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to AV Design &
Development

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High-Performance Balanced Audio Interface Design, Part 1

By Bill Whitlock

■ *Balanced interfaces, at least in theory, are immune to interference of all kinds. For 50 years, virtually all audio equipment used transformers at their balanced inputs and outputs. High noise rejection was taken for granted, while very few engineers understood the reason: the transformer's extremely high common-mode impedance—about a thousand times that of its solid-state "equivalents." Widespread misunderstanding of the meaning and underlying theory of balanced interfaces has resulted in all-too-common design mistakes and seriously flawed testing methods. Therefore, noise rejection in today's real-world systems is often inadequate, or at best, marginal. Traditional input stages will be discussed and compared. I will describe a novel IC that compares favorably to the best transformers. Other topics will include tradeoffs in output stage design, effects of non-ideal cables, and a design error called the "pin 1 problem."*

INTRODUCTION

"At present I give seminars and do consulting work. The seminars have changed over the years because I am always trying to provide better ways to describe the general issue of interference control. The buzzwords in the engineering community are still **grounding and shielding**. These are the words that attract attention and get students to sign up for a course. It is a trick because grounding is usually **not** the way to solve interference problems. It is important to know what grounding is all about, and then we can talk about the **real** issues.

A circuit diagram does not show physical size, relative position, physical spacing, or interconnection order. It says nothing about parasitics or loop area. The effects of long cables or of the power grid are not even suggested. The electrical nature of the facility is not represented. Yet with all this missing

information the engineer is supposed to function. It is a deep mystery to most, and the easy way out is to ignore it all until there is a problem."

—Ralph Morrison, *Solving Interference Problems in Electronics*, 1995, reprinted by permission of John Wiley & Sons, Inc.

High signal-to-noise ratio is a very important goal for most audio systems. However, AC power connections unavoidably produce ground voltage differences, magnetic fields, and electric fields. This makes the task of transferring an analog audio signal from one system component to another, while avoiding audible contamination, anything but trivial.

The dynamic range of a system is the ratio, generally measured in dB, of its maximum undistorted output signal to its residual output noise or noise floor. Fielder has shown that as much

Anadigm's Analog Solution for AutoEQ Subwoofer Signal Processing

By Rob Baum
and Steve Tatarunis

Home theater-in-a-box packages offer a clean integration of components with simple setup, yet most of these modest systems do not satisfy even the mainstream customer, let alone the sophisticated end-user. An assortment of "loose" bookshelf speakers, a surround receiver, and a powered subwoofer can entail system integration challenges, not just to the do-it-yourself end-user, but even to the CEDIA trained installer. Offering customers the simplicity of entry-level systems, with the performance of properly integrated subwoofers using some type of measurement tuning to "close the loop" is a worthy goal, not often achieved.

Shortcomings in the subwoofer become painfully obvious when those systems attempt to play music with deep bass, as opposed to just the "noise" of movie low frequency special effects. AutoEQ for subwoofers is a hot feature now, but available only at the top end of the market—you are not likely to find autoEQ in a subwoofer in Best Buy or Circuit City. In fact, you are typically not going to find any subwoofer over \$500 at these stores (unless you head into the Magnolia section of Best Buy). The opportunity that we will explore is adding autoEQ for under \$20, complete with the mike, which would translate to a less than \$600 retail autoEQ subwoofer product.

SUBWOOFER PROBLEMS AND OPPORTUNITIES

There are many external factors that conspire to detract from the bass performance, even if the subwoofer is properly designed. Packaging a good woofer and an amp with adequate power is only part of the equa-

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tion. Is the woofer in phase with the satellites? Even the most careful, color-coded wiring will not mean much if the sub plate amp or the surround receiver has an inverting input.

Is the speaker in the corner on the floor, or out in the room as a coffee table? Loading conditions can change the bottom end by 12dB. Is the sub located in an acoustic null? Or perhaps the "visibly acceptable location" could be the cause of a particularly nasty standing wave? Most of us are at the mercy of our listening environment, and the average customer doesn't know or care about the details—they only know they want good bass.

