Understanding & Measuring Digital Audio Levels

The sound levels in a digital audio signal are retained as digital values captured during the analog to digital conversion. Sound levels are not related to the VPP of the digital serial data stream within the cable. This article describes how sound levels are specified in the digital audio system and how they are metered using the Sencore DA795 Digital Audio Analyzer.

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DA795 DigiPro Digital Audio Analyzer

dB or decibels

Audio signal or sound levels are measured using a decibel (dB) system. The dB system is used to compare two levels or a change in signal voltage or power. One dB is the level change that is just noticeable by most people. A 6 dB change is considered to be about twice the volume.

Sound signal level in dB can be considered either as a power or as a voltage. The level in decibels is 10 times the logarithm of the ratio of two power levels. Where P is the measured power in watts and P Ref. is a reference power in watts.

$$dB = 10 \log (P/P\ Ref.)$$

Sound signal level in dB can be considered as a voltage ratio. The level in decibels is 20 times the logarithm of the ratio of two voltage levels. Where V is the measured voltage and V Ref. is a reference voltage.

$$dB = 20 \log (V/V\ Ref.)$$

The resistance is assumed to be the same so calculations using either the power or voltage formula agree.

Units of Sound Level Measurement

Sound signal level is expressed using various dB units of measurement including:

dBm: decibels or dB referenced to 1 milliwatt (.001 watt)
dBu or **dBv**: decibels or dB referenced to 0.775 volt (dBu is more commonly used)
dBV: decibels or dB referenced to 1 volt

These dB measurements all provide a dB value that indicates the level of the audio signal. The suffix letter indicates the reference used to determine the dB value. The "m" indicates a dB reference based upon 1 milliwatt. The dBu or dBv indicates the same reference which is 0.775 volts. You will see dBu used much more often. The "V" indicates a dB reference based upon 1 volt.

Audio Level Measurements - (Computed mW & dBm for 300 ohms)

RMS Volts	Peak Volts	Power mW	dBm	dBu (dBu=dBv)	dBV
20	28.4	1333	31.25	28.27	26
15	21.21	750	28.7	25.7	23.5
10	14.14	333	25.2	22.2	20
5	7.07	83.3	19.21	16.2	13.98
2	2.83	13.3	11.25	8.24	6
1.23	1.74	5	7	4	1.8
1	1.414	3.33	5.23	2.22	0
.775	1	2	3	0	-2.2
.548	.774	1 (300 ohm)	0	-3.8	-5.2
.1	.14	.033	-14.7	-17.2	-20
.01	.014	.0033	-34.7	-37.8	-40
.001	.0014	.000033	-54.8	-57.8	-60
.0001	.00014	.0000033	-74.8	-77.8	-80
.00001	.000014	.00000033	-86.9	-97.8	-100

Chart 1. Audio levels comparison chart showing how RMS levels relate to dBm, dBu, dBV values. (mW and dBm levels refer to 300 ohms)

Chart 1 shows some sample values of RMS audio voltage levels through the typical audio range in the first column. The remaining columns show how these RMS levels relate to levels in dbm, dBu, and dBV. The mW and dBm levels indicated in the chart are impedance or resistance related. The chart reflects a professional balanced 300 ohm line level in which .548 Vrms results in 1 mW which is 0 dBm. A 1 Vrms is a 0dBV level measurement and 0 dBu is .775Vrms referenced.

Chart 1 also provides an illustration of the dynamic range offered by analog audio signal levels. The audio can peak to 10 Vrms or slightly more at full loudness and dip to sensitivity levels of only several microvolts. This provides an approximate 120 dB range from the largest to smallest level.

In analog sound it is desirable to not overdrive equipment as clipping of the audio cycle causes audio distortion. While there is some discussion on what level clipping occurs among various calibers of audio equipment, exceeding a level of 24 dBu (12.5Vrms) is generally accepted as a level in which clipping is likely to start. Actual clipping levels may vary from 20dBu (7.75Vrms) to 28 dbu (20Vrms).

