Fundamentals of audio test

- audio test fundamentals
- measuring modern audio
- how to avoid the most common mistakes in audio test

The recognized standard in audio test

Since 1985 AP has provided audio test and measurement instruments to R&D and production lines for every type of audio device.

AP is the number one maker of audio analyzers in the world.

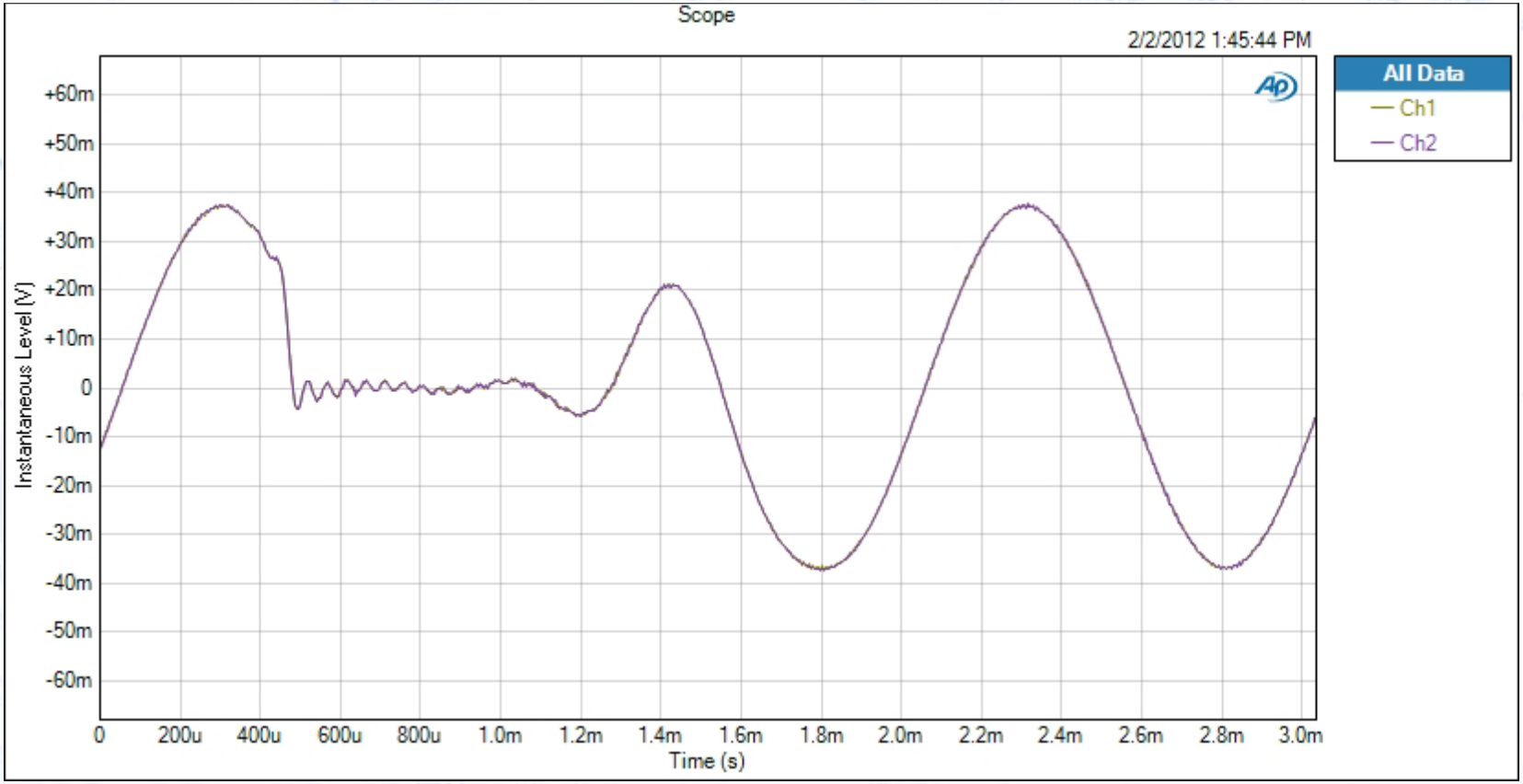
Who uses AP?

☑ **Audio Precision analyzers are used by makers of all types of audio technology**

- ⇨ Pro audio
- ⇨ A/V receivers
- ⇨ Smartphones
- ⇨ Semiconductors
- ⇨ Loudspeakers
- ⇨ Microphones
- ⇨ Automotive head units
- ⇨ Blu-ray players
- ⇨ MP3 players
- ⇨ Bluetooth headsets
- ⇨ Tablets and PCs
- ⇨ Hearing aids
- ⇨ Telecom
- ⇨ Military

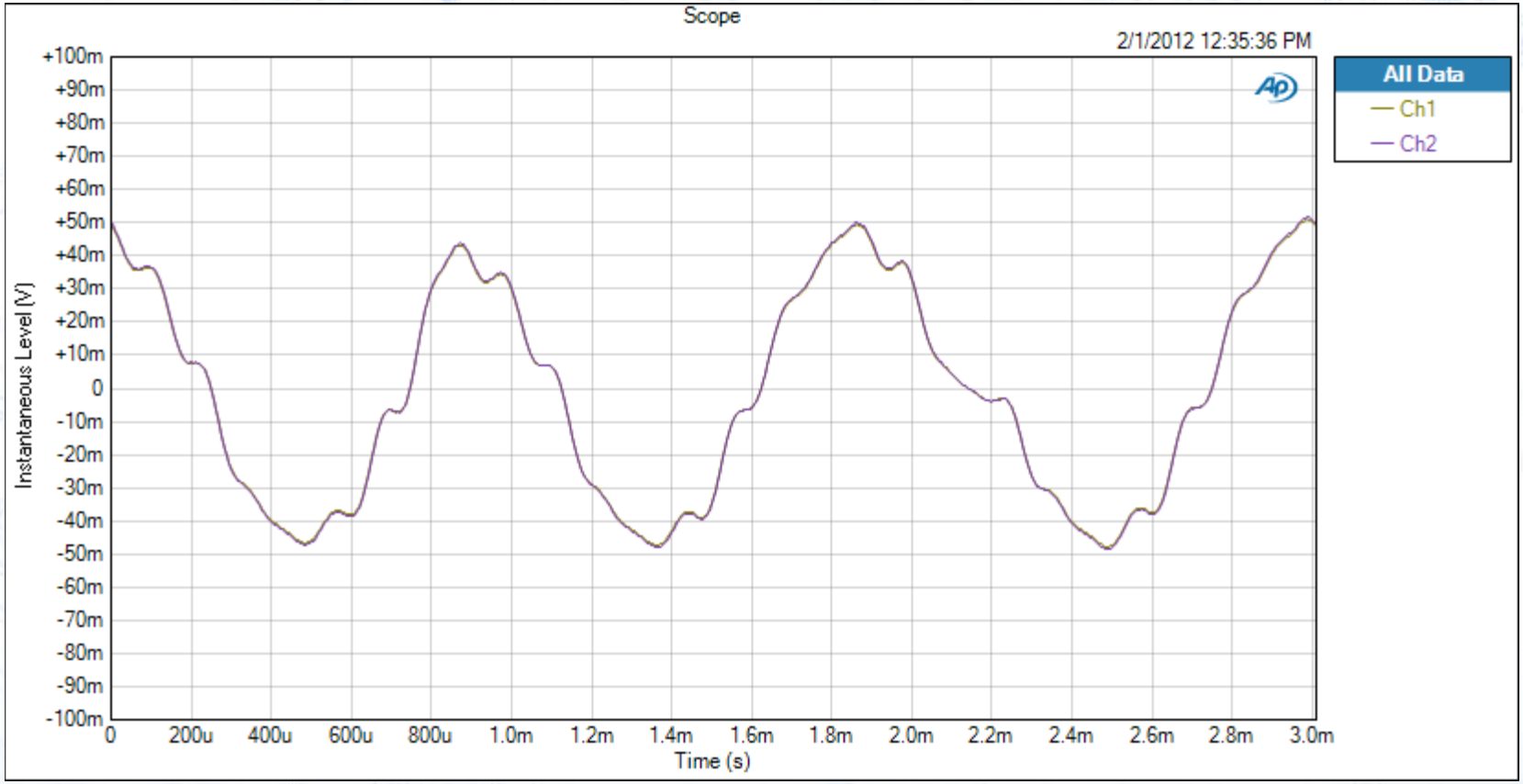
Why: Improve quality

- ☑ **Good test allows higher quality, which sells better than lower quality**



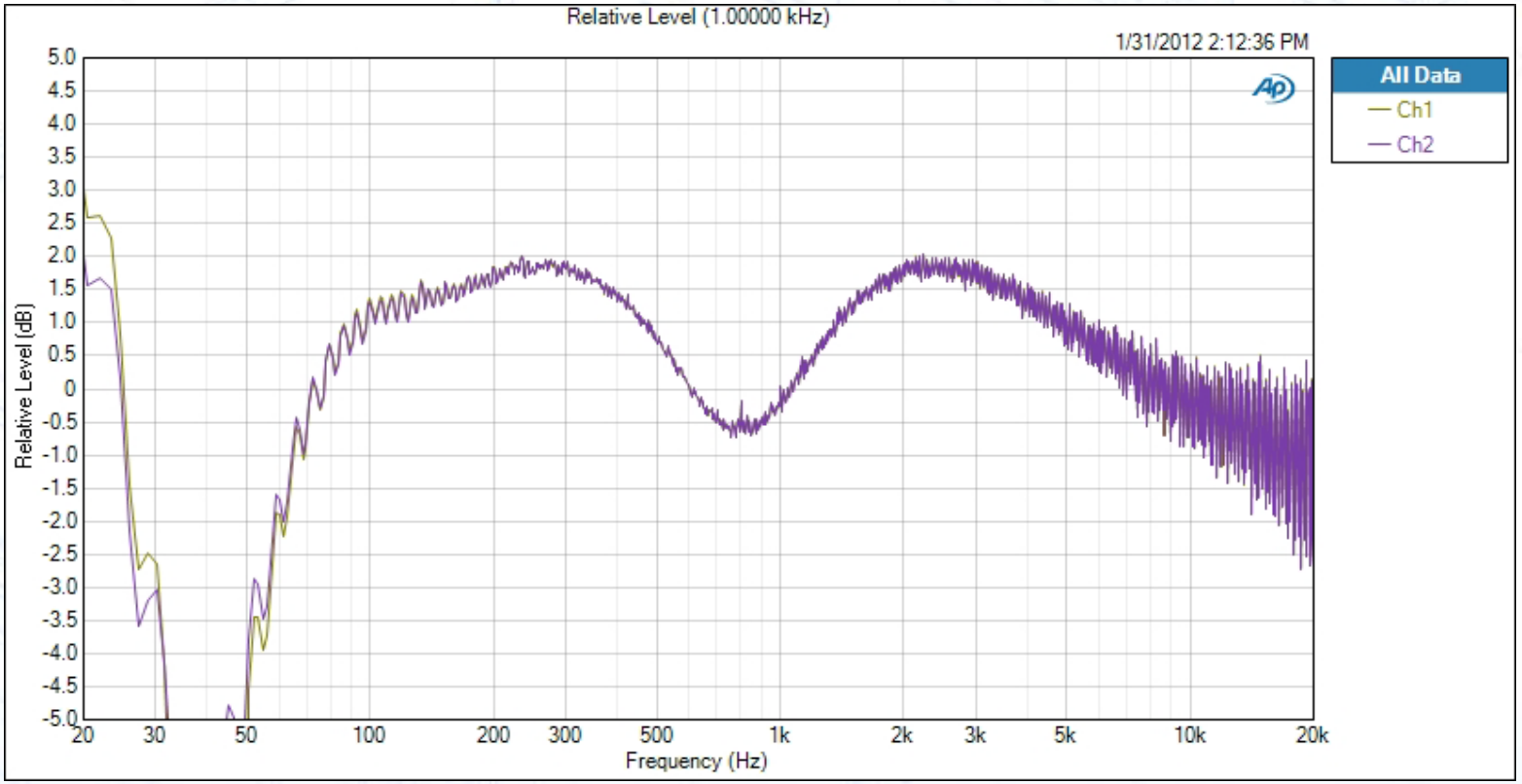
Why: Reduce cost

- ☑ **Reduce costs from re-designs, recalls and returns by catching mistakes before they become expensive**



