTiB). The percentage of those setups that have the rear speakers connected is significantly lower still. When secondary viewing locations such as dens and bedrooms are included, the numbers fall to only 26% of systems using an AVR or HTiB. This means that some 74% of flat panel TVs (FPTVs) are fully dependant on their internal speakers. These statistics are also born out by the high number of large screen displays sold each year compared to the significantly smaller number of AVR and HTiB systems sold.

Consumer awareness of audio and its impact has been rising. CEA survey data has shown that audio has nearly reached the level of importance afforded to video quality in consumer's minds. In recent surveys, consumers have ranked audio second in priority when asked what is important in purchasing a new FPTV. This is an increase from the eighth most important ranking seen in earlier surveys. The increased consumer awareness is perhaps fueled by the growing availability of digital media, but also by the grown number of FPTVs being installed in secondary viewing locations. As FPTV prices have come down in recent years, we have seen FPTVs move from primary viewing locations such as the living room/media room, to begin penetrating secondary viewing locations such as the den and bedroom. Recent consumer survey data from eBrain indicates that up 40% of new FPTV installations are going into secondary locations. With an even lower incidence of AVR/HTiB use in secondary viewing locations, consumers are even more dependant on the DTVs internal speakers. Consumers can now directly compare DTV+AVR/HTiB configurations to DTV-only type setups within their own homes. The audio quality and viewing differences are stark enough that consumers easily recognize the importance of improved audio to their overall enjoyment. And since consumers are recognizing this importance and unlikely to accept less, the only viable solution is to improve the inherent audio quality coming from traditional DTV solutions.

### **The Path to Improve DTV Audio**

To improve the inherent DTV audio capabilities, we need to look at the key sub-systems components that make up that system. A DTV sound system is comprised of several components starting with the tuner and direct analog inputs, through the electronics, to the amplifier, and finally to the speakers themselves. The speakers are by far the weakest component in the DTV audio system. The speakers convert high power electrical signals into acoustic energy by moving the speaker cone in and out. This movement compresses the air and creates the sound that we hear. The speaker cone should be lightweight for the best sound reproduction and paper cones are often used in DTVs. Unfortunately, lightweight materials are also easily distorted resulting in audible artifacts. In addition to the cone issues, speakers do not deliver a uniform sound level at all frequencies. For a given speaker/enclosure, there are audio frequencies where the sound pressure level (spl) is much higher than it should be, as well as other audio frequencies where the sound pressure level is much lower than it should be. These frequency dependant anomalies cause a wide range of unwanted audio effects and greatly detract from the audio realism, and can completely mask important audio clarity key to presenting the true media viewing experience.

The sleek form factors popular with consumers are forcing the use of ever smaller speakers. Small speakers are physically too small to move the large amounts of air necessary for generating deep rumbling bass notes. In years past when there was significantly less bass content in media, small speakers may not have been such a problem for consumers. Today,

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Hollywood and the music industry have made great strides in creating realistic audio tracks rich in bass content. Since small speakers cannot reproduce low frequencies, this rich content is unavailable to consumers and greatly diminishes the experience.

What the frequency dependant anomalies and inability to reproduce bass tones have in common, is that they both require digital signal processing (DSP) correction. Compensation and correction of the electrical signal before it is sent to the speaker is the only way to overcome these physical characteristics which are inherent in the speaker's design while maintaining the style and form factors consumers demand. Functions like tone control are not effective. If a speaker is fundamentally unable to reproduce a low frequency tone because of its physically small size, amplifying that low frequency content is not going to make much difference. What is needed is an effective DSP-based correction at the amplifier level, with adequate processing to compensate these speaker anomalies. Only then will this provide consumers a realistic audio experience rivaling their theater experience.

### **D2Audio Speaker Compensation and Immersive Processing**

D2Audio provides a complete DTV audio solution that incorporates speaker correction, immersive audio processing to improve realism and enjoyment, while also supporting the complex I/O requirements of modern Digital TVs. The D2Audio® SoundSuite™ immersive audio enhancement software is an essential component of the D2Audio DTV offering. The D2Audio SoundSuite software runs on the D2Audio Digital Audio Engine™ (DAE) family of Class-D PWM controllers with on-chip DSP digital signal processing.