If you want to convert between the different dB units of measurements, you don't really need to work the formulas. Many handy electronic calculators are available at some helpful websites. Here are a few website examples:

www.bcae1.com/decibels
www.analog.com
www.sengpielaudio.com/calculator-db-volt

VU Meters

The VU (volume unit) meter is another voltage measurement method for analog audio level measurement. The VU meter is a voltmeter with a response time designed to reflect the loudness of live audio as the ear would interpret the loudness. Relating VU measurement units to the other dB units of measurement for audio can only be done with a sine wave test tone. In a professional audio balanced system, 0 VU corresponds to +4 dBu. You may also see 0VU as +4 dBm although this assumes 600 ohm balanced impedance. This is the only impedance in which 4 dBm equals 4 dBu.

Note: Consumer related semi-professionals may use -10dBV (0.3162 V = -7.78 dBu) as 0 VU in unbalanced audio equipment recording applications. European studio recordings may assign 0VU as 6 dBu.

Level	Level in dB	Voltage (RMS)
International studio level - USA	+4 dBu	1.228 V
European studio level - ARD broadcast level	+6 dBu	1.55 V
Domestic recording (Consumer units)	-10 dBV	0.3162 V = -7.78 dBu

Chart 2. Worldwide reference for 0 VU.

Analog vs. Digital Levels — the dBFS Scale

Digital audio levels are measured differently than analog audio levels. Yes, yet another and different dB system is used. The dB system in digital audio starts at the top and defines the loudest sound level that is to be digitized. This top or full scale view of the audio levels results in a full scale or "FS" system of dB measurement. A 0 dBFS measurement unit is to be the highest audio level. Assuming this is to be at the highest audio level before clipping occurs, this corresponds to an analog level of 24 dBu. Therefore, 4 dBu (dBu =dBv) is the same as - 20 dBFS or 0 VU.

While this is generally accepted as the range of digital audio, it is not a hard standard. When digital audio values are converted back to analog, some digital audio equipment provides level selections to shift the analog output levels of 0 VU to -18 dBFS or -14 dBFS. Lowering the dBFS relationship increases the audio sound levels output from the D/A converter.

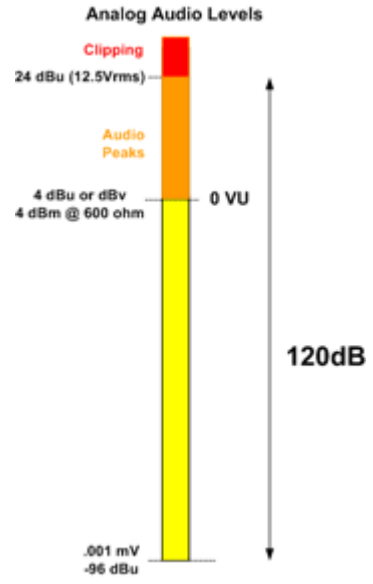

Figure 1. Analog audio levels in respect to 0VU, clipping level and dynamic range.

Measuring Digital Audio Levels — VU Meter/dB Meter

In the same manner as an analog level meter indicates audio levels, a digital audio meter indicates the level of both the left and right channel PCM audio signal within an AES3, S/PDIF or ADAT digital audio signal.
The DA795 provides two different meters for measuring digital audio signals. They include:

1. VU/Peak Program Material (PPM) Meter
2. Level Meter dB FS

The VU/PPM Meter provides level monitoring of audio program material using a VU and Peak meter integrated together showing both left and right digital audio channels simultaneously. The Level Meter dB FS indicates the digital audio level in dB with reference to full scale (FS).

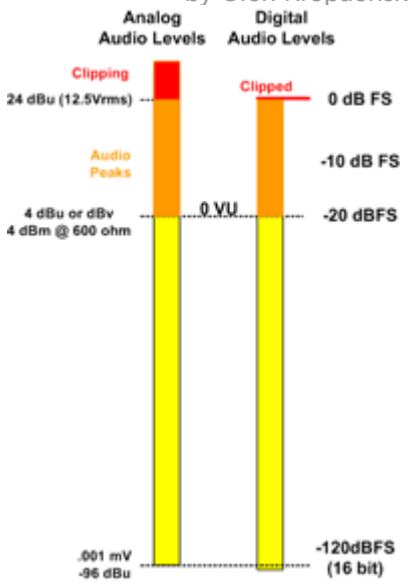

Figure 2. Digital audio levels in comparison to analog levels.

