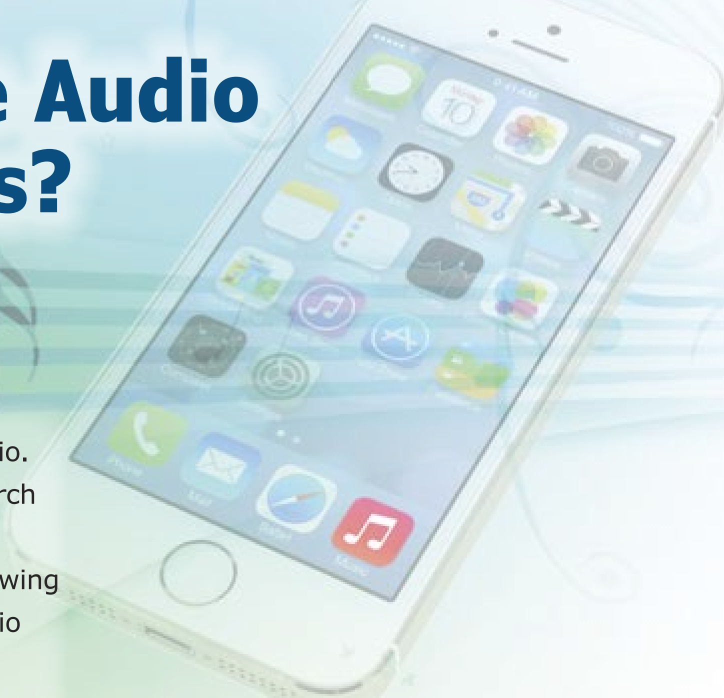
High-Performance Audio from Smartphones?

The Testing Showdown



This month, we return to the topic of smartphone audio. Since our last article on this subject (*audioXpress*, March 2015), we've been busy in the test lab measuring the performance of eight high-end smartphones. The following is a discussion of the current state of smartphone audio playback as well as our test results.

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The market for boutique high-performance smartphones is growing. For years, there have been a limited number of designer phones that were more show than go—all of which were technologically dated even when first introduced. These products were merely glorified feature phones or smartphones with a fancy crust.

In fact, early smartphones with MP3 stereo music playback as well as the original standalone iPods and MP3 players really set playback standards back a couple of notches from CD quality with marginal bit rates and mediocre audio processors. Their primary goals were portability and affordability.

To achieve these goals, compromises were made, particularly in the area of audio playback quality. However, over the last few years decent to even awesome on-the-go earphones with microphones for phone calls have been introduced to the market. The earphones were one of the missing pieces and now we are seeing some superb on-the-go audio delivery systems bundled into feature-filled smartphones.

Apple, Samsung, LG, and HTC are in a constant battle to offer the best high-end smartphones powered by multi-core processors, loaded with tons of RAM, higher-definition displays, and the latest 4G connectivity. Thankfully, the market has finally expanded to include audio performance and the winner is the consumer. Now, even Vertu has come out with its Signature series, offering audio "tuning" by Bang & Olufsen for a technically credible smartphone.

Playback Audio Quality

There are many features to consider when making a smartphone purchase but for now, we will focus on smartphone music playback audio quality. The most important aspect of smartphone audio quality is audio playback through earphones and headphones.

Almost all smartphone users have some or all of their music collection on their smartphones and place extraordinary value on this feature. Headphone listening is still predominantly done through wired connectivity and as such we will focus our efforts on evaluating what's coming out of that tiny headphone jack and leave discussions of the emerging Bluetooth audio market for another day.

Another consideration of music playback performance outside of headset playback quality is that the smartphone is often used as a music server for home audio systems. Many consumers connect their phones to their home systems via the headphone jack.

So, our challenge for this month's article is to compare the audio quality of eight portable devices. These products include one non-smartphone (the iconic iPod classic), several smartphones known for high-quality audio including the iPhone 5, the iPhone 6, and two recent designs from newcomer Vivo—the Xplay 3S and the X5 Max—whose main design goals are to bring superior stereo audio playback quality to the Android smartphone platform.

Perhaps HD audio and HD Voice have been the impetus for smartphone manufacturers to think not just about the camera pixels and screen resolution, but also that the phone might be used for voice communications (sorry for the sarcasm) and this could be an opportunity for product differentiation. With its HTC One M8, HTC has raised the audio standard among the Big 3 (i.e., Apple, Samsung, and HTC).

