Digital Audio Measurements Through Efficient FPGA Based Test Techniques

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Presentation Outline

- Challenges in manufacturing testing of audio products
- A solution to simplify digital audio testing
- Analog and digital audio testing
- The elements of AudioMASTER
Challenges in Manufacturing Test of Audio Products

General needs for:

• Higher productivity in test application development
• Short ramp-up times in Mfr. tests (e.g. contract manufacturers)
• Support for advanced testing, and allow less experienced personnel to develop and support even complex Mfr. tests
• High throughput in test
• Flexibility and modularity
• Reduced cost-of-ownership of test solutions
• Ensure easy deployment and ramp-up at a different location
Solution

• Move to higher levels of abstraction of working to speed up test development
  ▪ E.g. use versatile test sequencer & Custom StepTypes
• At the same time reduce the per-company maintenance of test solutions
• Have tools that allow less experienced users to handle even complex test requirements in a fairly easy-to-use manner
• Ensure a common, modular environment for analog and digital audio testing
Approach

• No need for lengthy code development and debugging
• Just select parameters and deploy application
• Lack of experience and domain specific knowledge can largely be overcome through assistance by intuitive, easy-to-use user interfaces
Audio Test Elements

- The solution meets the objectives by using off-the-shelf elements.
- Ensures upgrade compatibility and ease of maintenance.
- A solution for also the years to come.
Test Sequencer

- Ensures reuse of code
  - One Custom StepType can be reused many times
- Speeds up test developments
- Offers fast test execution
- Eases maintenance
- Versatile support environment
Application: Digital Audio

• Digital Audio Analysis
  ▪ DVD Players, Set-top Boxes, Game Consoles, Home Theater Systems (Surround Sound Systems)…
Digital Audio: SPDIF - AES/EBU Signal

• Serial digital signal with embedded sample clock
  ▪ Coaxial (RCA / BNC)
    0.5 Volt sourced
    & loaded with 75 Ohm
  ▪ Optical (TosLink)
  ▪ Balanced (XLR)
    Professional
    Typically 5 Volt, 110 Ohm
S/PDIF Coding Format

- Biphase Mark Code
  - Robust, DC-free
  - Pulse width down to 40 ns (@192 kS/s) $\leftrightarrow$ 25 Mbit / s
  - Avoid long series of logical ones or zeros without any transitions which otherwise makes clock recovery and synchronization difficult
Digital Audio Test Solution

- FPGA based front-end for fast, parallel bit manipulation (R-Series card from NI).
- Flexibility (LabVIEW FPGA implementation)
- Signal Conditioning interface (focused hardware)
- Audio Decoding features (Dolby Digital, etc.)
- Support from existing general purpose Audio Analysis features.
- Be flexible enough to allow for support of e.g.:
  - 5.1 Digital Audio: S/PDIF (PCM, Dolby Digital, etc.)
  - 7.1 Digital Audio: S/PDIF, I²S (PCM, DTS, Dolby +, etc.)
  - HDMI audio
Why Choose an R-Series Platform

• Perfect match of performance and price
• FPGA ideal for signal pre-processing and decoding
  - Bit manipulation, advanced triggers, monitoring…

• Multiple targets available
  - Up to four identical connectors using NI-7813R
  - Multi-channel test systems
  - Mixed-signal systems using NI-7833R ?
  - Future RIO targets ?
AudioMASTER S/PDIF

**New Solution** for S/PDIF digital audio:

- Uses NI-7813 FPGA module as basis (or other NI-78xxR)
- First module handles 2-inputs per front-end for digital audio analysis.
- Each NI-7813R can support up to 4 input modules, i.e. supports up to 8 inputs.
FlexSPDIF Digital

- Signal acquisition at:
  - 44.1 kHz, 48 kHz, 88.2 kHz, 96 kHz up to 24 bits.
- 2 inputs per FlexSPDIF:
  - SPDIF (BNC electrical)
  - Toslink (optical)
- Up to 4 FlexSPDIF per NI-7813R module:
  - Capture of up to 8 channels
Complete Approach to Automated Test