There are, however, solutions to these problems. For users and installers with patience and a sound level meter accurate in the bass (weighting defeated) or an audio-band spectrum analyzer, the optimum location and parametric EQ settings can be found, given the time and a bit of competence. Most consumers just will not go to these lengths. Velodyne, Sunfire, and Infinity offer automated technical solutions to these problems. Velodyne ("Digital Drive") and Infinity ("Room Adaptive Bass Optimization System") have introduced DSP-based equalization using a microphone or supplied sound level meter and test CD for their premium subwoofers; this feature can be very useful in practice—the only fly in the ointment is simply that they are expensive. For product engineers, developing DSP-based automatic EQ subwoofer solutions is a major commitment of time and budget.

DSP SOLUTIONS

DSP is the obvious solution, but not necessarily the simplest or most cost-effective one for EQ of mainstream home theater and autosound subwoofers. Loudspeaker engineering groups rarely include a team member or consultant skilled in producing DSP code. DSP often is not a comfortable option for many of the engineering managers in the audio community.

In a recent iPod docking station project, a client wanted to use a range of digital signal processing and opted for an "easy-to-use DSP with graphical interface for programming." The

cost was supposed to be only \$3 for the DSP, but we are three months into the project and the signal processing daughterboard is over \$18 and climbing. Now the DSP design team wants to change the DSP to bring down the cost \$5 (hey, the whole thing was supposed to cost \$5!), but the development time will be another month (or maybe two or three).

The aversion to DSP is not just due to the bill of material (BOM) costs. Finding DSP code writers with an understanding of acoustics is an elusive task. The docking station project is now into over 100 man-hours of DSP development time. There are too many horror stories of multi-year DSP projects that never quite reach completion.

And then today, almost all amplifiers are analog input, so A/D converters are needed to feed the DSP and then a D/A is needed to get the signal back into the analog domain to pass to the power amp. Even most class D (switching) amps are analog input. This will ultimately change, but the reality of the consumer market today is still

simply analog in and analog out.

HELLO, MOTO

Motorola Semiconductor, one of the leaders in DSP integrated circuits for audio, realized this and six years ago began development of an all-analog solution to signal processing. The result is essentially an analog signal processing integrated circuit with both analog input and analog output—and nothing digital in between. In July 2004 Motorola Semi became Freescale Semiconductor, with 2005 sales of \$5.8 billion; Freescale is the ninth largest chipmaker in the world. The dynamically programmable Analog Signal Processor (dpASP) product line, originally called Field Programmable Analog Array (FPAA), was spun off in 1999. This was followed by a management buyout in December 2005, which led to the creation of Anadigm, and not surprisingly located next to Moto/Freescale Semi in Tempe, Ariz.

To date, Anadigm has had a low profile in audio. The main application for dpASP has been RFID—Radio Fre-

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quency Identification, the inventory tags that cause the alarms to go off when you are caught shoplifting (but RFID tags can do many other things). What is of greater interest to audio is Anadigm's audio applications of dpASP, which can add unique features to auto sound products, subwoofer plate amps, and pro sound products such as loudspeaker processors.

HELLO, ANADIGM

Audio market acceptance over the years of Anadigm's devices has been limited due to Anadigm's focus on the RFID business—along with insufficient geographical coverage. However, this is all about to change as Anadigm is now committed to the development and support of audio devices. Perhaps the most crucial aspect to acceptance is the availability of reference designs in the form of a wide range of total solutions for automatic equalization, from board layout, BOM, and commercial viable reference implementations.

Applications for Anadigm's devices range from all sorts of audio signal processing: limiters/compressors to prevent power amp clipping, pre-set EQ correction, AutoEQ room interaction, parametric EQ, electronic crossovers, loudspeaker management systems for pro-sound—to the initial application for subwoofer plate amps and home and autosound. Also available for the automatic EQ subwoofer solution is a calibrated measurement microphone with optional integrated preamp. The reason for the mike/preamp combination is to avoid a high gain mike input stage in a powered woofer in which the mike preamp would be near the power supply (or even worse—a plate amp with switching power supply or switching amp output stage).