VU/Peak Program Material Meter

The DA795's VU/PPM meter provides comprehensive level measurements on both the left and right digital audio channels when measuring/monitoring program audio material. In all, three measurements are indicated including:

1. VU (Main VU Bars - Also numeric VU readout at right of display above left VU bar and below right VU bar)
2. Instantaneous Program Peak Meter (Small bar above or to the right of main bar)
3. Peak Capture or Hold Meter - Captures and displays maximum peak program levels for left and right channels. Reset by selecting the "Max" field and clicking.

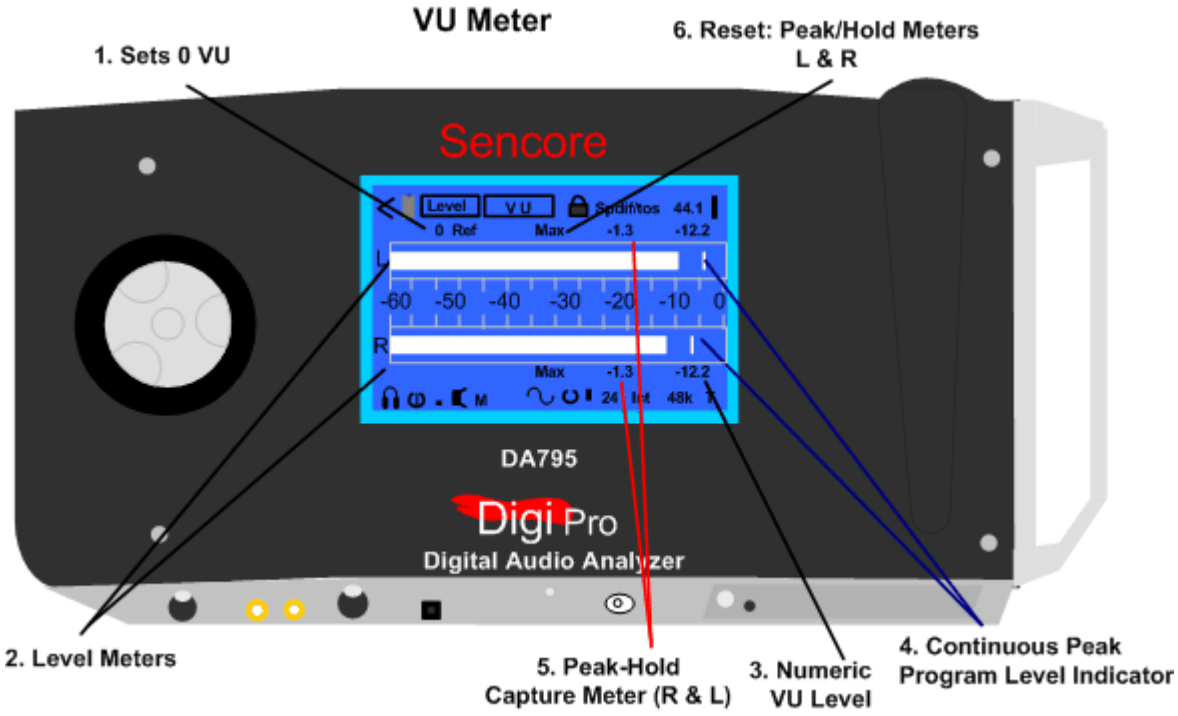

Figure 3. The DA795's VU Meter measures audio program levels and peak levels on both digital audio channels.

Field Descriptions:

1. **VU Reference Level:** Scales the digital signal level dB FS to which the meter's OVU point is referenced. The level can be adjusted from 0 to 24. This scales the 0 VU from 0 dBFS to -24 dBFS. (Standard setting would be "20 Ref" resulting in a -20dB FS = 0 VU)
2. **VU Graphic Bar Level Meter:** Indicates VU level of left and right digital audio.
3. **VU Numeric Level Meter:** Indicates VU level of left and right digital audio.
4. **Peak Program Meter:** A single bar the bounces above the main bar indicating peak program levels.
5. **Maximum Peak Level Meter:** Captures and updates the maximum or peak level of the audio program material.
6. **Max Reset:** Resets Maximum Peak Level Meter. Highlight field and click to reset.