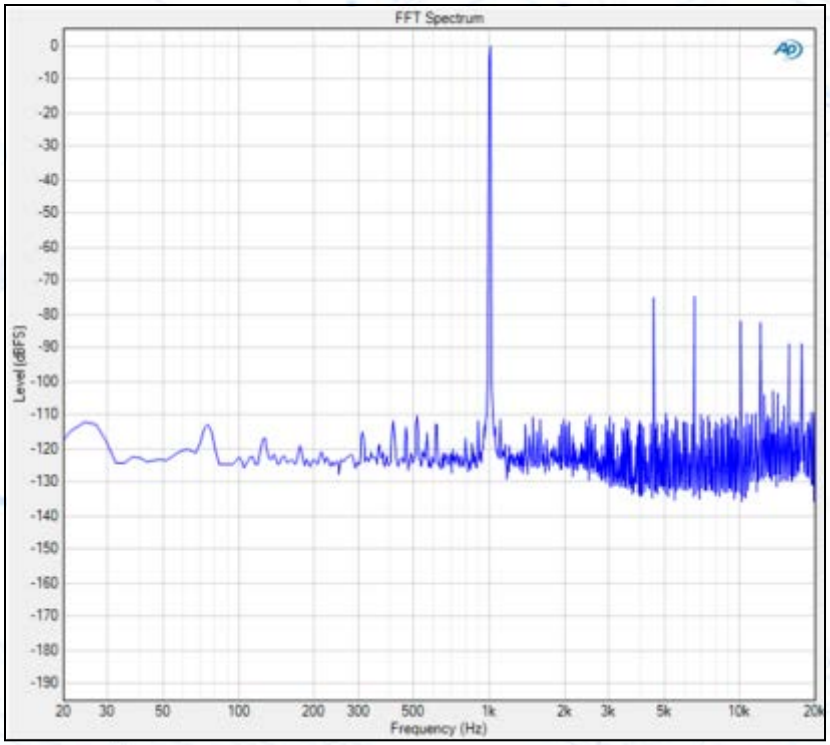
Why: Save time

- ☑ **Verify new designs for speed to market and make sure faults are found quickly to keep production running smoothly**

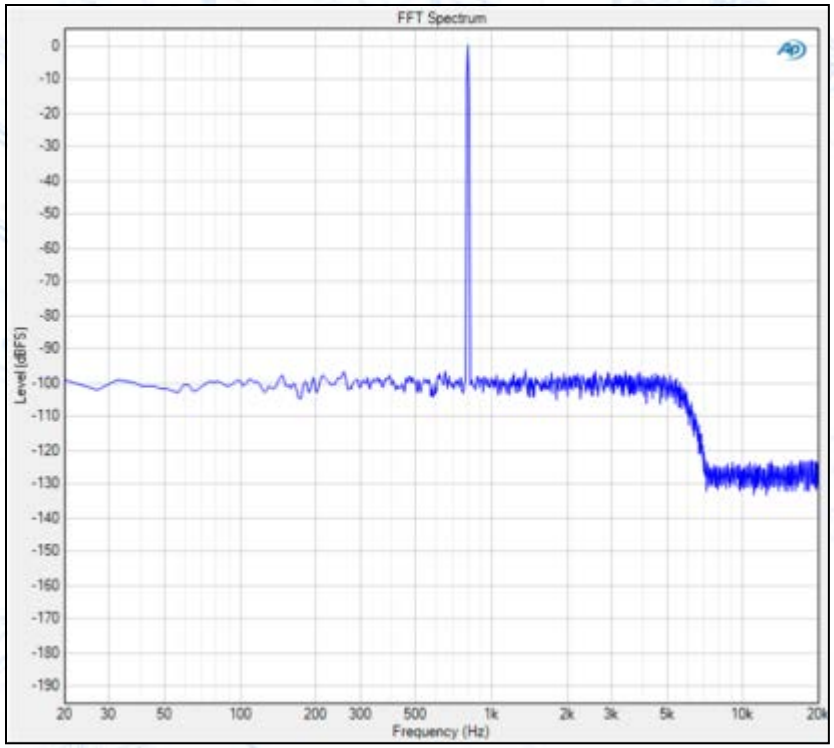


Why: Trust & reliability

- ☑ **Evaluate components you're considering for your product and test work done by subcontractors**



Bluetooth CVSD codec -71 dB THD+N



Bluetooth aptX codec - 70 dB THD+N

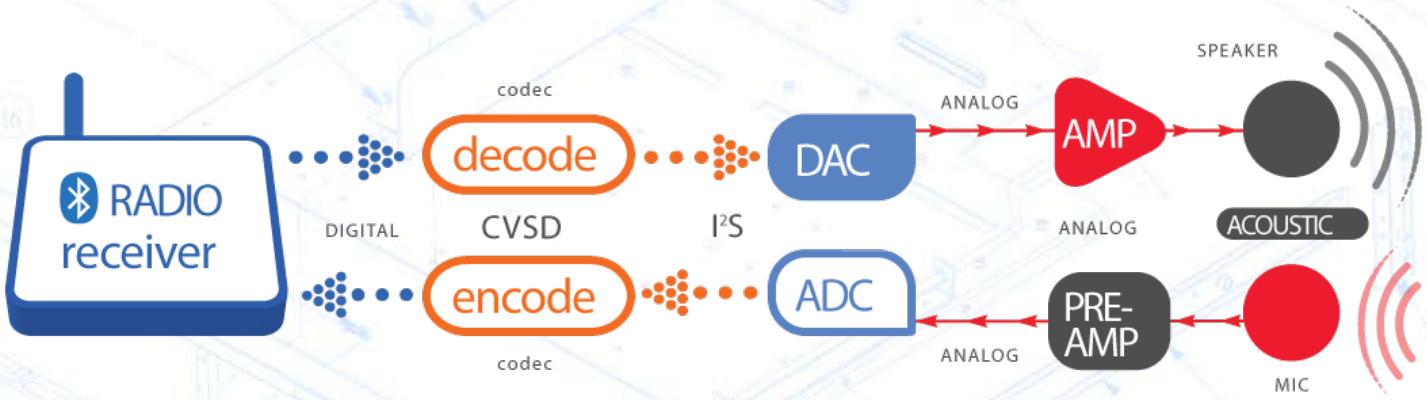
Audio is different

- ☑ **Extremely wide dynamic range of signals**
  - ⇨ Electronic analog of our range of hearing can range from 0 dBspl to >130 dBspl
  - ⇨ 80 dB - to over 100 dB range is common
  - ⇨ Levels from microVolts to hundreds of Volts
- ☑ **Wide frequency range**
  - ⇨ 20 Hz - 20 kHz common (1,000:1, 10 octaves),
  - ⇨ 10 Hz- 100 kHz (10,000:1, 13+ octaves)
  - ⇨ If this was radio this would be like 1 MHz to 1 GHz - from the AM radio band to microwave!

> For every +6dB, double the voltage... For every -6dB, half the voltage

It’s always analog somewhere

- ☑ Analog audio
- ☑ Digital audio
- ☑ Cross domain analog and digital
- ☑ “Third domain” digital interface and metadata



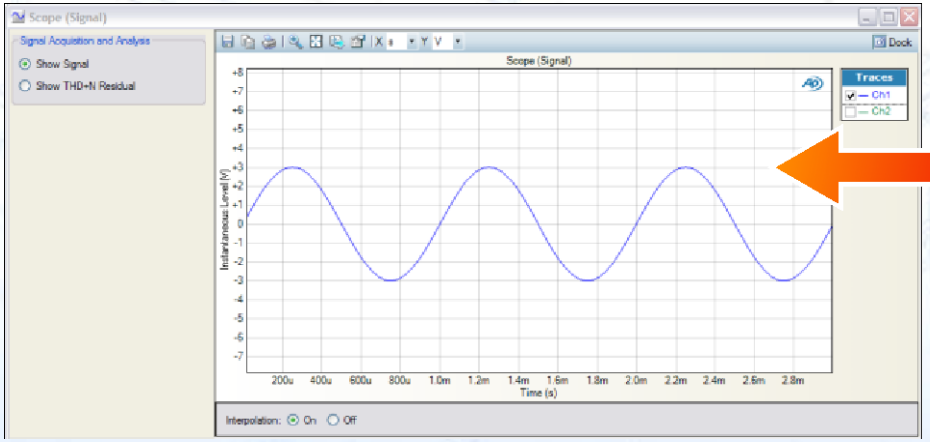
Common Measurements: The Big 6

① Level & Gain

- ⇨ Level: Amplitude of an audio signal, expressed in dB.
- ⇨ Gain: Relative level of output vs. input

$$\frac{\textbf{Output} \text{ level (Volts)}}{\textbf{Input} \text{ level (Volts)}} = \text{Gain (dB)}$$

dBV	Volts
+20	10.0
+18	7.94
+12	3.98
+6	1.99
0 dBV	**1 Volt**
-6	0.50
-12	0.25
-18	0.125
-20	0.1
-40	0.01
-60	0.001
-80	0.0001
-100	0.00001



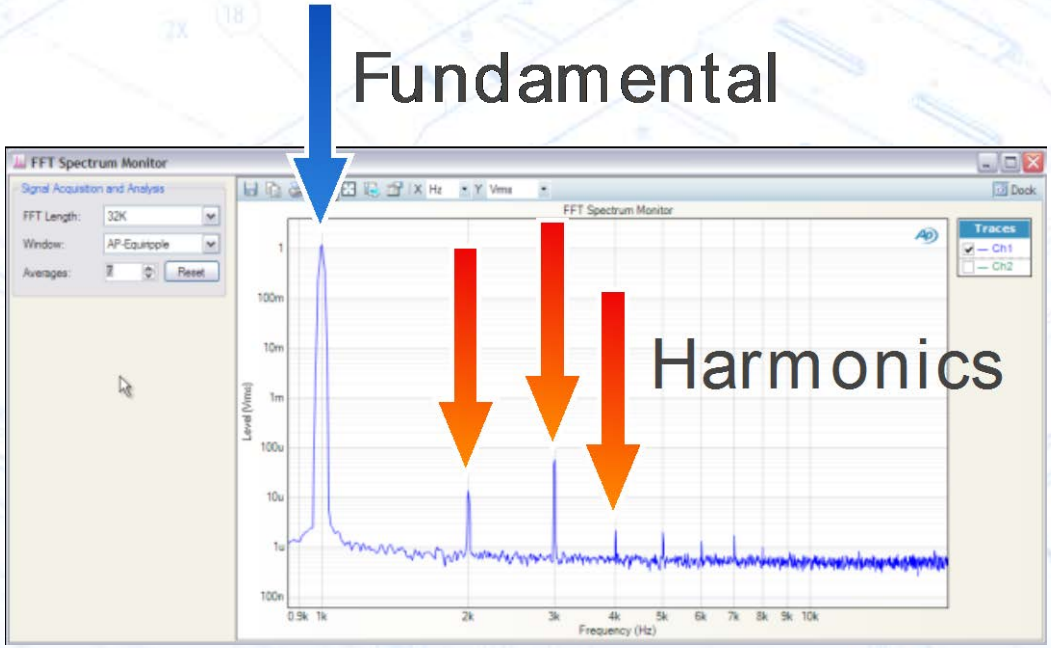
The greater the amplitude of the signal, the higher the level

