

PERCEIVED LOUDNESS ADVANTAGE

ENRICHING THE LISTENING EXPERIENCE WITHOUT TURNING UP THE VOLUME

(WP-A001-0110)

OVERVIEW

Most of today's consumer electronics products – from telephone handsets and portable media devices to PCs, television sets, and other home audio systems such as docking stations – all deliver an audio experience through small, low cost speakers. These speakers produce relatively low volume levels and achieve a limited or non-existent bass response in the frequency range below 200 Hz. Coupled with the distortion caused by digitized, compressed audio, the result is washed out solo instruments, lost vocals, and muddy articulation of movie dialog. The sound does not convey the emotion of a plucked bass string or the impact of a movie explosion.

**REVISION
HISTORY**

DESCRIPTION	REVISION	ORIGINATOR	DATE
Initial Release November 2008	2.0	Karen Parnell	January 2010

1. BREATHING LIFE INTO DIGITAL AUDIO

Most of today's consumer electronics products – from telephone handsets and portable media devices to PCs, television sets, and other home audio systems such as docking stations – all deliver an audio experience through small, low cost speakers. These speakers produce relatively low volume levels and achieve a limited or non-existent bass response in the frequency range below 200 Hz. Coupled with the distortion caused by digitized, compressed audio, the result is washed out solo instruments, lost vocals, and muddy articulation of movie dialog. The sound does not convey the emotion of a plucked bass string or the impact of a movie explosion.

Virage Logic's Sonic Focus[®] audio post-processing uses psycho-acoustic techniques to eliminate these artifacts of digitally compressed audio and sub-optimal speakers. The Sonic Focus components – Adaptive Dynamics[™], X-Matrix[™], Extrapolator[™], and the recently introduced Virtual Bass[™] – are designed to work seamlessly with each other and each algorithm is tuned to achieve a unified final result. This white paper will show how audio post-processing, particularly Virtual Bass, can increase perceived loudness at lower power consumption. This leads to important benefits such as longer battery life, lower bill-of-materials (BOM) costs and improved design flexibility.

2. LOUDNESS ADVANTAGE

Can audio post-processing enrich a digitized, compressed audio stream so that its apparent loudness is increased while power consumption is reduced? Yes, and Virage Logic's Sonic Focus suite that delivers this advantage also enables a competitive differentiation for the OEM and ODM. Sonic Focus can deliver the same perceived loudness while reducing the Sound Pressure Level (SPL), and the power consumed, by 1.3 dB to 2.4 dB on a given system. This means that OEMs and ODMs can lower their BOM cost several million dollars by using fewer, and less expensive, amplifiers and speakers to deliver studio quality audio playback with extended life on a single battery charge.

An independently conducted scientific analysis of SPL measurements confirmed that Sonic Focus-enhanced audio achieved a measureable loudness advantage. Thus, the Sonic Focus technology unlocks the ensuing system cost benefits. This white paper details the scientific analysis that confirmed this loudness advantage. It describes a complete Sound-to-Silicon solution comprising ARC[®] Sound 2xx hardware IP, ARC MQX[®] real time operating system, ARC optimized audio codecs such as MP3, AAC, WMA, and Dolby Digital, and ARC Sonic Focus post-processing software that delivers this advantage for OEMs and ODMs.

Adaptive Dynamics[™]

One of the four individual Sonic Focus components contributing to this loudness advantage is Adaptive Dynamics. It uses a unique "look-ahead" process to master the audio waveform. Adaptive Dynamics re-creates the detail commonly lost in today's music, movies and games, regardless of encoding format.

Adaptive Dynamics restores information that may have been lost in compression. It adds clarity to the entire audio spectrum and recreates the original tonality of voice. The listener hears the speaker's natural timbre. Audio enhancement techniques based on frequency-domain equalization (EQ) compensation do not reduce compression artifacts and muffle one frequency to emphasize another – altering the tonality of the vocals or dialog.

Since common audio enhancement techniques do not adequately enhance fidelity of the audio, the listener compensates. What the eye does to a compressed video image with missing elements, the ear does to compressed sound. Long term, this leads to listening fatigue – the mind works overtime to fill in the holes. Virage Logic's Adaptive Dynamics overcomes these problems by filling in the holes.

X-Matrix™

As its name implies, surround sound should wrap the listener in a new environment, which is what X-Matrix does. However, surround sound is difficult to create with two speakers. The commonly used solution tends to work in a single spot in the center between two speakers. A meter to the left or right of center and the impact of voice, as well as overall voice clarity, are lost.

X-Matrix expands the soundstage while adding a virtual center channel to emphasize the vocals or solo instruments. The result is a full, rich, and natural surround sound experience with increased vocal clarity for headphones or stereo speakers that is without phase shift artifacts. X-Matrix ensures that the voice is clear, distinct and well articulated – regardless of the listener’s position relative to the speaker.

Extrapolator™

Virage Logic’s Extrapolator creates a virtual concert hall with all the acoustical effects contained in that physical space simulated in software. This produces a listening experience that comes close to an actual performance. Extrapolator uses advanced physical modeling techniques to expand stereo source material and create a life-like acoustic environment. Vocals and solo instruments become more pronounced in the front, while background effects and ambient details are emphasized in the rear.