The newest member of the Digital Audio Engine family is the DAE-3 which incorporates several specialized enhancements for Digital TV (please see the D2Audio white paper "*DAE-3 Family of Solutions for Digital TV Applications*" for more information on the DAE-3 product). The DAE on-chip DSP is heavily used to improve the underlying digital Class-D sound quality, as well as to perform immersive signal processing. This same hardware also supports third party enhancement techniques from suppliers such as SRS Labs® and Dolby Labs®. Various consumer electronics brands have their own merchandizing plans focused on third party logos and specialized processing. The DAE family of controllers is very flexible, allowing consumer brands to select the D2Audio SoundSuite family of immersive processing algorithms, or one of the several third party enhancements.

D2Audio was the launch partner for the SRS Lab® TruSurround HD4™ (TS HD4) advanced multi-channel virtualizer that supports up to 4.1 output channels of content. Modern virtualizer techniques like TS HD4 require additional amplifier channels over and above the standard DTV audio outputs for headphones, line outputs and subwoofers. The D2Audio DAE-3 has complete support for the new TS HD4 algorithms from SRS Labs.

The foundation of D2Audio SoundSuite immersive processing is found in the speaker compensation algorithms that address the physical speaker anomalies. Uncompensated speakers are by far the weakest link in the audio system. D2Audio applies extensive technology in this area to insure that speaker output levels achieve a flat and realistic sound that can be used as a starting point before other immersive enhancement techniques are applied. D2Audio applies a number of proprietary methods to assess and correct the various frequency dropouts and resonances seen in TV speakers. Much of what we encounter is the result of 3-

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inch and smaller drivers. We often find that expensive speaker/enclosures are selected in an attempt to improve audio quality, only to be limited by the fundamental size of the speaker drivers themselves. Such small drivers greatly limit the audio quality regardless of the amount of money spend on enclosures and other such techniques. D2Audio maintains that reasonably priced speakers/enclosures should be selected, and that DSP processing is essential to compensate and correct these speakers before applying additional immersive processing techniques.

In addition to correcting for audio defects inherent in DTV speakers, D2Audio delivers a full range of immersive audio enhancements that can also be applied to the audio content for improved realism. Several of these enhancements depend on psycho-acoustic techniques that fool the ear and brain into “hearing” a larger and deeper sound stage with increased bass content. The ear-brain system is susceptible to audio-based illusions just as the eye-brain system is susceptible to optical illusions. For example, one technique causes sound from two speakers placed relatively close to each other to sound as though the speakers are widely spaced. This creates a much stronger stereo effect and makes the sound stage wider and larger. In the case of bottom-mounted speakers, a similar technique can be used to raise the apparent audio source up to the center of the screen. This effect is particularly important in making dialog sound as through it is coming from the character’s mouth rather than from below the screen.

One of the most powerful psycho-acoustic techniques is the D2Audio® DeepBASS™ algorithm used to strengthen the bass response. A rich bass track is essential for realistic impressions of large massive events in movies, and deep bass has become a key component in nearly every type of modern music. The D2Audio DeepBASS algorithm is a highly effective bass extender that monitors the bass content in the original media and then performs a psycho-acoustic enhancement that moves a specially modified version of the original bass content into a higher frequency range where small speakers can reproduce it. By changing the playback frequency, the D2Audio DeepBASS algorithm takes bass content that is unavailable to the consumer by virtue of the poor speaker response, and puts it in a range where it can be heard. The original bass content is heavily modified from its original form. This modification allows the ear to “hear” the bass notes as they were intended, even though the energy has been moved to a higher frequency range. This is the fundamental nature of the psycho-acoustic enhancement. The D2Audio DeepBASS algorithm is especially effective relative to other bass extenders. This gives consumer electronics brands the flexibility to adjust the bass effect to match their merchandizing approach and customer’s needs.

The DAE-3 Digital Audio Engine incorporates 10 internal PWM engines that can be used to fully support the advanced 4.1 channel configurations for SRS® TruSurround HD4™, including an active subwoofer, as well as headphone, line outputs, and line level subwoofer outputs. A modern DTV is a high channel count configuration that consumes as many as 10 channels of PWM, separate of SPDIF and I2S I/O requirements. The DAE-3 is the only PWM controller with the required number of outputs to support advanced configurations such as SRS® TruSurround HD4™. The DAE-3 can be used with a full range of output power stages with power levels from 8 watts to 30 watts or more per channel. This high degree of flexibility means that the most economical power stage can be selected for the applications while always maintaining the desired level of power and performance. Firmware, OnScreen Display (OSD) coding, and other

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aspects of the design remain unchanged across a wide range of models, while performance and cost can be targeted for the specific platform.