HD Audio

HD Audio comes into play on a few fronts: stereo music playback through earphones or headphones, using your smartphone as a music server, and audio through the smartphone's speakers. Of course, we can simplistically limit our focus on the bit rate and clock speed—24 bit/96 kHz is better than CD quality (16 bit/44 kHz)—and memory capacity in smartphones is more than enough to accommodate more music than you can handle in high definition. Lossless formats such as FLAC (or ALAC for Apple users), can be either CD quality (16 bit/44 kHz) or master quality (24 bit/96 kHz). One by one, smartphone makers have been jumping on the "HD Audio" bandwagon with 24 bit/96 kHz-compatible conversion chips. HD Audio can go further, but first there needs to be more widespread availability of program delivery services. And then, there is the performance of the playback DAC.

Why Do We Care About the DAC?

When Philips introduced the first CD player in early 1980s, the sound was miserable. At first listen, the lack of hiss compared to cassettes was refreshing. But, after a while the sound was fatiguing. What was wrong could fill a book, but the last 30 years of digital audio design have addressed most of the issues. One dirty little secret was the intermodulation distortion (IMD) that was always missing from the early datasheets of the DACS, often 3% IMD or more.

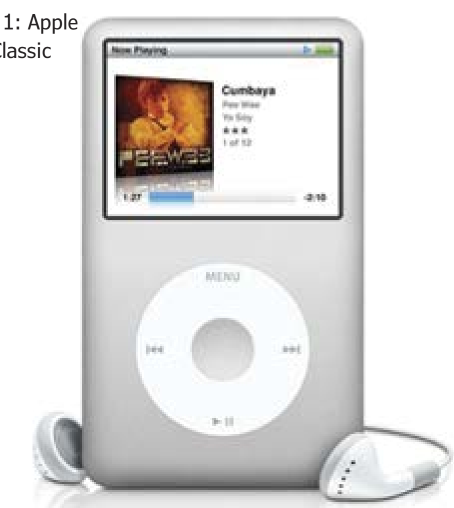
IMD is nasty and the least musical distortion. It is also a source of listening fatigue, the stuff that makes you reach for the off switch after a while. IMD originates primarily in the DAC (let's just say that over the years, the DAC has been the worst offender for IMD issues). Also, smartphones have so much digital and radio frequency stuff going on within such close quarters, it is impossible to wrestle the best from even great DACs. Nevertheless, recent smartphone introductions not only have top-grade DACs, but some of the smartphone designers have also managed to extract fine performances from the DACs and the rest of the smarthphone's audio system.

Candidates for Test

Recently, we measured the performance of eight devices. Here's a quick summary of our test subjects.

- Apple iPod Classic—The iPod started the whole portable music craze when it was first introduced in October 2001 (see **Photo 1**). The current version plays video and audio. It has 160 GB of onboard storage. Supported audio formats include AAC, Protected AAC, HE-AAC, MP3, MP3 VBR, Audible (formats 2, 3, 4, Audible Enhanced Audio, AAX and AAX+), Apple lossless, AIFF, and WAV. In addition to its headphone jack, audio signal is also available via the proprietary Apple dock connector.

Photo 1: Apple iPod Classic



- Samsung Galaxy S5—Samsung's flagship Android phone (see **Photo 2**) was released in April 2014. (It was replaced by the S6, but we were unable to test the newest version for this article.) Its strong sales helped Samsung capture more than 32% of the global smartphone market in the second quarter of 2014. The S5 has 32 GB of onboard storage, with another 128 GB available via micro SD. Supported audio formats include MP3, M4A, 3GA, AAC, OGG, OGA, WAV, WMA, AMR, AWB, FLAC, MID, MIDI, XMF, MXMF, IMY, RTTTL, RTX, and OTA.

