Oxford Digital EQ and *MajEq* Auto-Tuning System

An introduction and overview

Oxford Digital

1. About Oxford Digital Limited

1.1 Background

- Oxford Digital Limited (ODL) is an independent company that was spun out of Sony's Oxford Pro-Audio Lab in June 2006. Sony has no retained interest in ODL.
- ODL's core strength is in its engineering team of highly experienced audio design engineers with a diverse skills set that provides end-to-end project coverage
- ODL's core businesses:
  - Technology Licensing:
    - Tiny DSP Core and Toolset – an end-to-end audio DSP solution
    - Oxford Digital EQ – for real-time arbitrary frequency response creation
    - *MajEq* Auto-Tuning System
  - Contract Research and Development
    - Problem solving and development of new Intellectual Property for clients
    - Accelerating Time to Market
    - Provision of specialist skills
    - Integration/customisation of TinyCore and Oxford Digital EQ for client applications

1.2 The ODL Team

Team skills include:

- Processor architecture development
- Firmware and HDL for FPGAs and ASICs
- Maths and signal processing algorithm development
- DSP effects and algorithms
- System Architecture/System Level design
- Hardware design
- All types of software (including real-time embedded)
- Core Research and Development
- Collaboration with our clients and their customers (where required)

These broad skills allow us to handle, as required, all parts of a project from concept through to customer support for our clients

1.3 Customer Base

Customers who have kindly released us from our NDA for the client list include:

(USA) [Denon, Marantz, …]	www.dm-holdings.com
(Germany / UK)	www.dialog-semiconductor.com
(UK)	www.sadie.com
Sony Ericsson Mobile Company (Japan)	www.sonyericsson.co.jp
Sony Semiconductor (Japan)	www.sony.net
(USA)	www.srslabs.com
(USA)	www.ti.com/audio
(UK)	www.warwickaudiotech.com
(Japan)	www.yamaha.com

2 Oxford Digital EQ

2.1 Concept

The Oxford Digital EQ is targeted at medium to high end pro-audio and commercial systems where:

- There is a medium to high EQ DSP budget available
- The operator is skilled and expects to be in control of operations

It provides comprehensive EQ facilities including two new EQs:

- ***SmoothEQ***
  A new EQ that allows arbitrary specification of frequency response from either GUI or

automatic input of frequency and gain at arbitrary points (e.g. processed input from acoustic measurement system)

- ***New Graphic EQ***
  based on a constrained set of ***SmoothEQ*** frequency points

2.2 Application Areas and Unique Selling Points (USPs)

Include:

- Live Sound / Touring Sound / Installed Sound Venue Correction
- Room Correction (e.g. Home Theatre & AV Systems)
- Music Production (New creative possibilities through GUI and combination of different effects)
- Aspects of the ***Oxford Digital EQ*** are covered by UK Patent Application Publication No: GB 2 458 631 A and International Patent Application Publication No: WO2009/112825

There are several techniques already in use for correction of response curves by arbitrarily specified filters which mostly fall into:

- Use of 2nd order Bell/Parametric EQs
  This is a long, tedious and skilled process as each time a new EQ is added it also has interaction with all other EQs. In addition, most required correction is not symmetrical in shape (unlike Bell EQs) making exact matches difficult to achieve

- Use of FIR Filters
  The response of the equipment, room or venue can be captured by measurement system, then inverted to produce the required corrective response and finally turned into an FIR filter by convolution. Unfortunately this has two weak points:

  o As low frequencies are usually involved, the FIR filter has many taps and the delay through the filter is such that it makes it unusable in many “live” applications where sound latency is an issue

  o There will be a need to adjust the response due to errors and artefacts in the measurement system. It is not possible to make fine adjustments to this type of EQ (which may have 1000s of parameters), so a second layer of EQ and processing needs to be added for correction of these errors

The **SmoothEQ** does not suffer from any of these problems – see below.

2.3 SmoothEQ

Features:

- Minimum phase IIR filters for low delay latency (required in live sound and other areas)
- Dynamically Controllable in Real Time
- No nasty noises when changing response
- Ability to produce better quality results and much faster than conventional EQ methods for arbitrarily specified responses
- Use of less DSP resource than conventional EQ methods for arbitrarily specified responses
- Ability to easily trim results for fine adjustment without adding a new layer of EQ

2.4 Oxford Digital EQ V2.0

Oxford Digital EQ V2.0 includes:

- ***SmoothEQ***
- A New Graphic EQ which operates without interaction of bands
- High and Low-Pass filters with continuously variable slope
- Baxandall style Tone Control
- High and Low Shelving filters which have continuously adjustable in-band frequency response ‘over’ control.
- Classic ‘bell’ or ‘presence’ filters with continuously variable gain, frequency and Q

Demonstration versions of Oxford Digital EQ V2.0 are available for download (under NDA).