Level: also known as amplitude

Common Measurements: The Big 6

② THD+N: Total Harmonic Distortion plus noise

- ⇨ Summation of all distortion and noise ÷ Total level
- ⇨ Usually a single frequency measurement
- ⇨ .0001 Vrms (noise+distortion) ÷ 1 Vrms (total level) = 0.01% or -80 dB at 1 kHz



Harmonics

Undesired extra energy at multiples of the fundamental

1kHz => 2 kHz... 3 kHz... 4 kHz... etc
4 kHz => 8 kHz... 12 kHz... 16 kHz... etc

Common Measurements: The Big 6

- ☑ **Frequency Response - "flatness"**
  - ⇨ Amplitude versus Frequency, usually a specification
  - ⇨ "Response ±2 dB 20-20kHz", sometimes a graph
- ☑ **Signal-to-Noise Ratio**
  - ⇨ in dB below a maximum or reference level
  - ⇨ "SNR = 96 dB A weighted"
- ☑ **Phase**
  - ⇨ Phase between the two channels - a graph or a spec. across a frequency band
  - ⇨ "± 2 Deg. 20 - 20kHz", sometimes a single number at high frequency (10kHz)
  - ⇨ Stereo "image" is directly affected by phase error
- ☑ **Crosstalk**
  - ⇨ A measurement at a single frequency or a graph of Amplitude versus Frequency.
  - ⇨ "Crosstalk <85 dB"

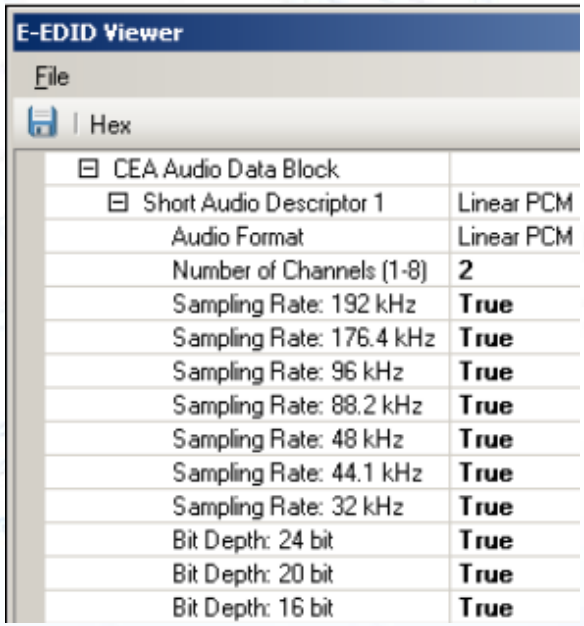
Many other Audio Measurements

- ☑ Maximum output
- ☑ Equalized frequency response
- ☑ Weighted Noise, Equivalent Input Noise
- ☑ Individual Harmonic amplitude - odd, even, 3rd etc.
- ☑ Inter Modulation Distortion - SMPTE, CCIF, DIM/TIM
- ☑ Input-Output Phase, Group Delay, Polarity inversion
- ☑ Gain Linearity
- ☑ Gain or Loss, Input & Output impedance
- ☑ Noise based measurements - pink, white, band-limited

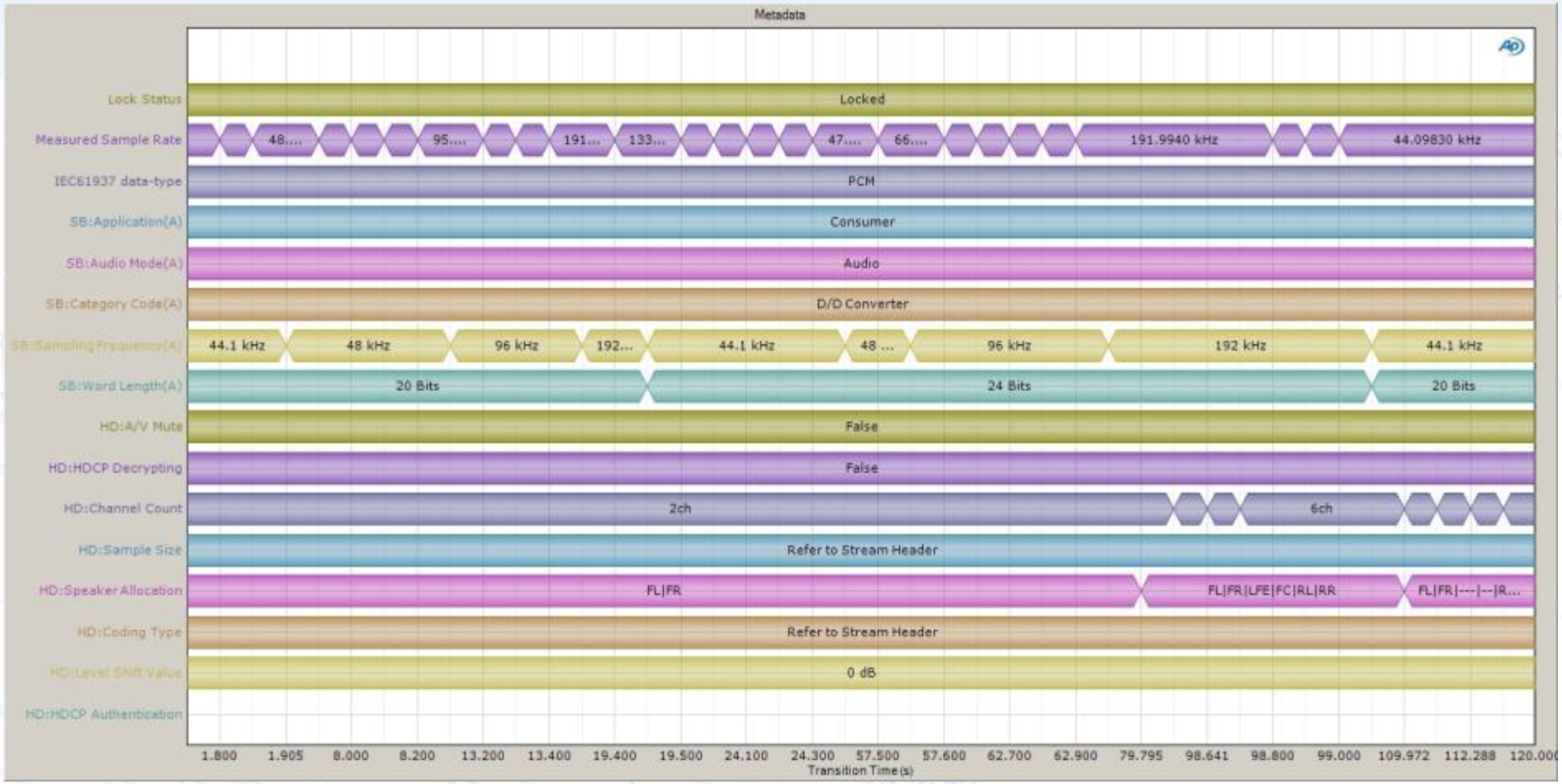
Digital Audio

- ☑ **ALL the analog measurement types but within the digital data stream:**
  - ⇨ Big Six and variations on these
- ☑ **The interface or transport itself**
- ☑ **More likely to be a problem with metadata**

Bit	If not set means:	If set means:
0	Consumer (S/PDIF)	Professional (AES3) (changes meaning of control word)
1	Normal	Compressed data
2	Copy restrict	Copy permit
3	2 channels	4 channels
4	—	—
5	No pre-emphasis	Pre-emphasis
6–7	Mode, defines subsequent bytes, always zero	
8–14	Audio source category (general, CD-DA, DVD, etc.)	
15	L-bit, original or copy (see text)	

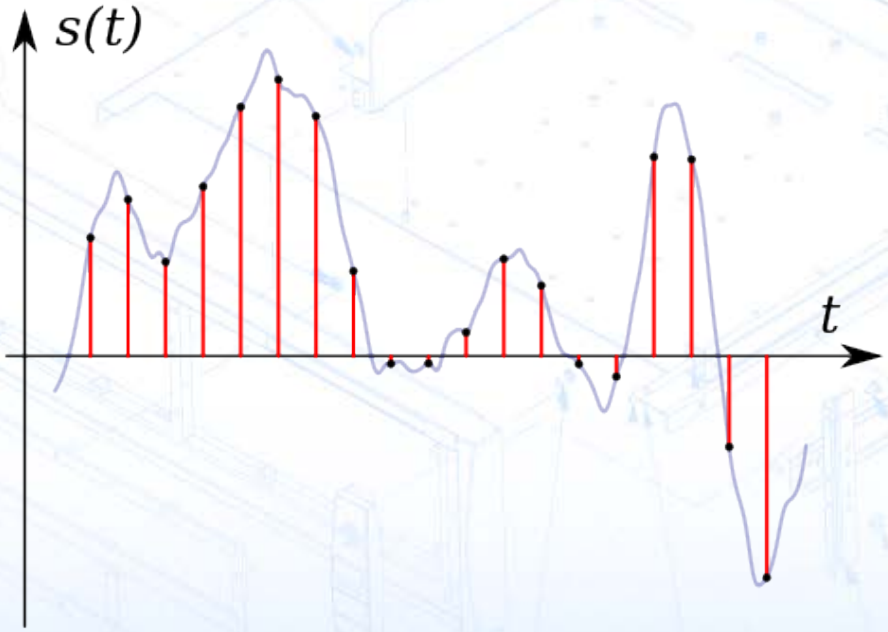


Digital metadata



Some basic digital concepts

- ☑ **Sample rate**
  - ⇨ How many times a second a digital sample is taken
- ☑ **Nyquist frequency:**
  - ⇨ ½ the sample rate equals maximum frequency that can be captured

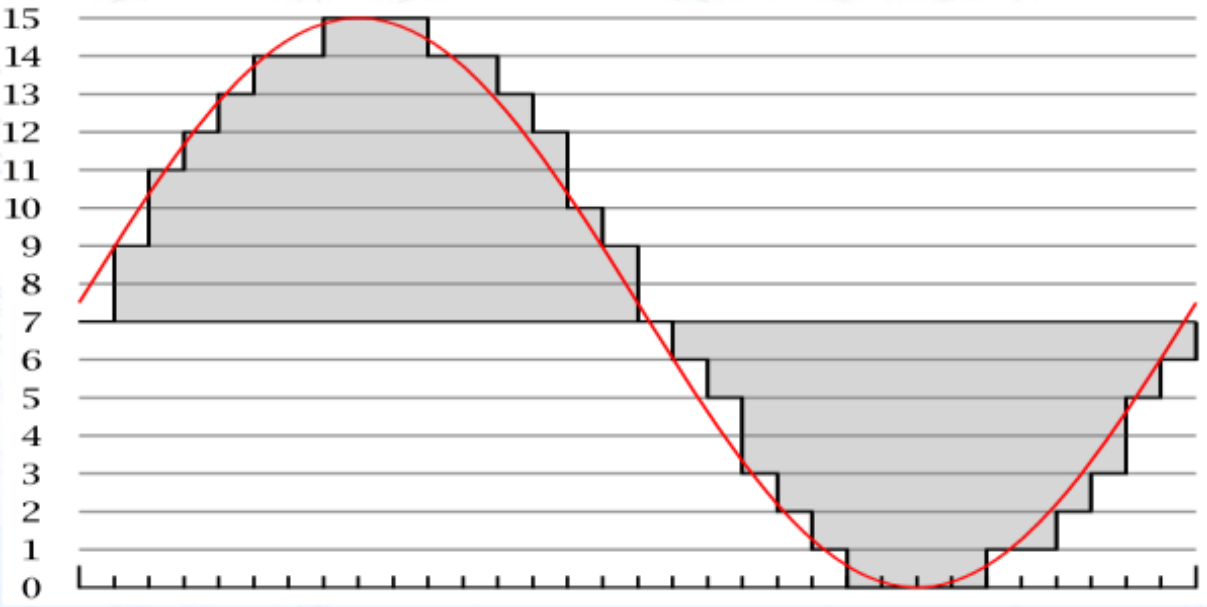


Common Sample rates	
8 kHz	Telecom
16 kHz	“Wideband”voice
44.1 kHz	Compact disc
48 kHz	Pro audio
96 kHz	Stereophile
192 kHz	HDMI