Competitive offerings on the market use a phase-based approach, looking for in-phase and out-of-phase information to determine what portion of the audio signal should be in the front, center, and rear. These solutions require pre-encoding the source material with these phase differences. Unfortunately, most commercially available compressed digital content does not include this surround pre-encoding. Thus, phase-discrimination surround sound decoding techniques are ineffective. The result is that most sound spreading technology directs audio to the center channel, while the audio from the rear speakers is largely noise.

Virtual Bass™

The Virtual Bass technology delivers a deep and rich bass response on existing speakers or headphones, thereby eliminating the need to add subwoofers or other costly audio components. Virtual Bass is based on the well-known principle of the missing fundamental. When the basilar membrane in the ear receives a pure sine wave, say 200 Hz, it vibrates not only at 200 Hz but also at its harmonics at 400, 600, 800, 1000... Hz with decreasing amplitudes. The brain interprets this spectrum as a pure 200 Hz sine wave. Conversely, when all the harmonics are presented to the ear but the fundamental tone is absent, the brain still interprets this spectrum as having the fundamental tone, and the subject “hears” the fundamental frequency. So Virtual Bass utilizes the principle of psychoacoustics of sound perception.

Virtual Bass technology differs from other techniques in the greater amount of intelligence it applies to the enrichment process. It identifies portions of the spectrum that represent vocals, bass, and other elements. So it can selectively enrich each portion individually and then present the stream to the listener such that the voice sounds natural and not like the more nasal sound that other techniques produce. Furthermore, the bass sounds big and full of emotion. Other solutions add distortion and muddy the audio, resulting in the listener actually getting fatigued over time.

3. DOES BASS CONNOTE POWER? – THE PERCEIVED LOUDNESS ADVANTAGE

The success of the Sonic Focus Virtual Bass technology led to the hypothesis that the perception of bass is linked to the perception of power since bass implies the displacement of a greater volume of air. If true, implementing Sonic Focus will lead to greater perceived loudness.

To test this hypothesis, an independent group of audio professionals, Charles Salter Associates (CSA), conducted three experiments. (The complete findings are described in the "Sonic Focus Processing Evaluation White Paper".) In the first experiment, the Sonic Focus software was algorithmically programmed to produce the same loudness level as the unprocessed music. The generated Sound Pressure Level (SPL) was measured using electronic instruments in a sound-isolated room. For A-weighted SPL measurement, which closely matches the ear's frequency response, Sonic Focus resulted in 2.4 dB lower SPL on average for the same loudness level.

In the second experiment, CSA tested the hypothesis using five human subjects who were presented randomized music loops and amplifier settings. They were exposed to unprocessed music as well as the same music processed through Sonic Focus. Their task was to adjust the volume setting when listening to the Sonic Focus-processed music so that the perceived loudness was the same as that of the unprocessed music. The subjective results were on average within 0.15 dB of the algorithmic result in Experiment 1, confirming the 2.4 dB advantage of Sonic Focus for perceived loudness equivalency.

In the third experiment, CSA used a mathematical model of the human ear instead of human subjects. This experiment confirmed the subjective measurement as it also obtained on average 1.3 dB lower SPL for Sonic Focus. Thus, Sonic Focus reduced SPL conservatively by 1.3 dB, and realistically by 2.4 dB for the same level of perceived loudness. This testing conclusively proved that with Sonic Focus enabled, listeners can experience the same level of perceived loudness while dissipating 25 to 40 percent less power in the speakers, assuming locally linear characteristics.

4. BENEFITS OF VIRAGE LOGIC'S LOUDNESS ADVANTAGE TO OEMS

A loudness advantage leads to important benefits for system design. Systems with equivalent perceived loudness can be built with less expensive amplifier and speaker components, leading to BOM cost savings. Systems can also use smaller form factor speakers, leading to greater design freedom, innovation and differentiation.

For example, when one of the world's largest OEMs selected Virage Logic's Sonic Focus software, they were also able to incorporate lower power speakers into their system (saving \$0.25 per speaker for four speakers per system), lower power amplifiers (saving \$0.50 per amplifier for two amplifiers per system), and achieve a more compact thermal and electrical design (saving \$1 per system). At their current run rate of 1 million units per year for this consumer electronics product, this customer saves millions of dollars per year in BOM costs.

5. PORTABLE MEDIA PLAYER SYSTEM-ON-CHIP (SoC) REFERENCE DESIGN

Audio is becoming ever more important in today's smart phones. In fact, the cell phone speaker is being used increasingly for listening and sharing music. With Sonic Focus technology the listener will experience an increased level of loudness while using smaller power amplifiers and the small speakers typical of today's portable handsets. Figure 1 illustrates the major blocks contained in Virage Logic's Sonic Focus-powered solution.

These blocks include an ARC Sound 2xx Subsystem that consists of an ARC 600 processor with powerful XY Memory for digital signal processing. The combination is ideally suited to executing the Sonic Focus software, since it accelerates compute-intensive tasks such as Fast Fourier Transforms and Viterbi decode, two functions used extensively when decoding compressed digital audio.