The DAE-3 incorporates a complete on-chip DSP with internal memory. This DSP is fully programmable and can be updated with firmware to support a wide range of audio decoder formats. Several popular encoding techniques such as the Dolby Digital AC-3 and DTS are recognized by consumers today. Advanced versions are now becoming available on HD-DVD and Blu-Ray devices. Other encoding techniques such as AAC, popular in the Japanese broadcast environment, are supported by the DAE-3 as well. Only a fully programmable DSP has the flexibility to deal with new and emerging encoding standards, and is clearly the best choice for advanced digital TV designs.

The DTV segment is an especially cost sensitive segment. D2Audio has been aggressive in carefully crafting the DAE-3 controller to minimize overall system costs (Bill of Material or BOM cost). The internal ADC to support legacy analog audio inputs is one example where incorporating new capabilities helps to reduce the overall system BOM cost. With the DAE-3, D2Audio has improved BOM cost compared to the original and popular DAE-1 adopted for many recent DTV designs. When the cost of third party licenses paid for by the consumer electronics brands are considered, the royalty free D2Audio SoundSuite further improves the D2Audio BOM cost advantage. But the greatest impact on overall system BOM cost is the opportunity to select reasonably priced DTV speakers/enclosures and combine them with the D2Audio SoundSuite speaker compensation to improve the sound. It is exciting to be able to improve sound quality and viewing experience while at the same time greatly reducing overall BOM cost for the system. Selecting expensive speakers and enclosures may seem like the easiest way to improve audio quality, but the small driver sizes dictated by stylish form factors greatly erodes the value of this approach. DSP correction using D2Audio SoundSuite is really the only effective solution.

### **The Impact on Advanced DTV Audio**

The impact on viewing experience is dramatic for DTVs employing Intelligent Digital Amplifiers from D2Audio. The Digital Audio Engine at the heart of these amplifiers brings a new level of realism to digital media. This is especially true of the newest member in this family, the DAE-3, with its specialized support for modern high channel count DTV configurations. The integrated DSP is especially useful for correcting and compensating the physically small DTV speakers and tight enclosures. New sleek form factors popular with consumers force the use of less than ideal audio enclosures, and only through the use of DSP-based correction can this situation be mitigated. Layering on top of the speaker compensation, is an additional full range of D2Audio SoundSuite immersive processing algorithms that bring a new level of realism to the viewing experience. Realistic audio is increasingly important to consumer brands. As more and more FPTVs are installed in secondary viewing locations without the benefit of an AVR or HTiB audio system, consumers are increasingly able to notice the negative impact on their viewing – and by association, may develop negative feeling regarding their DTV purchase. The prospect of buyer's remorse is a real one. To have purchased an expensive DTV with a beautiful video image but with limited audio capability is going to raise consumer concerns. The brand is likely to take the brunt of this issue with their name prominently displayed on the bezel of the TV itself. Consumer brands understand this linkage and have reacted by upgrading speakers and enclosures within the limits that modern styling will allow. Unfortunately, this has resulted in increasingly high speaker/enclosure expense, but with no real improvement in audio quality.

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The more cost effective approach is to employ DSP correction and to hold speaker/enclosure expenses in a more reasonable range. The nature of poor DTV audio is inherent in the physical nature of the speakers, and can only be improved with advanced psycho-acoustic DSP-based algorithms.

### **The Output Going Forward**

Consumers will increasingly be able to make direct comparisons between the viewing experience of home theater and that of stand-alone DTV configurations. Recent surveys of consumer interests and concerns show that a complete digital media experience is essential, including striking video and immersive audio. Considering the rapid commoditization of DTV and the driving need of major consumer brands to maintain their differentiation, audio is an obvious and cost effective area in which to invest. We are rapidly approaching the point where consumers cannot immediately identify the quality differences between the walls of beautiful platforms on display at the typical big box retailer.

A major China brand has already recognized and addressed this problem by deploying an immersive D2Audio sound system along with a retail point of sale audio demonstration to allow consumers to experience the impact of realistic audio first hand. The impact of D2Audio speaker compensation and the immersive processing components is quite dramatic. By allowing consumers to hear the differences directly in a retail environment will draw a high level of attention to this China brand and their approach, translating into increased sales. Look to D2Audio for effective tuning and immersive audio enhancements to truly empower Digital TV audio using DAE-3 and D2Audio Sound Suite.