A compelling attribute of the Anadigm autoEQ subwoofer application is that it will be ready to go—no development time or cost—from various

offshore plate amp vendors, with no licensing fee. Anadigm can supply an autoEQ board, both in the US and from their agents in Asia, or just the dpASP IC with data package.

dpASP designs can reach the market quickly for several reasons:

1. Anadigm provides board layout and BOM for its reference designs (i.e., specific reference designs, such as front end signal processing for subwoofer AutoEQ).
2. Anadigm Designer software offers templates for subwoofer audio applications.
3. Board level reference designs optimized for production—i.e., not eval boards, but viable complete solutions at production pricing.
4. Availability of board level products fabricated in China by competent manufacturers.
5. Boards offered in China for local assembly by your existing OEM vendor.

While op amp solutions are more cost-effective than dpASP, other circumstances, such as flexibility, favor the use of dpASP solutions. Upscale

10% accuracy (and forget about achieving this at high power levels with temperature drift). Active networks such as electronic crossovers, active equalizers, and so on, typically offer 5% tolerance components. DpASP delivers the analog sound quality advantage with precision and reliability over standard analog components due to better than 0.1% component matching within the IC with no drift over temperature. Additionally, the board level product offers optional active differential input connections, which are preferred for superior noise immunity.

ANADIGM MODULES

Anadigm announced the Sonic-Master 1 subwoofer module in October 2006. It is a simple upgrade to existing subwoofer plate amp designs, delivering an enhanced feature set for advanced subwoofers with minimal cost and negligible product development. Anadigm's audio dpASP provides a flexible platform for subwoofer signal conditioning, enabling equalization, bandpass filtering, and limiter protection to an active subwoofer design. The limiter is a welcome function for class D amplifiers whose overload characteristics are often not pretty. Such a platform also enables the addition of AutoEQ while remaining in an analog environment.

Chipsets are available from Anadigm from a number of international vendors and distributors; also available is a separate daughterboard or integrated plate amp design. It comes out of the box with usable pre-sets: no

engineering time or money is wasted on a steep learning curve. During product development, designers may customize the default settings using Anadigm Designer, an easy graphics-based package. There is no need to teach yourself how to use DSP, or hire a DSP programmer: this system works in the analog domain. If us-

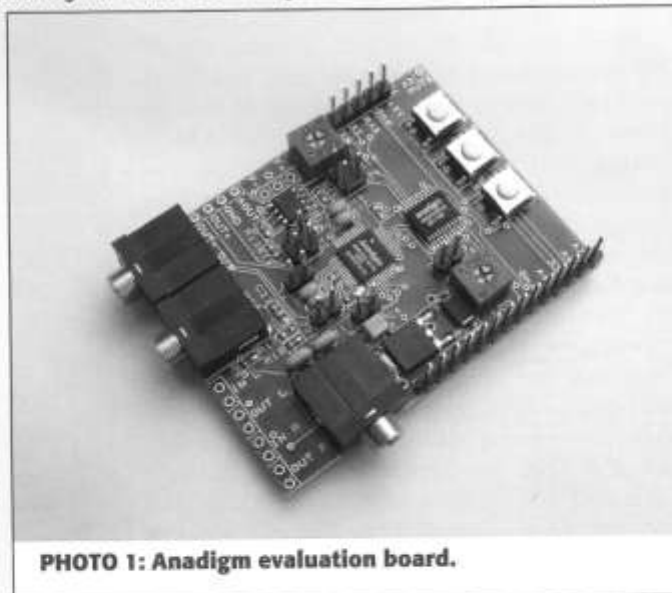


PHOTO 1: Anadigm evaluation board.

designs can achieve a level of precision with dpASP not possible with other solutions.

SonicMaster 1 is Anadigm's subwoofer signal processing board level solution. It provides accuracy and control of the filter characteristics to a very high tolerance. Passive crossover filter networks rarely achieve

ers want to get under the hood and adjust settings for, say, the threshold of the clipping limiter, it is simple to adjust the user adjustable software settings. (www.anadigm.com/sup_downloadcenter.asp?tab=ad2)

WELCOME TO THE MACHINE

The SonicMaster 1 is a 3.3V, two-chip solution using dpASP with an Audio (Finite) State Machine, enabling audio

designers to develop signal-processing functions that can be dynamically configured. These functions include filters such as high pass and low pass (Linkwitz-Riley), notch, bandpass, Linkwitz Transform. Long time constant averaging peak detector and automatic gain control are easy to implement. The latest templates include the signal generation that enables AutoEQ equalization tuning.