- The Digital Audio test solution handles analysis as well as generation, here is shown the analysis path.
Protection of IP / Encryption

- Digital Audio >16 bits and/or 48 kHz must be encrypted in many situations
Separate Input and Output Sessions

Sharing the same FPGA Session!
S/PDIF Front Ends

- **S/PDIF Receiver (FPGA program)**
  - Supported Hardware: NI PCI/PXI - 7813/7833-R boards (so 4 different targets)
  - Very fast lock-time (typically one frame)
  - Supported frame rates: 32k, 44.1 k, 48k, 88.2k, 96k and 192k
  - PCM mode 16, 20 and 24 bit real time and continuous DMA transfer to host
  - RAW (compressed data) re-packed and transferred to host
  - Auto detect of sample rate and data format (PCM, AC3, MPEGxx, etc..)
S/PDIF Front Ends

- Auto management of Status Bits (C-bits) and parity check (P-bit)
- Built-in simple S/PDIF test generator (FPGA sine/cosine left/right signal or DMA data from host) for program self-test and validation
FlexSPDIF Digital

- E.g. linear PCM up to 24 bits at:
  - 22.05 kHz
  - 24 kHz
  - 32 kHz
  - 44.1 kHz
  - 48 kHz
  - 88.2 kHz
  - 96 kHz
  - 176.4 kHz
  - 192 kHz
FlexSPDIF Digital

Supported hardware:
- PXI/PCI-7811R FPGA module as basis.
- PXI/PCI-7830R FPGA module
- PXI/PCI-7831R FPGA module

<table>
<thead>
<tr>
<th>Encoding</th>
<th>Sample Rate</th>
<th>Bit-Depth</th>
<th>Channel Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear PCM</td>
<td>44,100 Hz</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Linear PCM</td>
<td>48,000 Hz</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Linear PCM</td>
<td>96,000 Hz</td>
<td>24</td>
<td>2</td>
</tr>
<tr>
<td>RAW Dolby Digital® (AC3)</td>
<td>48,000 Hz</td>
<td>16</td>
<td>6 (5.1)</td>
</tr>
<tr>
<td>RAW-DTS</td>
<td>48,000 Hz</td>
<td>16</td>
<td>6 (5.1)</td>
</tr>
</tbody>
</table>
FlexAUDIO Digital

- Generator - 1 output
  - S/PDIF (BNC)
  - TosLink (optical)
  - AES3 (XLR)
- Analyzer - 1 input
  - S/PDIF (BNC)
  - TosLink (optical)
  - AES3 (XLR)
- Up to 192 kSa/s
FlexAUDIO Digital

- Generator - 1 output
  - S/PDIF (BNC)
  - TosLink (optical)
  - EBU/AES3 (XLR)

- Analyzer - 1 input
  - S/PDIF (BNC)
  - TosLink (optical)
  - EBU/AES3 (XLR)
Dilemma with Sound Card Solution

• Sound Cards are not made for audio measurements.
• Sound Cards offer no true quality metrics:
  ▪ Differs from brand to brand and model to model
  ▪ Change frequently
• MS-Windows and its (changing) features hide some HW functionality.
• What happens at the next automatic update of Windows?
• Sound Cards shows microphonic behaviour.
Advantages over Sound-Card Solution

• High-level LabVIEW driver, no Microsoft sound card driver dependencies

• High performances triggering and synchronization
  ▪ PXI/RTSI and PFI trigger lines, external Clock Reference for generation...