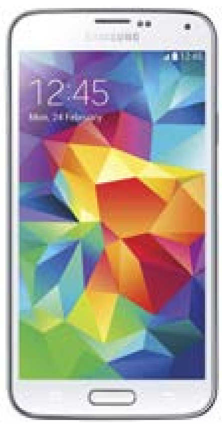


Photo 2: Samsung Galaxy S5

- Sony Xperia Z2—Given Sony's audio heritage, it is not surprising to see it place an emphasis on quality audio delivery in smartphones (see **Photo 3**). The Z2 offers several standard audio enhancements and 32 GB of onboard storage with an extra 64 GB available via micro SD. Supported audio formats include MP3, 3GPP, MP4, SMF, WAV, OTA and OGGMP3, 3GPP, MP4, SMF, WAV, OTA, OGG MP3, 3GPP, MP4, SMF, WAV, OTA, OGG MP3, 3GPP, MP4, SMF, WAV, OTA, OGG MP3, 3GPP, MP4, SMF, WAV, OTA, and OGG.

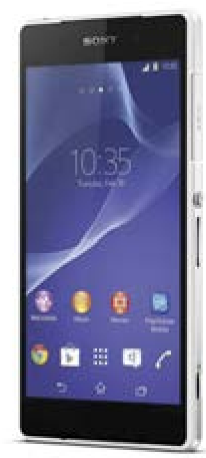


Photo 3: Sony Xperia Z2

- Apple iPhone 5s—Apple has always paid attention to smartphone audio quality and the iPhone 5s is no exception (see **Photo 4**). It comes with up to 64 GB of onboard storage and supports AAC, Protected AAC, HE-AAC, MP3, MP3 VBR, Audible (formats 2, 3, 4, Audible Enhanced Audio, AAX and AAX+), Apple lossless, AIFF, and WAV formats. In addition to the headphone jack, HD audio is also available from the proprietary Lightning connector.

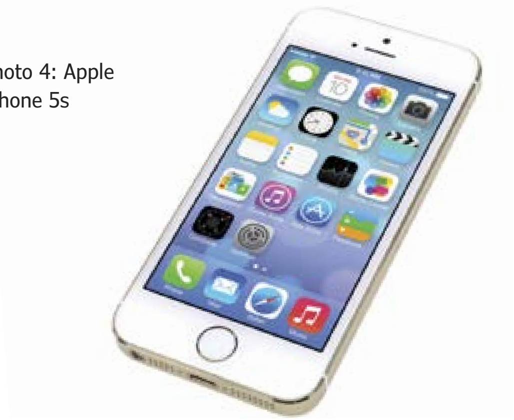


Photo 4: Apple iPhone 5s

- Apple iPhone 6—The iPhone 6 (see **Photo 5**) is the successor to the iPhone 5, advertised storage and audio specs are similar to the 5S, but will they differentiate on the test bench?

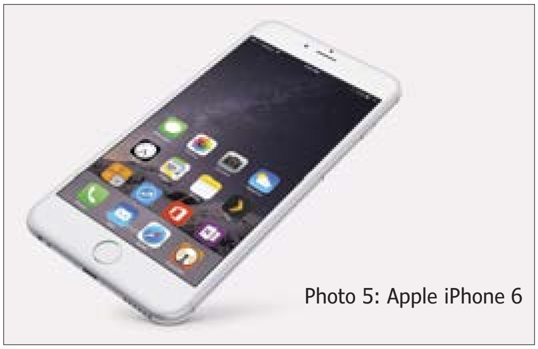


Photo 5: Apple iPhone 6

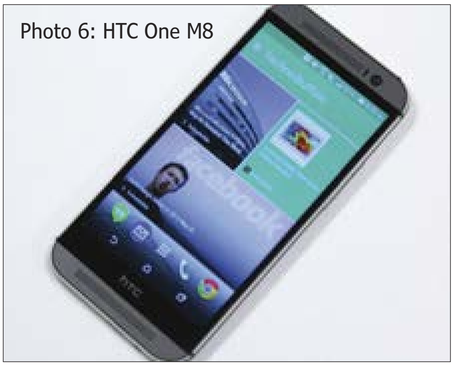


Photo 6: HTC One M8

- HTC One M8—The M8 has a pair of front facing speakers (one on each side of the display) and HTC touts its on-board "Boom Sound" listening experience (see **Photo 6**). It offers 32 GB of onboard storage with up to 128 GB available via micro SD expansion and will play all popular audio formats.