Some basic digital concepts

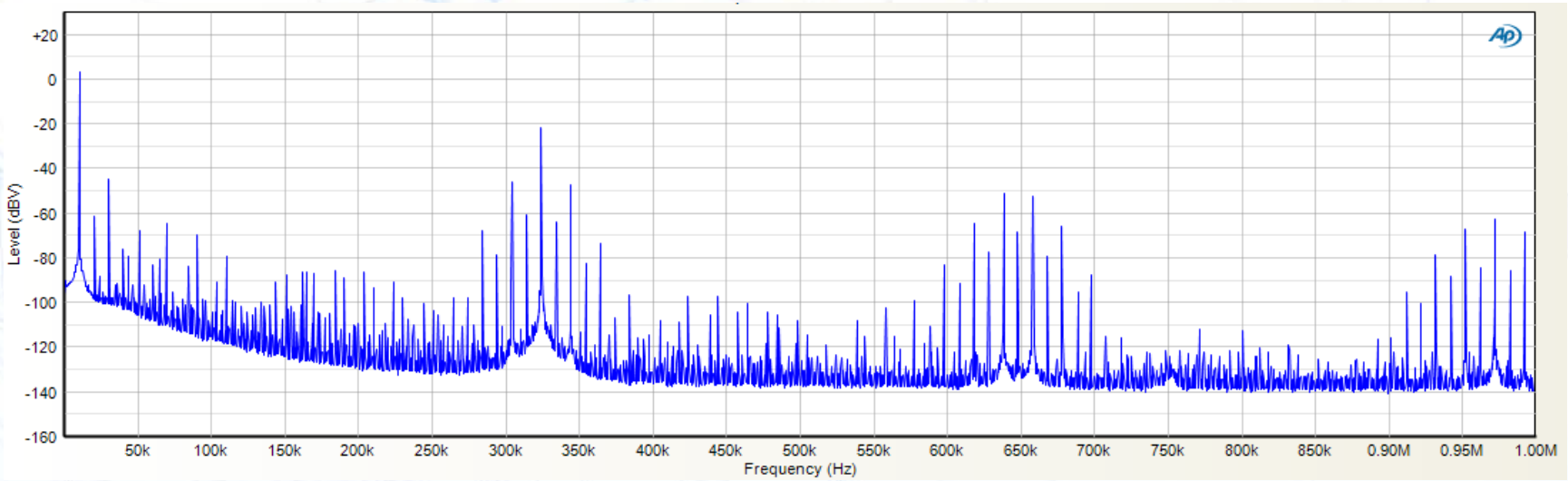
- ☑ **dBFS**
  - ⇨ Digital Full scale vs. Analog volts
- ☑ **Bit depth**
  - ⇨ How detailed “resolution” of each sample
  - ⇨ 8 bit = 2^8 = 256 levels
  - ⇨ 16 bit = 2^{16} = 65,536 levels
  - ⇨ 24 bit = 2^{24} = 16.7 million levels

Common Bit depths	
8 bit	Telecom / 48 dB
16 bit	CD quality / 96 dB
24 bit	Pro audio / 144 dB



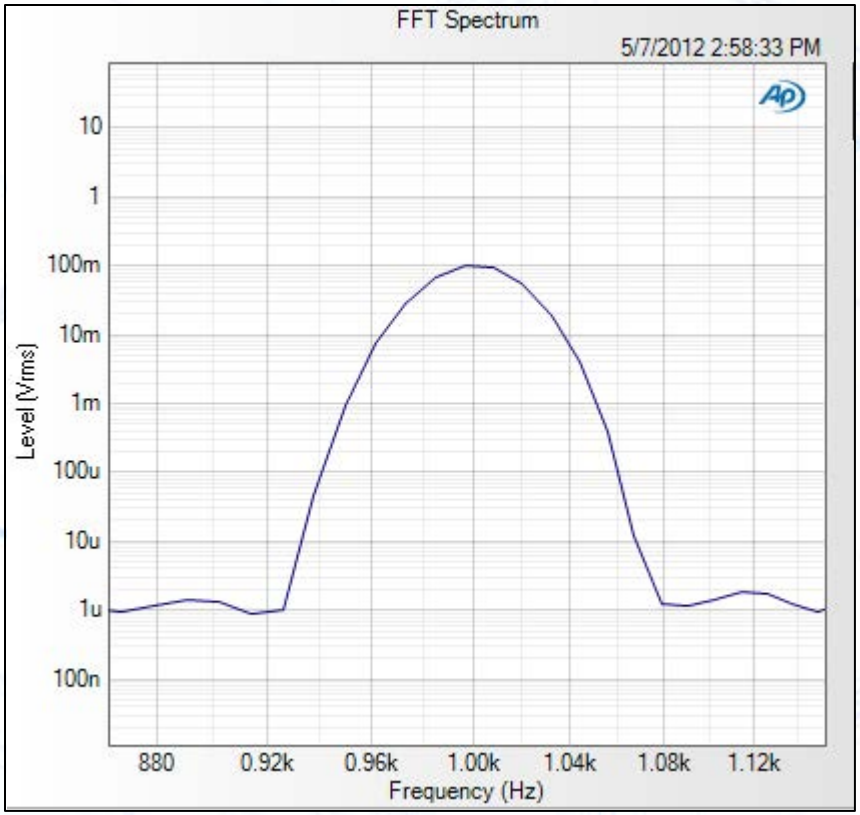
One more concept: FFTs

- **Fast Fourier Transform**
  - The basis of modern audio analyzers
  - View signals in frequency domain
  - Easy way to see distortion and noise
  - Can derive most other measurements mathematically

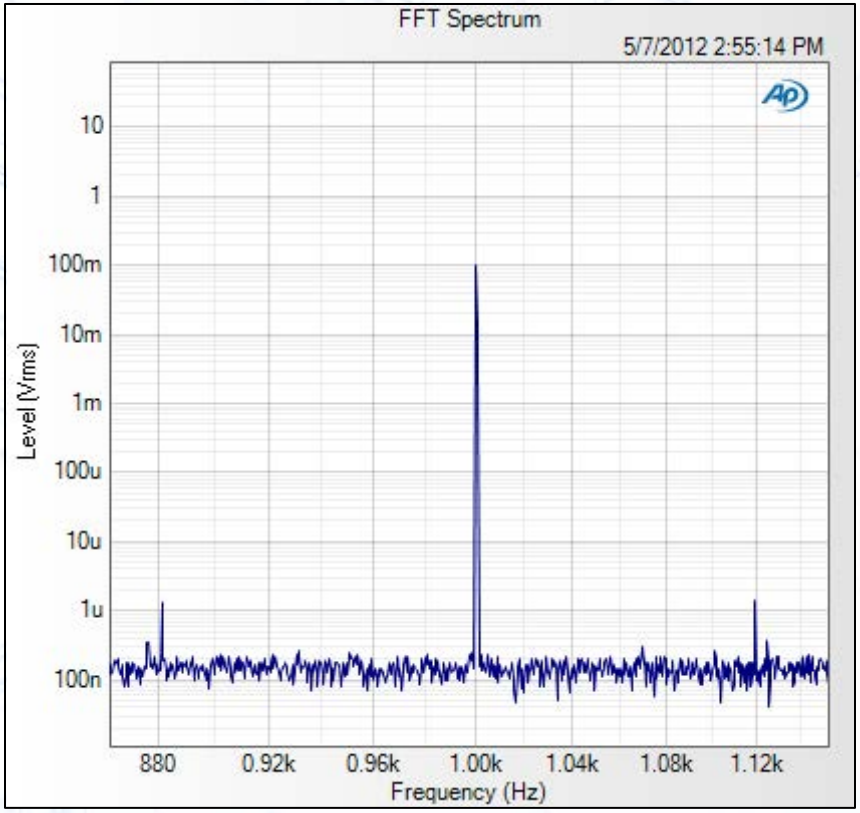


One more concept: FFTs

- ☑ **Not all FFTs are equal**
  - ⇨ Bin width and bit depth



16,000 points



1.2 million points

Common digital audio interfaces

- ☑ **Consumer**
  - ⇨ PCM, HDMI, Bluetooth,
  - ⇨ On the way out: SPDIF
- ☑ **Pro audio**
  - ⇨ AES/EBU, MADI
  - ⇨ On the way up: AVB
- ☑ **Broadcast**
  - ⇨ SDI, AES
- ☑ **Chip level**
  - ⇨ I^2S, I^8S, PDM, TDM
  - ⇨ On the way up: Slimbus








Sometimes all in one device!

Modern audio protocols

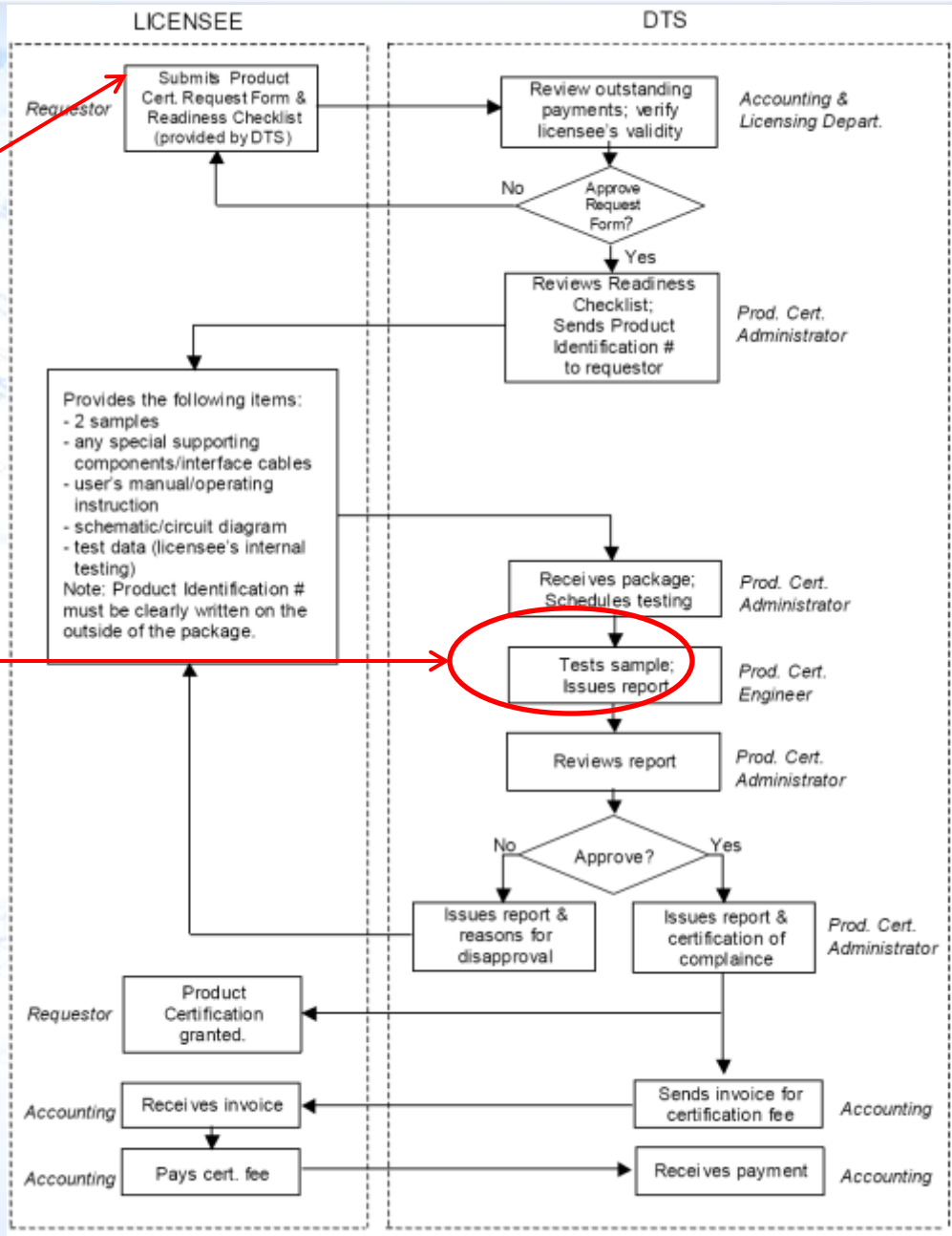
- **Linear PCM**
  - Typically a .wav file.
  - On digital media like CD, DVD where size is no issue
  - 10 MB per minute… per channel… = huge
- **Encoded**
  - To save space
  - To transport multiple channels across systems designed for two channels
  - Can be “lossy” like MP3, Dolby Digital,
  - Or lossless like Dolby TrueHD, FLAC, Apple Lossless
- **Test implications of encoded audio**
  - Can’t use traditional sine wave tests on encoded audio
  - Analyzer must have encoder and decoder or encoded file streaming capability
  - Can check for “bit accuracy” by comparing to reference file