• Low-level access to Status and Validity bits
Advantages over Sound-Card Solution

• Bit-true data transfer
  ▪ No un-controlled gain adjustments or interpolation / mute operations

• Other measurements like actual physical frame rate

• Offers trigger and synchronization for signals

• Provides a consistent, transparent and well defined sets of quality metrics for audio measurements
AudioMASTER – Mixed Signal 1

Measurement of Sound Card Digital to Analog Audio Conversion
AudioMASTER – Mixed Signal 2

Measurement of Sound Card Analog to Digital Audio Conversion
Mixed-Signal Audio Test

- Mixed-Signal systems can be tested using the common PXI triggering features
Mixed-Signal Audio Test

- Mixed-Signal systems can be tested using the common PXI triggering features.
One Solution - Two Domains

- Test of **Analog Audio** (NI-446x):
  - Headsets
  - Hearing aids
  - Loudspeakers
  - Microphones
  - Consumer electronics
  - Rub & Buzz
  - Etc.

- Test of **Digital Audio** (NI-78xx):
  - S/PDIF for test PCM, AC3 (Dolby Digital®), DTS
  - I²S for e.g. HDMI
  - Digital microphones
  - Headsets
  - Etc.
AudioMASTER Provides High Level of Abstraction for the Development of Audio Test

- Efficiency in app development
- Ease-of-use

Configuration based Application Development
Test Sequencer Supported Test

1. Analog Multi-tone

2. Analog Amplitude Sweep

3. Digital S/PDIF

- Using high-level Custom StepTypes in conjunction with a test sequencer like TestStand™ greatly simplifies audio testing.

- The Custom StepType can be a high-level tool solution (point & click rather than coding)
Measurement Configurations

- Channel Configuration
  - Range, Differential/Single-Ended, AC/DC, Signals, etc.
- Trigger
  - Internal, External, Analog, etc.
- Generator
  - Start/Stop Freq., Lin, Log, Table Values, Amplitude, etc.
- Analyzer
  - Start/Stop Freq., Lin, Log, Pre/Post-Delay, Segment Time, etc.
- Results
  - Results to be included in the analysis
Types of Excitation/Stimulus Signals

- Single Tone

(simplest source)
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  (simplest source)
- Amplitude Sweep  
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- Coherent Sweep & Chirp  (continuous frequency sweep)
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- Multiple Pure Tones, or Stepped Frequency (discrete frequency excitation)
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- Multi-tone (two or more simultaneously generated sinusoidal signals)

![Graph of signal types](image_url)
Types of Excitation/Stimulus Signals

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- **Step Response** (step between high and low amplitude at same frequency)
Types of Excitation/Stimulus Signals

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- Multi-tone (two or more simultaneously generated sinusoidal signals)
- Step Response (step between high and low amplitude at same frequency)
- White Noise (equal energy at all frequencies)
Common Audio Measurements

- Frequency response
  - Discrete tone excitation (swept sine)
  - Broadband excitation
- Distortion
  - Total Harmonic Distortion (THD, THD +N)
  - Signal In Noise And Distortion (SINAD)
  - Signal to Noise (S/N) ratio
  - Intermodulation Distortion (IMD)

![Graph showing harmonic distortion and noise](image-url)
Multi-Tone Testing

- Multi-tones offer significant advantage in terms of speed in test execution.
- Building a Multi-tone signal is straightforward given good tools.
Multi-Tone Generation

• Tones are easily generated from a table:
  ▪ Frequency
  ▪ Amplitude
  ▪ Phase
Calibration Tool and Manager

✓ Calibrate against non-linear environments
  • Anechoic test chambers,
  • Artificial mouths,
  • Microphones,
  • Other test system interfaces

✓ Enforce Calibration intervals
LimitTest Support

- Supports
  - Point Limits
  - Tunnel Limits
  - Window Limits
Limiter Functions

• Limiter types:
  - Point
  - Tunnel
  - Window

• Limiters can float in “x” and “y” direction or both.

• Limiter units depend on the actual test.

• Limiters can be combined.
Limiter Dilemma

- Using only fixed limiters, problems may be hidden, e.g. oscillation.
- Floating limiters feature tight test tolerances.
- A limiter may for example float +/- 5 dB but have a test tolerance of +/- ½ dB.
To Learn More

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