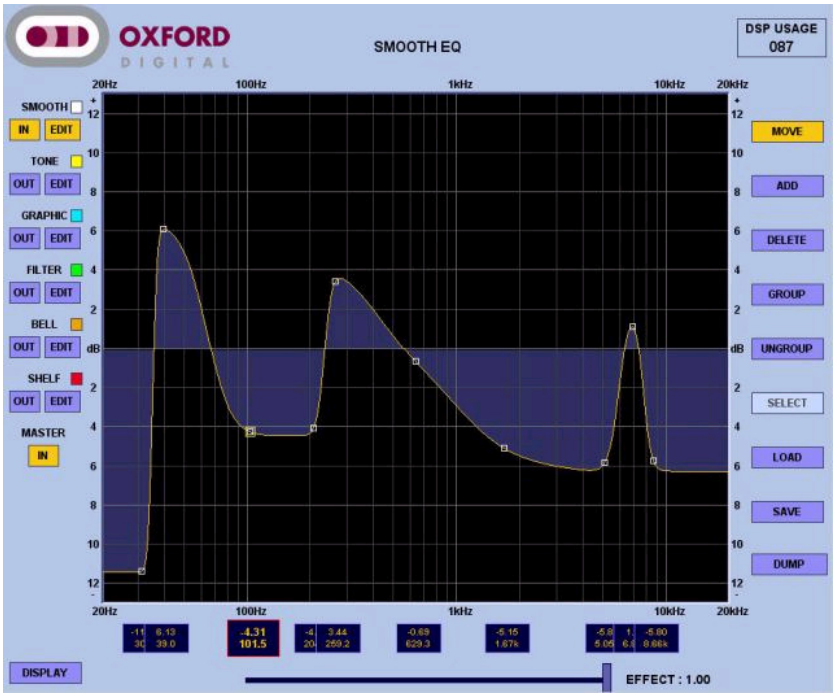

Fig. 1 Example of response of the ***SmoothEQ*** (Yellow line shows actual response)

Fig. 2 Example of response of the New Graphic EQ (Yellow line shows actual response)

3 MajEq Auto-Tuning Tool

3.1 Concept

The MajEq system is targeted at low and medium end pro-audio and commercial systems where:

- There is a low to medium EQ DSP budget available
- The operator is unskilled and expects to largely rely on automated set up – however, manual fine adjustment is available if required

The MajEq system incorporates the following:

- Measurement system to capture the frequency response of CE devices including speakers and headphones
- Alternatively, measurements can be imported from external systems (e.g. SMAART, SysTune)
- Means to produce a correcting “target” EQ curve
- Means to select the useful band where correction should be applied (so as not to over-drive speakers outside their useful range thus avoiding nasty noises and damage)
- Means to define a fixed DSP budget (e.g. 5 bi-quads)
- More efficient use of the DSP budget than conventional parametric EQs – up to 40% fewer poles
- Means to automatically produce the correcting EQ curve with guaranteed convergence within a few seconds
- Means to “edit” the correcting response via familiar EQ controls (filters, parametric EQs) if it is desired to over-ride the measurement system – all within the same defined DSP budget
- Means to layer additional EQ (e.g. Classical, Pop, Jazz, Rock curves &/or regional sounds) – all within the same defined DSP budget

A typical result produced by the MajEq system is shown below in Fig. 3:

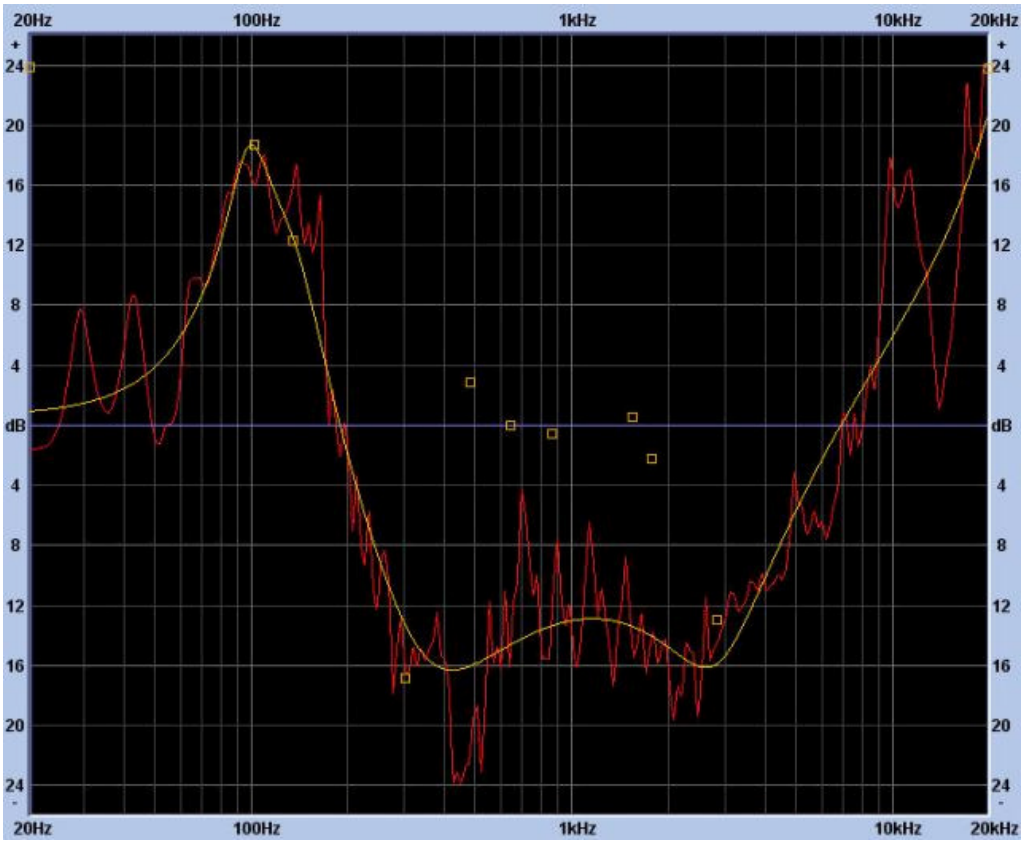

Fig. 3 *Using the MajEq system*: Use of 5 bi-quads produces this curve within a few seconds

It can be used with any bank of standard bi-quad sections.

3.2 Unique Selling Points

The USPs associated with the Oxford Digital *MajEq* system and tuning methodology are:

- The Measurement System is included
- Measurements can also be taken by external systems (e.g. SMAART, SysTune) and imported into the system
- A fixed DSP budget for equalisation and aesthetic tonal correction can be defined (i.e. the number of bi-quads available)
- It makes extremely efficient use of the limited equalisation DSP in the device – up to 40% more efficient in terms of DSP than a conventional parametric EQ
- Ability to modify frequency response via familiar controls (like filters, tone controls & parametric EQs) with **no extra** DSP
- Ability to layer additional EQ (Rock, Classical, Pop, Jazz, regional sound preferences) with **no extra** DSP
- Fast workflow (hours or even days using conventional parametric EQs for response equalisation can be reduced to minutes)
- It allows deskilling of the task as relatively unskilled people can produce good results
- It's a low latency, low processing budget solution
- Aspects of the *MajEq* system are covered by UK Patent Application No: 0922702.6 .

4 Marketing Activities

4.1 Technical Papers

Oxford Digital has presented technical papers at several conferences worldwide (see Appendix A).

4.2 Conventions and Exhibitions

Oxford Digital has sponsored and exhibited at many conferences and exhibitions alongside other leading brands – see selection below.