Dolby & DTS

- ☑ **Many different formats**
  - ⇨ Dolby Digital, Dolby Digital Plus, Dolby TrueHD
  - ⇨ dts-HD Master Audio’
- ☑ **Many different technologies**
  - ⇨ Receiver, DVD, Blueray, Broadcast, mobile,
- ☑ **Extremely complicated requirements for certification**
  - ⇨ Up to one week to complete all tests
- ☑ **Automation can save a lot of time**
  - ⇨ Dolby & DTS provide pre-defined audio analyzer projects

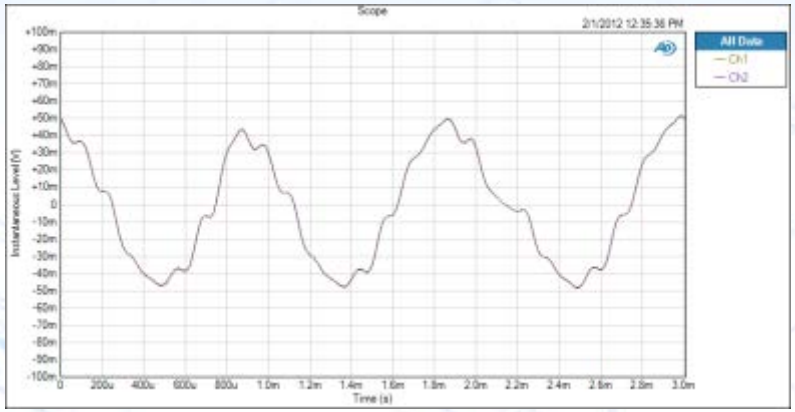
DTS Certification Process

- ☑ **Pre Certification Testing**
  - ⇨ Done before Cert. Request Form submission
    - ✓ DTS FAE (Field Application Engineer) Group available for support during this phase.
    - ✓ Testing is the same as conducted at DTS.
    - ✓ Resulting data may be ~~used by DTS~~ if problems are encountered during testing for troubleshooting purposes.
- ☑ **Use recommended test equipment.**
  - ⇨ 2722 or APx585
  - ⇨ Saves time



Why testing is important

- ☑ How much is an hour of R&D?
- ☑ How much is a recall or returns?



Audio analyzer or sound card?

Audio analyzer or sound card?

- ☑ **Trust & reliability**
  - ⇨ Believe your own results
  - ⇨ Others believe your results
  - ⇨ Calibrated & traceable

Is the error you see caused by your product or your "analyzer"?

Audio analyzer or sound card?

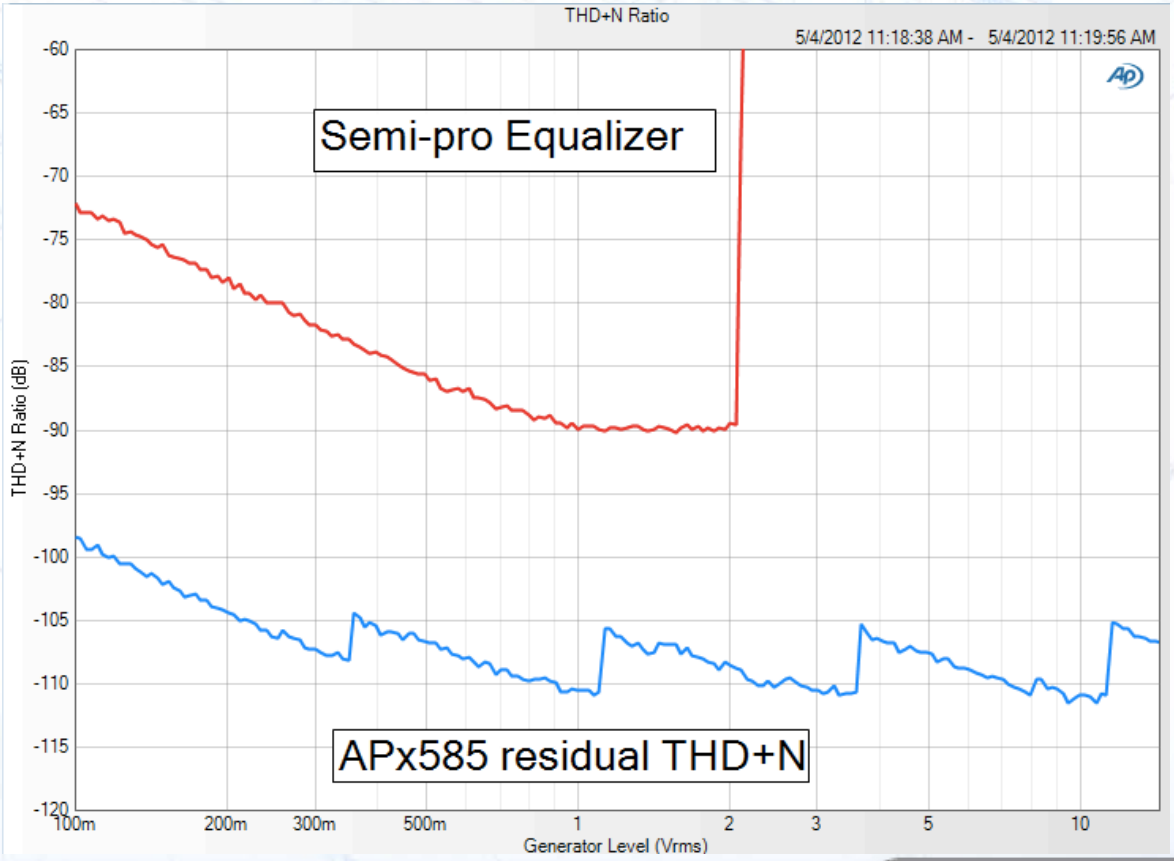
- ☑ **Productivity & sophisticated measurements**
  - ⇨ No wasted time
  - ⇨ Built in measurements & proven algorithms
  - ⇨ Easy to share test data with others
  - ⇨ Professional technical support

Who do you call when there's a problem?

Audio analyzer or sound card?

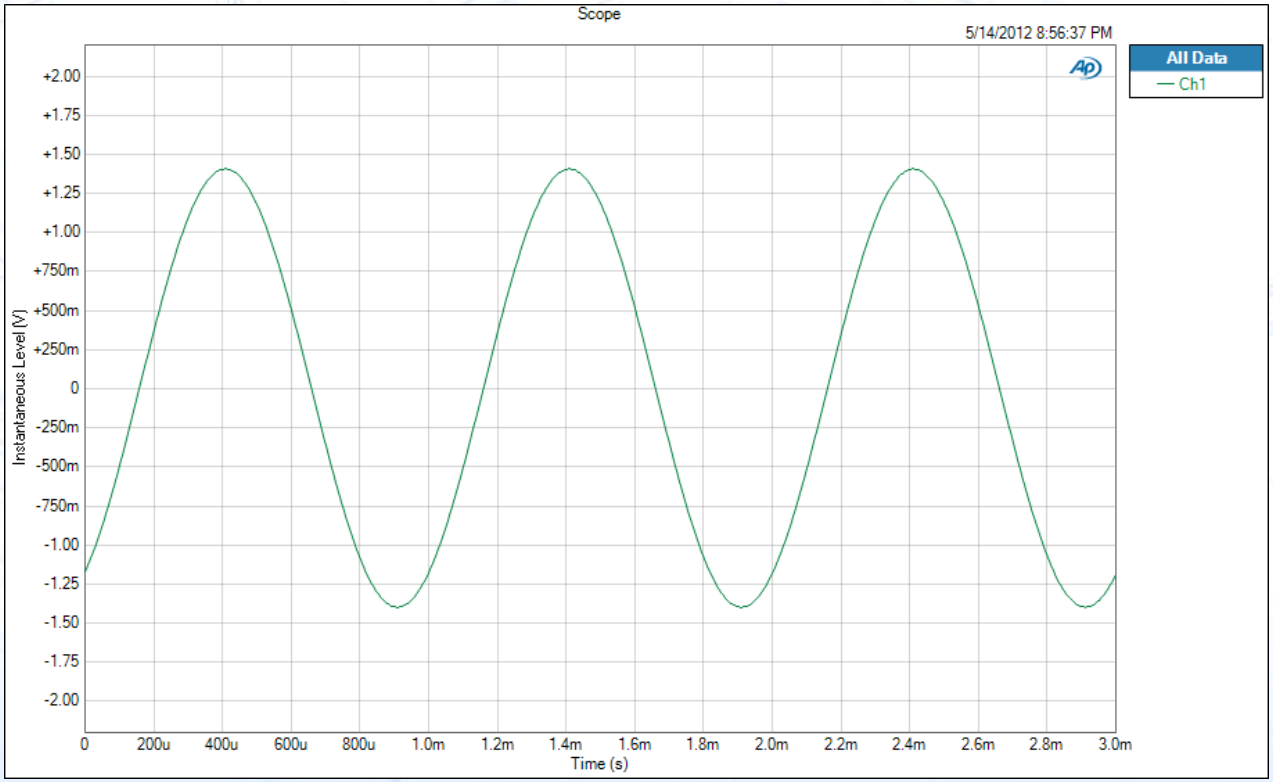
- ☑ **Connectivity & performance**
  - ⇨ Must be able to connect to the device directly
  - ⇨ Must have better performance than the device tested

Do you trust a hacked home receiver to test your new product?