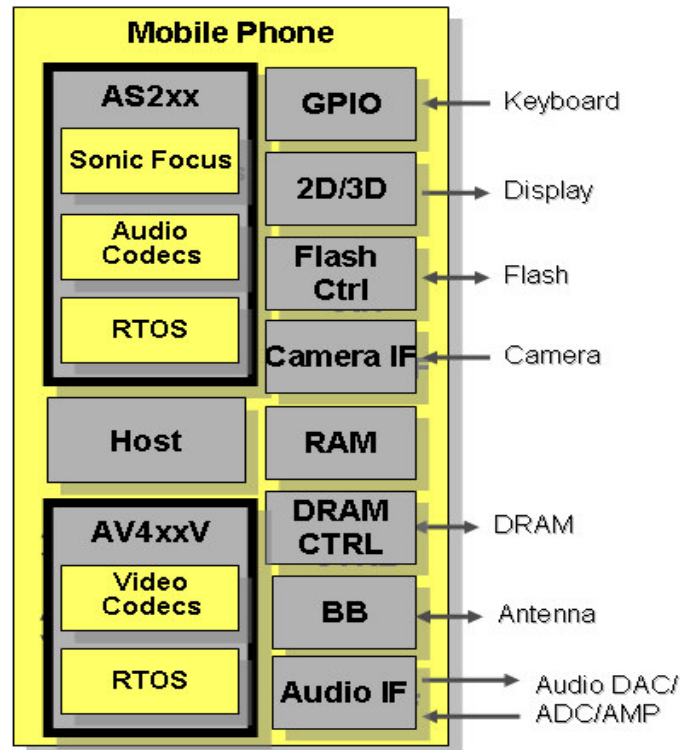


Figure 1. Mobile Phone Media Player Running Virage Logic's Sonic Focus Software.

In addition, the ARC Sound 2xx Subsystem comes with a verified and optimized set of codecs and the Sonic Focus audio enrichment post-processing software. Included with the solution is the MQX operating system, as well as Media Software Framework for coordinated interaction between encoders, decoders, post-processing algorithms, and data converters.

6. CONCLUSION

Today's audio content is digitized and compressed, stripping out much of the emotion contained in the original performance. This content is then played through low-cost speakers that produce low volume levels and cannot reproduce a satisfying bass response. Virage Logic's Sonic Focus software enriches digitized audio streams restoring their original quality. In addition, the Sonic Focus software compensates for the deficiencies of small inexpensive speakers to produce a bass response that conveys the emotional impact missing in today's portable and home consumer electronics devices – leading to the perceived loudness advantage at lower power consumption.

Virage Logic delivers a complete audio solution that consists of Sonic Focus audio post-processing, a complete set of optimized ARC audio codecs, the ARC MQX RTOS, the ARC Media Software Framework, and the ARC AS 2xx subsystem IP, all available today.

VIP Partners

Virage Logic is an integral part of the SoC design and manufacturing ecosystem. Our VIP Partner program's mission is to help increase interoperability and provide access to complete solutions that enable mutual customers to accelerate silicon success by reducing design infrastructure integration time, design time and improving manufacturability. The VIP Partner program brings together technology and business alliances with the following types of partner companies.

Foundry Support

Virage Logic partners with foundries and IDMs including Dongbu HiTek, GlobalFoundries, Grace, HeJian, IBM, MagnaChip, Samsung, SilTerra, SMIC, Tower, TSMC, and UMC. Our close relationships with leading foundries enable Virage Logic to gain early access to advanced technologies to help ensure we continue to be the company that is first to market with advanced technology products.

EDA Partners

The company's relationships with electronic design automation (EDA) leaders including Cadence Design Systems, Magma Design Automation, Mentor Graphics and Synopsys enable us to validate our IP's interoperability with industry standard software design tools. This helps ensure our customers realize the benefits of an integrated design flow and achieve first time silicon success.

IP Partners

In partnership with leading processor IP companies including MIPS Technologies and Imagination Technologies, Virage Logic collaborates to provide physical IP for reference designs that are optimized for power, performance and area for their SoC designs.

Design Service Partners

Our technology alliances with design service companies including Alchip Technologies, eSilicon, Global Unichip, OpenSilicon and VeriSilicon help ensure they have expert knowledge of Virage Logic's semiconductor IP. This allows our customers the flexibility to augment their design teams or outsource their SoC designs to meet their business objectives.

About Virage Logic

Virage Logic is a leading provider of semiconductor intellectual property (IP) for the design of complex integrated circuits. The company's highly differentiated product portfolio includes processor solutions, interface IP solutions, embedded SRAMs and NVMs, embedded test and yield optimization solutions, logic libraries, and memory development software. As the industry's trusted semiconductor IP partner, more than 400 foundry, IDM and fabless customers rely on Virage Logic to achieve higher performance, lower power, higher density and optimal yield, as well as shorten time-to-market and time-to-volume. For further information, visit www.viragelogic.com.

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