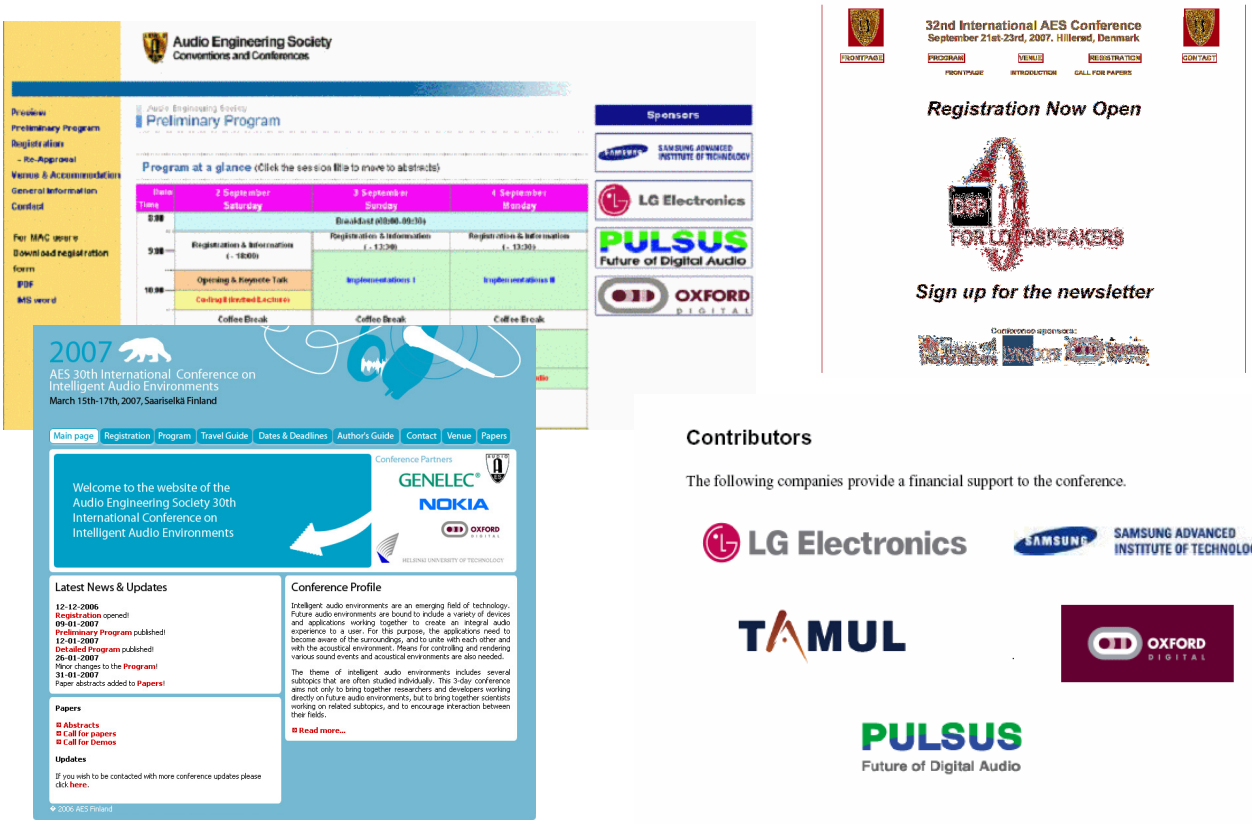

Fig. 6 *Examples of Trade Shows, Exhibitions and Conference Sponsorship*

5 Contact Information

We are happy to discuss any of the issues above (or indeed any other audio-related issues) in more depth. Please contact:

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APPENDIX A

Selected Oxford Digital Technical Papers

1. P. Eastty, “Digital Audio Processing on a Tiny Scale: Hardware and Software for Personal Devices”, Paper Number 7207, AES 123rd Convention, New York, October 2007.

2. N. Bentall, P. Eastty and D. Stott, “An Efficient, Low-Noise Filter Architecture for Bass Processing on a DSP Core”. Paper Number 7351, AES 124th Convention, Amsterdam, May 2008.

3. N. Bentall, P. Eastty and D. Stott, “Tiny DSP: DSP Core, Algorithm Development and 'Device Mastering’”. Paper Number 6 AES 34th International Conference: New Trends in Audio for Mobile and Handheld Devices, Jeju Island, South Korea, August 2008.

4. P. Eastty, “Accurate IIR Equalisation to an Arbitrary Frequency Response, with Low Delay and Low Noise Real-Time Adjustment”, Paper 7639, AES 125th Convention, San Francisco, October 2008.

5. UK Patent Application Publication No: GB 2 458 631 A, “Improving audio equalisation and filtering to address problems of disruptive phase response in graphic equalizers”.

6. International Patent Application Publication No: WO2009/112825, “Improving audio equalisation and filtering to address problems of disruptive phase response in graphic equalizers”.

7. UK Patent Application No: 0922702.6, “Determining a configuration for an audio processing operation”.