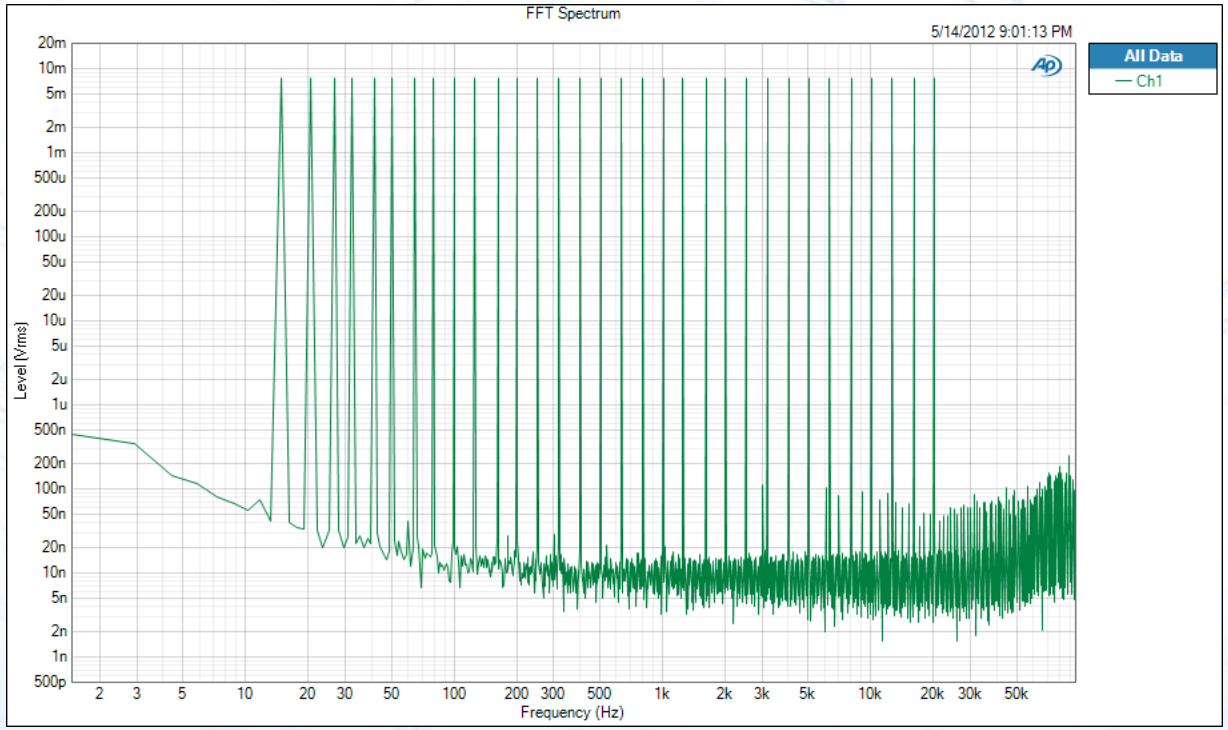
☑ Sine waves

- ⇨ Single sine wave or stepped sine sweep (level, frequency)
- ⇨ Classic traditional test method, international standard
- ⇨ Ideal for amplifiers, high performance recording devices
- ⇨ Not great for voice-quality devices
- ⇨ Stepped sine sweep can be very slow



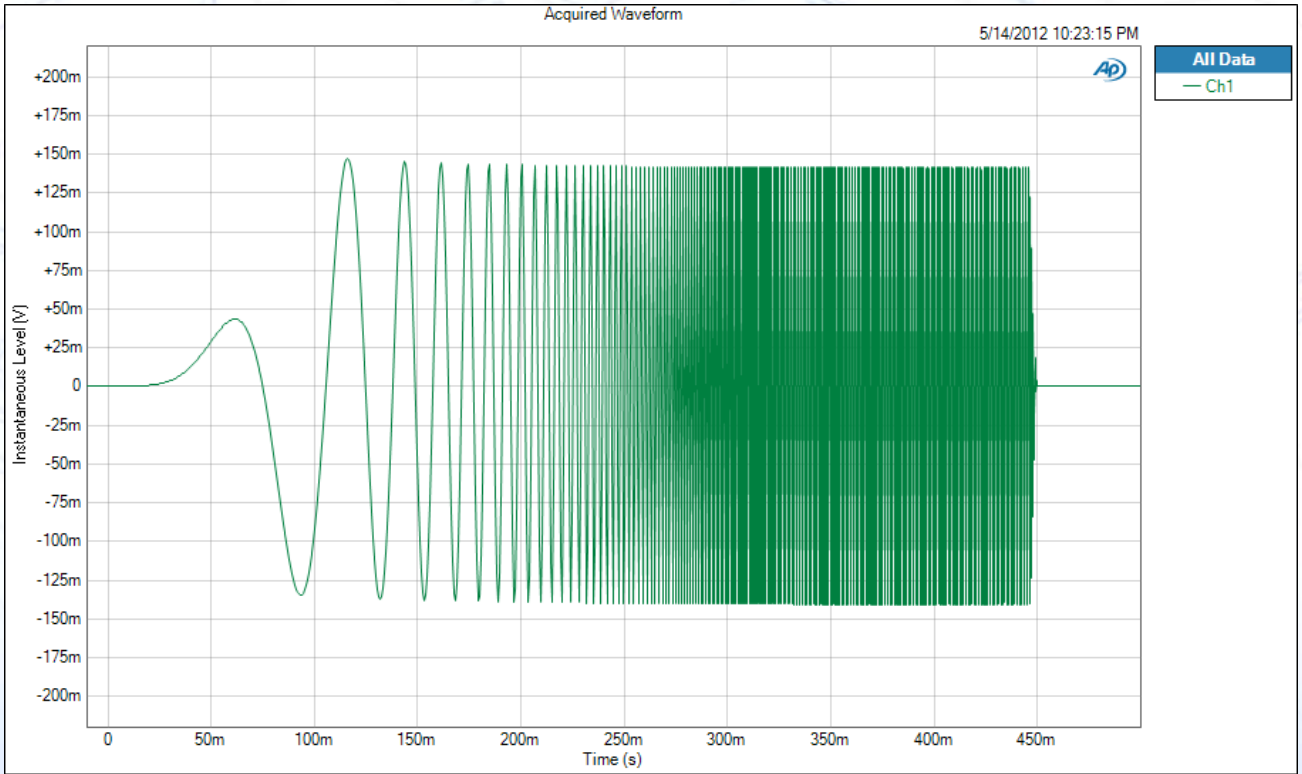
☑ Multitone

- ⇨ Single signal with multiple tones, typically 3,5,7 or 31 tones
- ⇨ Extremely fast: 20+ results in <2 seconds
- ⇨ Ideal for production lines, broadcast, and encoded formats
- ⇨ Some results differ from sine. Not wrong. Just different. TD+N vs. THD+N
- ⇨ Triggering – waiting for the right signal



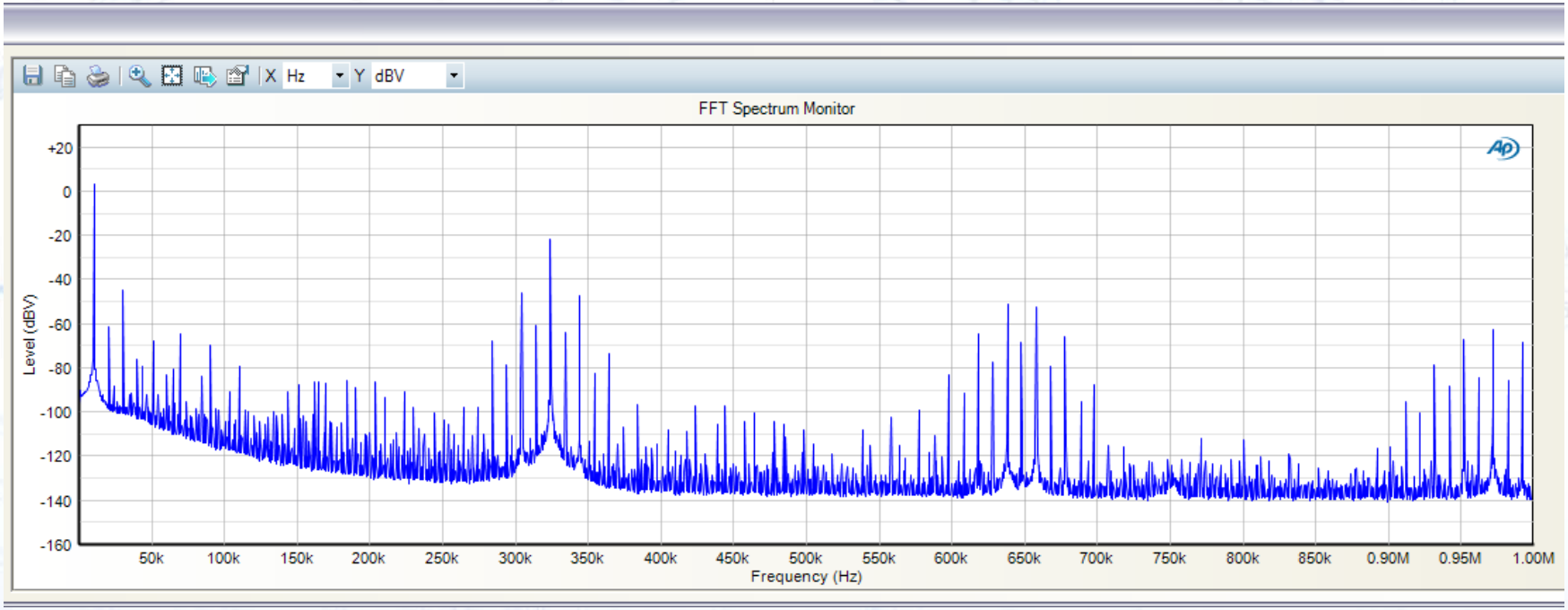
Modern test techniques

- ☑ **Continuous sweep (logarithmic sweep or “chirp”)**
  - ⇨ Measurement can calculate Impulse Response (IR)
  - ⇨ Results correlate with traditional stepped sine sweep
  - ⇨ Again, extremely fast: 20+ results in <2 seconds
  - ⇨ Good for electronic and loudspeaker test, excellent SNR



Modern test techniques

- ☑ **Ultra high bandwidth measurements**
  - ⇨ Required for modern Class D amplifiers
  - ⇨ Switching frequencies at 200-300 kHz
  - ⇨ Need high bandwidth and high resolution



Calibration

- ☑ **Similar, but very different**
  - ⇨ Adjustment
  - ⇨ Calibration
  - ⇨ Accredited Calibration
- ☑ **Traceability**
  - ⇨ an unbroken chain of comparisons
  - ⇨ measurement uncertainty
  - ⇨ documentation
  - ⇨ competence
  - ⇨ reference to SI units
  - ⇨ calibration intervals

Audio precision

Calibration Services
5750 SW Arctic Drive
Beaverton, Oregon 97005
USA

ACCREDITED
Calibration Cert #2527.01

Certificate of Calibration

Accredited Calibration
Certificate No: APx525-00000-110628-1

Description:	Audio Analyzer	Received Date:	New Instrument
Manufacturer:	Audio Precision	Date of Calibration:	28-Jun-2011
Model:	APx525	Procedure:	APxCalibration.exe 2.71
Serial Number:	APX2-00000	Report Form:	APx525CalReport.xls
Customer Name:	Audio Precision	Control Software:	APx500 2.7.0.98.36867
		Temperature ± 1°C:	22.6
		Relative Humidity:	10 < RH% < 80
		AC Mains:	120 V, 60 Hz
PO Number:		Data Type:	AS SHIPPED, NEW

This laboratory maintains A2LA accreditation to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994 for the specific calibrations listed in A2LA Calibration Certificate #2527.01. The accompanying report may contain data that is not covered by the A2LA Scope of Accreditation, but is included for completeness. The unaccredited data, where applicable, is clearly indicated as "non-accredited."

Measurement uncertainties at the time of test are given in the following pages, where applicable. Uncertainties are based on a coverage factor of 2 (k=2) corresponding to a confidence level of 95% based on the recommendations in the Guide to the Expression of Uncertainty in Measurement, 1993, ISO Geneva; and the NIST Technical Note 1297 (1994).

The test limits stated in the report correspond to the published specifications of the equipment, at the points tested.

The Data Type found in this certificate must be interpreted as:
As Received—Calibration data collected before the instrument is adjusted or repaired.
As Shipped—Calibration data collected after the instrument is adjusted and/or repaired.
As Shipped, New—This is a new instrument.