The first member of the SonicMaster series is the AN237K04, comprising the AN231E04 dpASP and the AN237C04 state machine. The AN237K04 features 100% analog signal path, options for push button or rotary controls, LDC display module, factory presets, or end user adjustments. Additionally, SonicMaster 1 provides programmable standby power mode, Auto Mute feature that eliminates low-level noise between cuts and standby mode, as well as control for no-signal power amp no signal shut down standby mode. In future iterations, the display and controls may be located on a remote control along with the measurement mike, using a diffused IR link.

The AN237K04 is dynamically reconfigurable, allowing modifications to circuit parameters while in operation. The device can therefore adapt in real time to changes in the environment where the subwoofer speaker is used. With this feature, designers could offer professional installers or end users the ability to alter frequency and rolloff characteristics in their homes

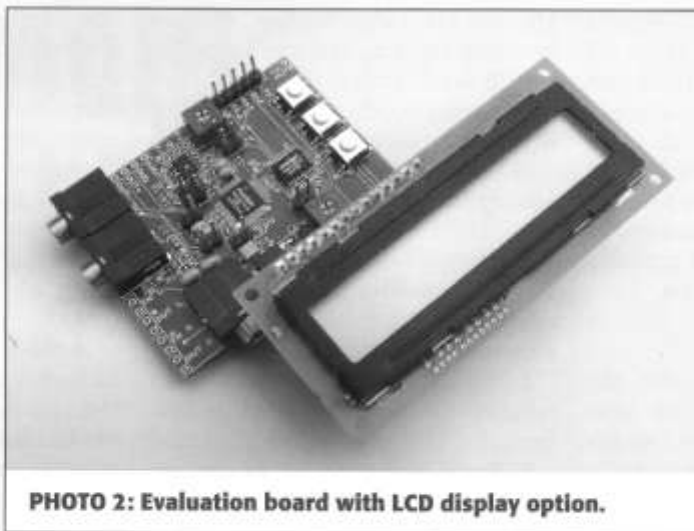


PHOTO 2: Evaluation board with LCD display option.

for optimal sound quality, or even implement a self-tuning function that would perform this step automatically.

Anadigm's SonicMaster solutions reduce the signal processing design cycle from months to a matter of days. Standardizing around a single printed circuit board serving multiple end products simplifies and improves product development, reducing the range of components that needs to be sourced by OEMs, allowing greatly reduced development cost and faster time to market. There are no fees for the complete reference design or technical support.

"The Subwoofer Processor modules offer real-time, reprogrammable signal processing under software control, while eliminating latency issues and the need to convert signals to and from the digital domain," said Simon Dickinson, COO of Anadigm.

"For the first time, the most advanced design ideas for subwoofers can be implemented quickly, with full control over phase and perfect repeatability. With SonicMaster dpASPs, we're giving audio engineers a subwoofer solution with the greatest flexibility and highest audio quality available today," added Richard Riker, CEO of Anadigm.

A full-featured starter development kit that includes evaluation board and embedded software is available for \$199. Samples and production quantities of the new SonicMaster 1 (Part AN237K04), are available now

from Nu Horizons (www.nuhorizons.com) and Anadigm. The SonicMaster 1 chipset plus a measurement mike will cost about \$20 in production quantities.

For product managers and buyers, it means buying plate amps from OEMs with an additional feature for a few extra dollars that translates to less than a \$100 rise in the retail price. For the marketing department, mid-priced subwoofers can offer the signal process-

ing feature set of competitors' flagship models with minimal unit cost, development cost, time, and effort. For the customer, integration of this product means they can achieve performance approaching that of sophisticated DSP-engined subwoofers at a fraction of the cost. **M³**

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