Level Meter — dB FS

The DA795's Level Meter provides a measurement of an AES/EBU or S/PDIF signal into Input 1. Both the left and right digital audio channel levels in dB are measured simultaneously. The meter provides digital numeric value readouts. (Default: O dB rms is referenced to the full digital scale 0dB FS) Several other measurement units are available including, dB peak, % rms, and % peak. The % measurements are referenced to full scale. Typically, the Level Meter is used to calibrate digital audio equipment levels while the VU/PPM meter is used to monitor audio program material levels.

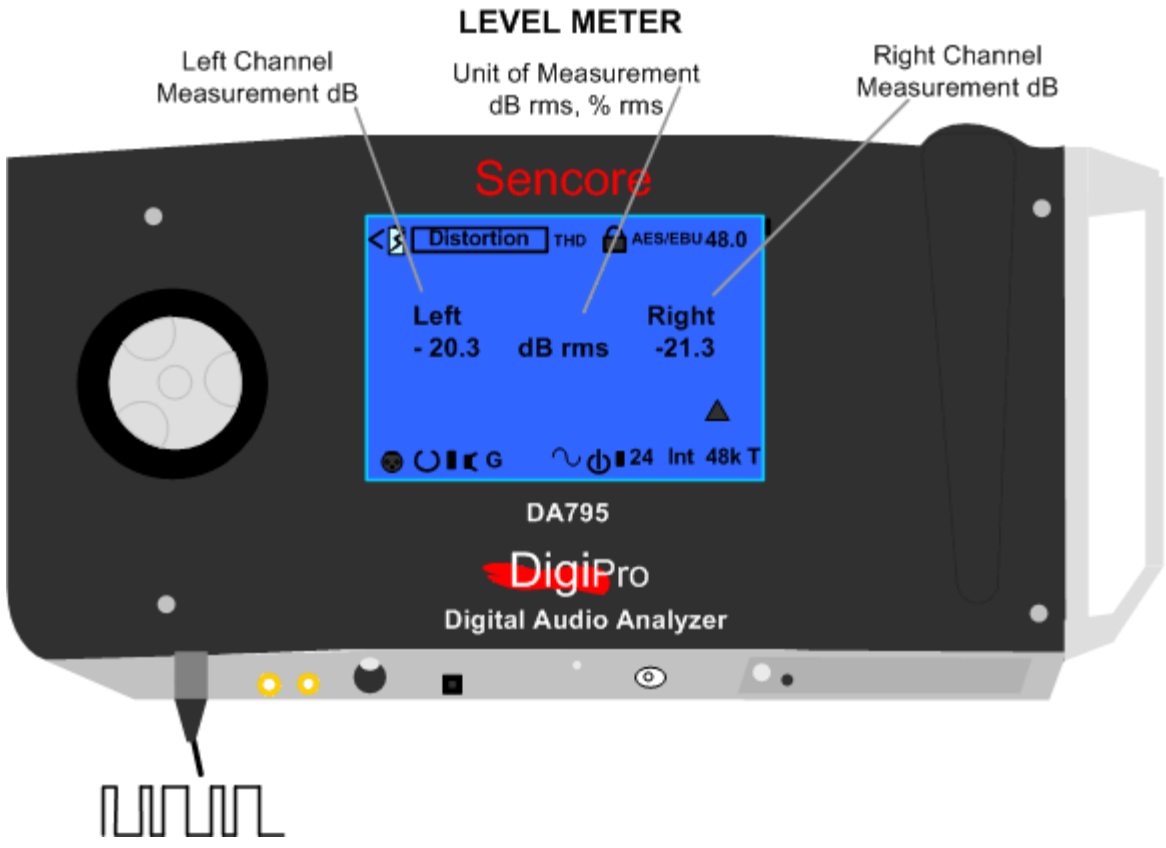

Figure 4. Digital Audio left and right Level dBFS meter of the Sencore DA795.

Your Solution to Digital Audio Analyzing

The DA795 provides comprehensive digital audio level measurements. The DA795 fully equips you for all digital audio troubleshooting and performance testing needs. For more information on analyzing digital audio signals with the DA795 DigiPro, call 1-800 Sencore (736-2673) or visit www.sencore.com.

Learn more - DA795 DigiPro Digital Audio Analyzer: http://www.sencore.com/products/da795.htm

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