Report Summary: 188 pass; 0 uncertain; 0 fail

As Received Condition: New Instrument

Remarks or Special Requirements:

Traceability Information for Calibration Equipment		Serial Number	Calibration Date
5520A	Fluke Multifunction Calibrator	9421009	05-Apr-2011
3458A	Agilent Digital Multimeter	MY45041233	04-Apr-2011
53131A	Agilent Frequency Counter	MY40019433	14-Apr-2011
TDS3052B	Tektronix Oscilloscope	B040953	01-Apr-2011
1620A/2626-S	Fluke Thermo-Hygrometer/Sensor	A73234/A82468	08-Apr-2011

Traceability is to national standards administered by the U.S. NIST. Supporting documentation relative to traceability is available for review by appointment. This certificate applies only to the item identified, and shall not be reproduced except in full, and only then with the written approval of Audio Precision.

SAMPLE

Mark Dakins
Calibration Technician

Bruce Hofer
Calibration Technical Director

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ACCREDITED

Calibration

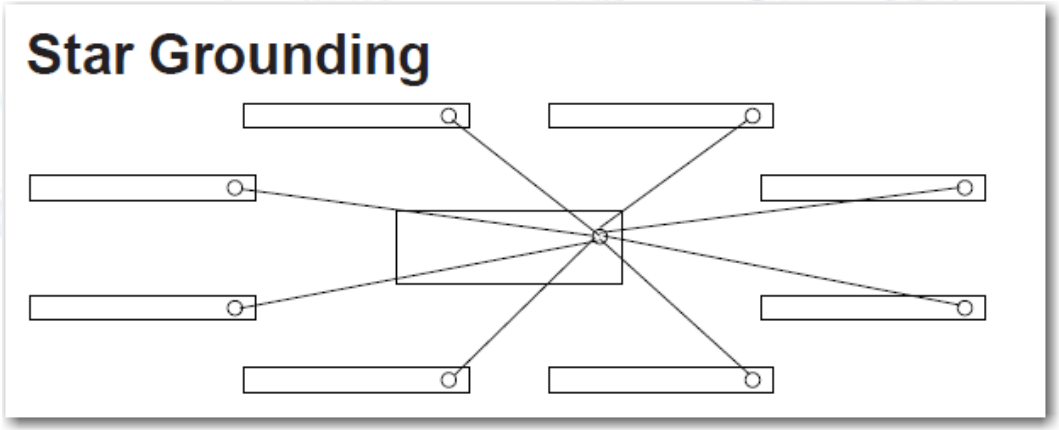
NIST

INTERNATIONAL METEROLOGICAL STANDARD

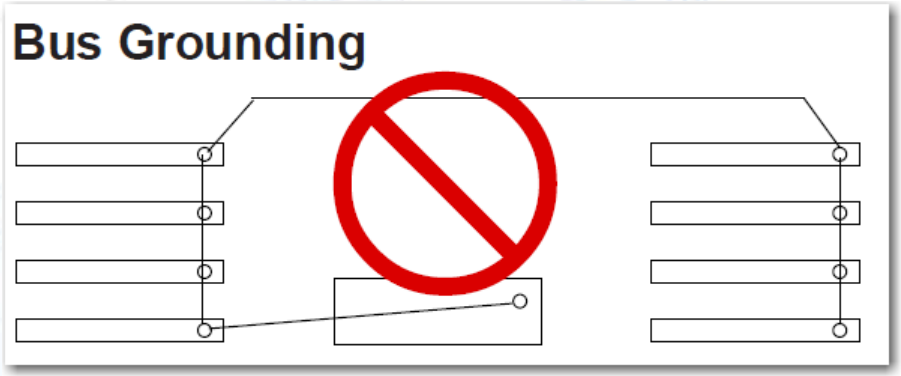
5520A Fluke Calibrator	3458A Agilent Digital Multimeter	53131A Agilent Freq counter	TDS3052B Tektronix Oscilloscope	1620A/2626-S Fluke Thermo Sensor	THD+N??

Common mistakes: grounding

- ☑ Most common mistake we see
- ☑ Star grounding is best
- ☑ Use heavy gauge and always check your grounds

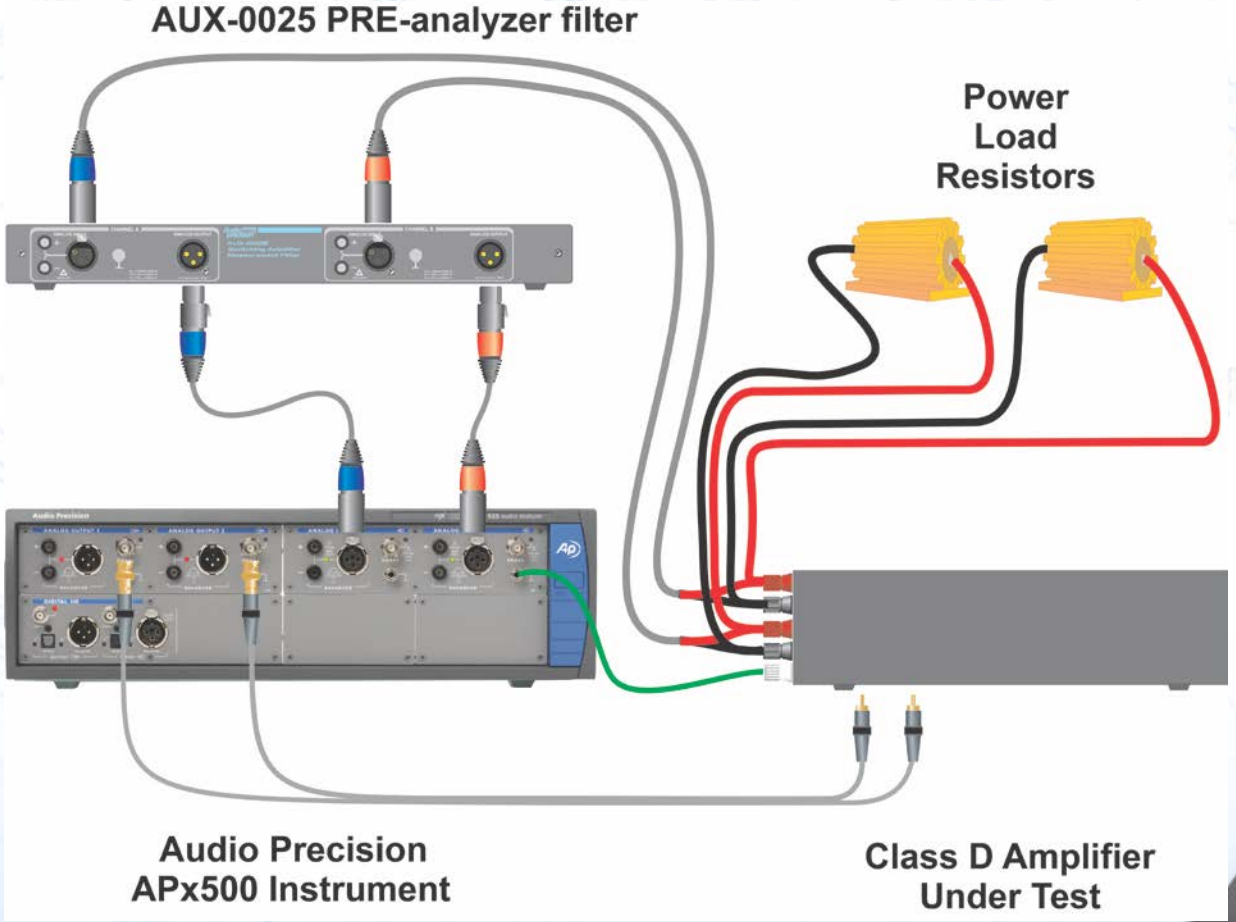


The resistance in each leg of the chain puts the devices at different ground potentials, and is not as effective as star grounding.

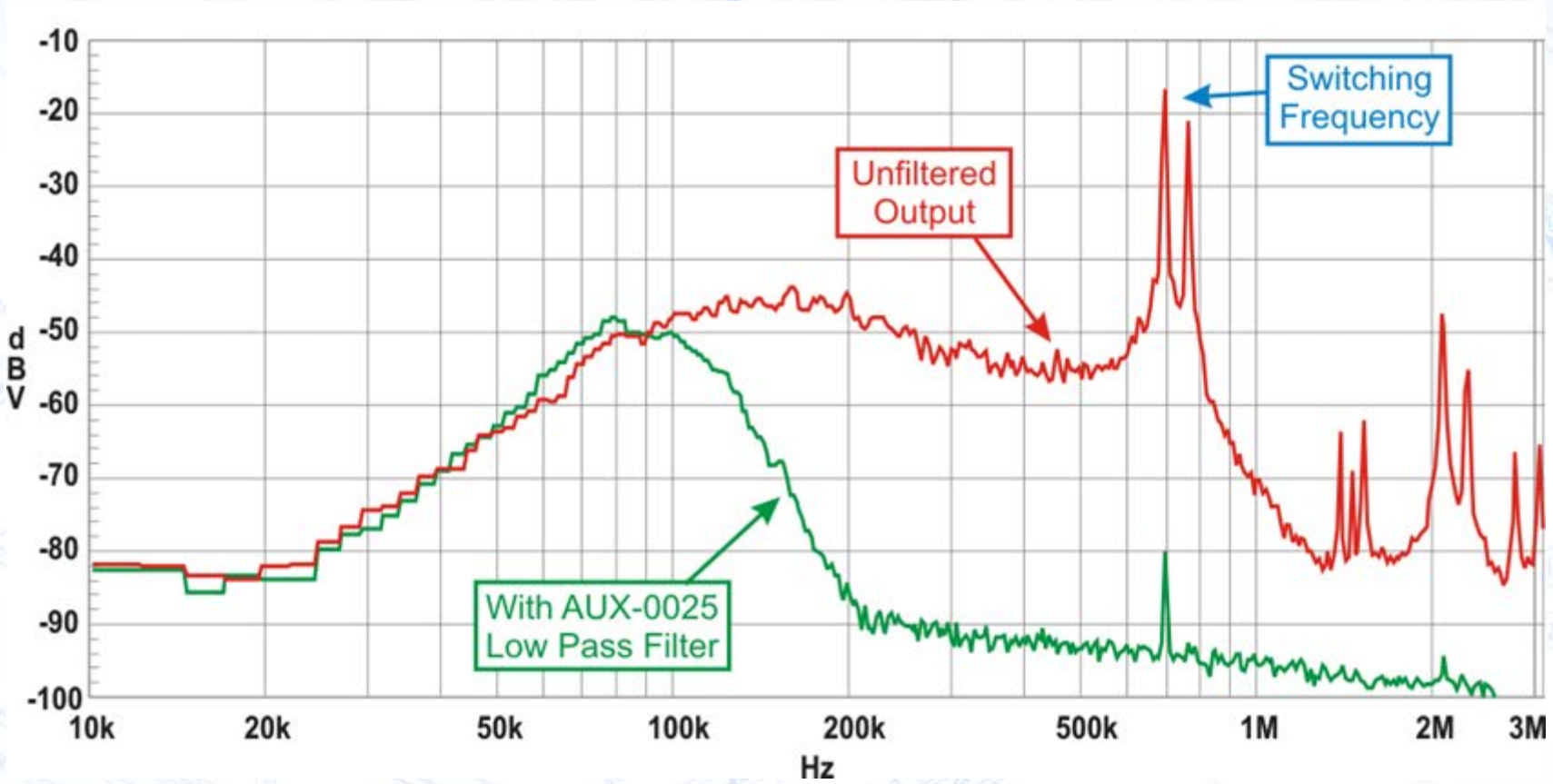


Common mistakes: Class D filtering

- ☑ Class D switching amplifiers have unique problem of out of band noise
- ☑ Can cause inaccurate measurements, or even damage analyzer inputs
- ☑ Simple filter stops the problem

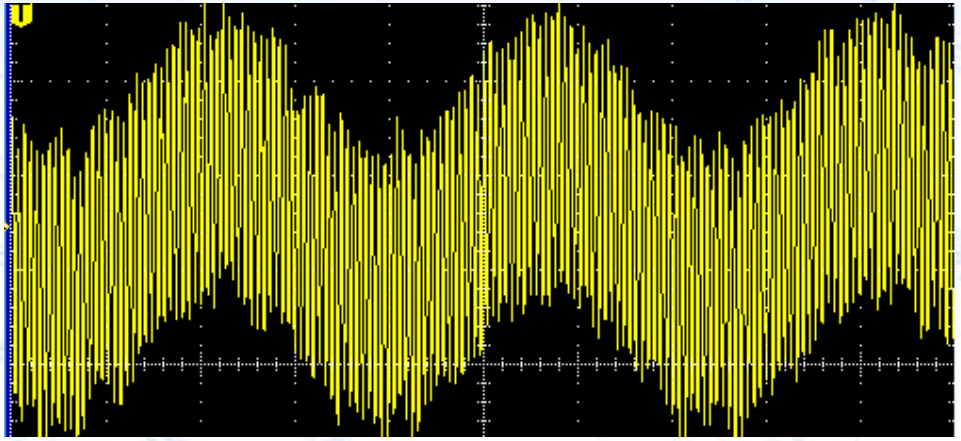


Filter effect in Frequency Domain

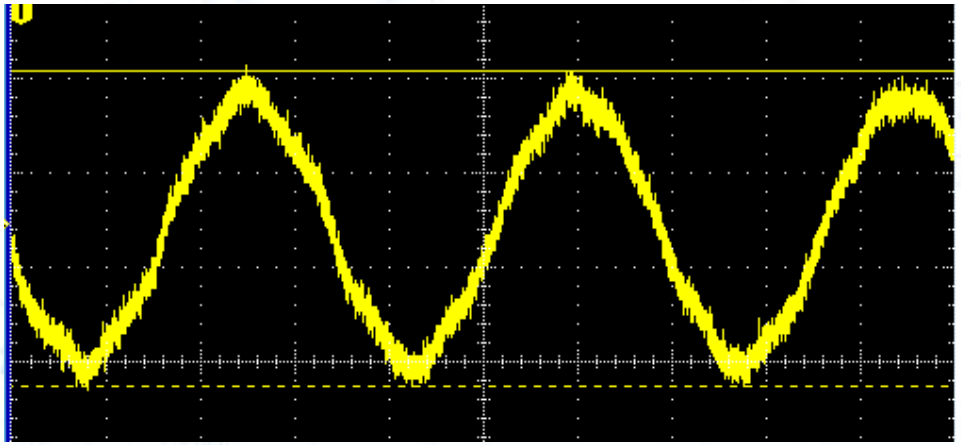


PRE-analyzer filter effect in Time Domain

- ☑ Typical Class D Low-level Output Signal Audio signal is masked by switching artifacts.



- ☑ Output Signal after PRE-analyzer filtering Audio signal is now clearly visible.

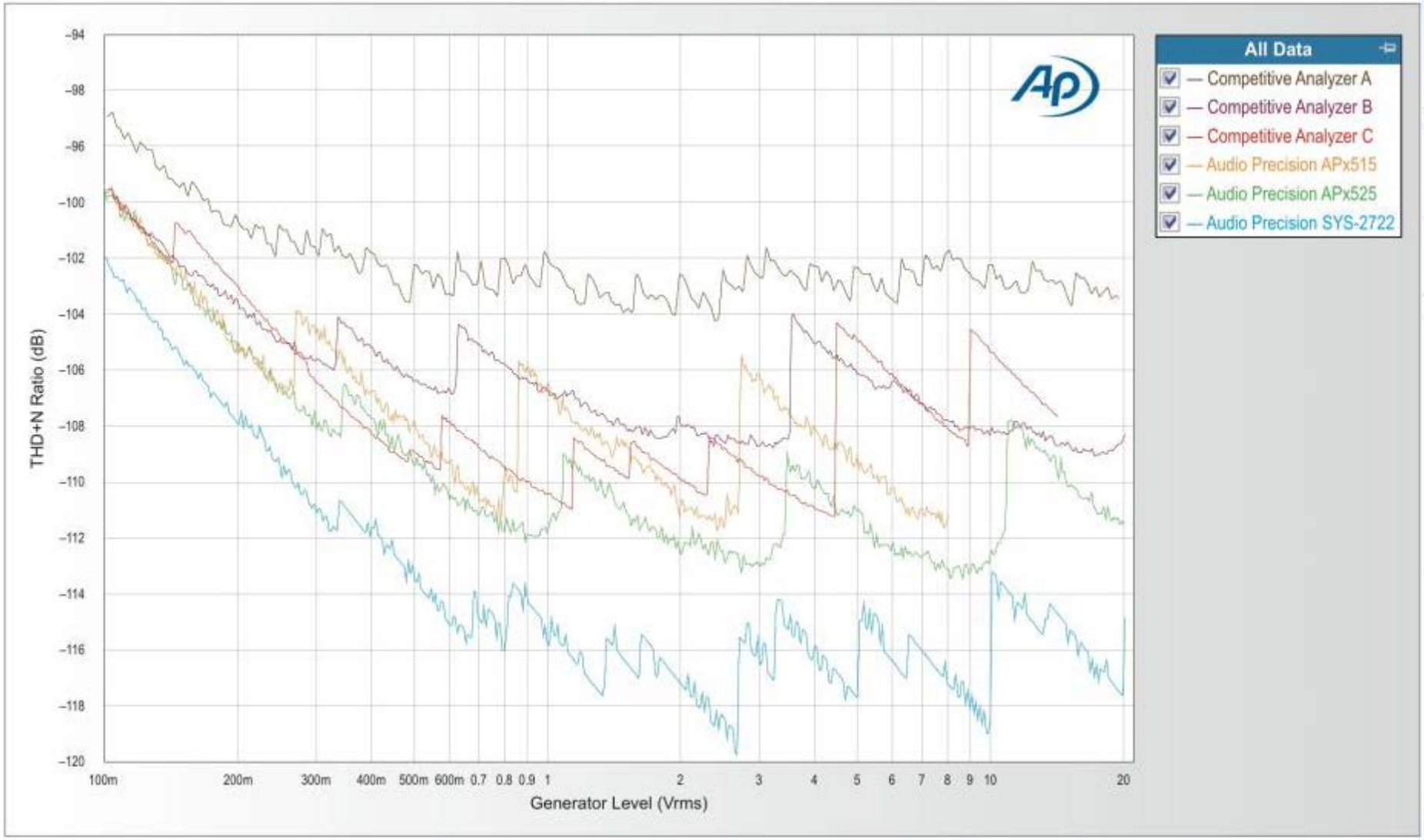


Common mistakes: Connections

- ☑ Sounds simple, but it happens a lot
- ☑ Crossed cables
- ☑ Bad cables
- ☑ Analyzer set for wrong connections
- ☑ Always check your connections
- ☑ Use Loopback mode to confirm settings

Demo and questions

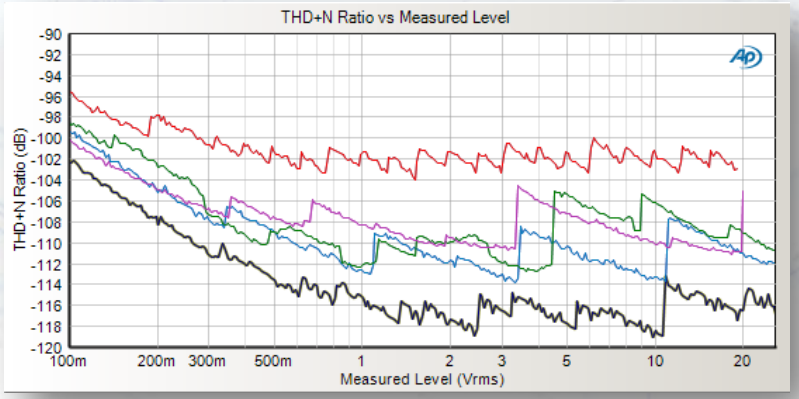
Audio analyzer comparison



The world's highest performance audio analyzer

Most advanced analyzer for R&D

- Vanishingly low residual noise and THD+N: —115 dB @ 2.0 Vrms
- True Dual Domain – analog and digital
- Generate and analyze a wide range of waveforms
- API automation
- LabVIEW integration
- Chip-level connectivity with PSIA
- User-defined sweeps, switcher support up to 192 channels

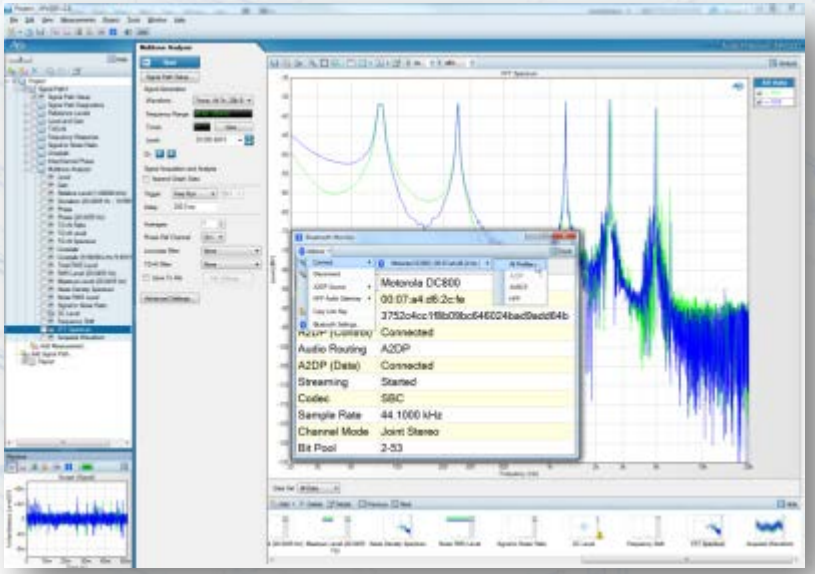


THD+N of AP 2700 (Black) compared with 5 other audio analyzers

Connectivity, Flexibility and Intuitive Operation

High performance for R&D

- Up to -110 dB THD+N
- Test *Bluetooth*, HDMI, I2S
- 1 million point FFT analyzer with 24 bit resolution from DC to 1MHz
- Multichannel and high bandwidth options



Multiple interfaces

- HDMI, Bluetooth, PDM
- AES/EBU, I²S, S/PDIF

Intuitive & easy to use

- One-click measurements
- Real-time monitors
- Automated reports

Fast, simple automation for production

- Up to 21 measurements in 1.2 seconds
- Automation without coding or use the .NET API and LabVIEW driver
- Lockable projects with limits

APx Series Family

APx525 family:
Audio testing for modern devices

- Typical THD+N better than –110 dB
- 1M point, 1 MHz FFT w/BW52 option
- 2 or 4 independent analog inputs, 192k digital I/O, digital serial I/O
- Maximum input voltage 300Vrms (bal)
- Regulated frequency sweeps, CMRR, CEA-2006 / CEA-490A measurements

APx525 2 channel analog
APx526 4 channel analog

APx585 family:
Multichannel & HDMI audio analysis

- 8 or 16 independent analog inputs 192k digital I/O, Digital Serial I/O
- Systematic test of HDMI & Blu-ray
- Automated Dolby/DTS compliance test with fully formatted reports
- Test EDID error handling with metadata event timing view

APx585 8 channel analog
APx586 16 channel analog

APx515:
High speed & reliable production test

- Typical THD+N better than –106 dB with a production test price point
- Comprehensive automated test in 3 seconds without any coding
- Small footprint, only 4 kg
- Share tests and results with any APx seamlessly

APx515 2 channel analog + 192k digital