- Vivo Xplay 3S—Vivo is a Chinese brand and its 3S has the distinction of being the first smartphone offered with a 2K display (see **Photo 7**). An equal emphasis is placed on audio, using the ESS Technology ES9018 DAC, the Texas Instruments OPA2604 amplifier, as well as DTS Headphones:X for surround sound support. The S3 has 32 GB of onboard storage and expansion via micro SD.

Photo 7: Vivo Xplay 3S

- Vivo X5 Max—The X5 Max is the successor to the Xplay 3S and is advertised as the "World's Thinnest Smartphone" (5.08 mm depth) but there's more to this phone than its dimensions (see **Photo 8**). Vivo built upon the success of the Xplay 3S to deliver a product that looks great and sounds even better.

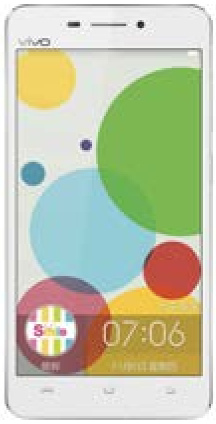


Photo 8: Vivo X5 Max

Summary of Testing and Results

The test results for each of the eight smartphones are listed in the **Tables 1–8**. During testing, we made a few notes on the test methods. Here are some of our observations.

Except for the iPod classic, all the testing was done with 24-bit .wav files. The iPod Classic would not play back the .wav files we created until they were transcoded to an Apple lossless format.

Total harmonic distortion plus noise (THD+N) and output levels were measured by playing back a 997 Hz, 0 dBFS tone, except again for the iPod

Classic. When playing back a 0 dBFS signal, this device exhibited abundant distortion so a –1 dBFS tone was used instead. The measurement passband for THD+N was 20 Hz to 20 kHz, no weighting filter was used.

For all devices, noise was measured by setting the volume to maximum and playing back a file that contained just –144 dBFS dither noise. The noise was integrated for 5 seconds.

All the devices exhibited essentially flat frequency response, so reporting eight graphs of a flat line is pointless. The listed result is the maximum deviation from flat from 20 Hz to 20 kHz. In the case of the HTC One M8, "Bass Boost" was disabled to achieve this result.

We measured the interchannel phase but all the devices exhibited perfect phase alignment between left and right making this test somewhat uninteresting.

Crosstalk or channel separation was measured by playing back a 10 kHz, 0 dBFS tone in one channel at a time and measuring the leakage in to the adjacent channel. The devices that exhibit poor separation when driving a 30 Ω load almost certainly have a resistor in the return (ground) path of the headphone jack. Some designers do this to provide a pseudo-balanced input and improve rejection of hum in the case where someone has their headphones plugged in at the same time that the phone is charging.

The High-Z configuration is driving a 100 kΩ input. Also, the 30 Ω configuration reflects the load presented by a typical headphone.

Closing Comments

There are dozens of recent smartphones on the market and well over a hundred once you account for older models still being sold. Picking the best for you can be a trying task. We won't attempt to rank the smartphones based on the test results but still, several things are clear.

The Sony Experia Z2 comes in solidly last with high noise, low drive levels, and low THD+N.

The HTC One, the Samsung Galaxy, and the iPod Classic are all quite reasonable middle of the pack contenders, but are all 10 dB worse than either the iPhones or the Vivos when driving a headphone at a reasonable listening level (100 VRMS in to 30 Ω).

Vivo 3S

		Left		Right	
		Vrms	dB	Vrms	dB
High-Z	THD+N @ Max Level	2.03	-81	2.04	-81
	THD+N @ 1 Vrms	1.04	-91	1.03	-91
	THD+N @ Best Level	0.734	-93	0.74	-93
		uVrms		uVrms	
	Noise	7.97		9.92	
		dB dB +/- Deviation		dB dB +/- Deviation	
	Frequency Response	0.02		0.02	
		Deg. Rel. to L			
	Phase	0			
		dB		dB	
	X-Talk	-69		-69	
		Left		Right	
		Vrms	dB	Vrms	dB
30 Ω	THD+N @ Max Level	0.51	-76	0.519	-77
	THD+N @ 100 mVrms	0.094	-90	0.096	-91
	THD+N @ Best Level	0.111	-92	0.113	-92
		uVrms		uVrms	
	Noise	2		2.1	
		dB +/- Deviation		dB +/- Deviation	
	Frequency Response	0.02		0.02	
		Deg. Rel. to L			
	Phase	0			
		dB		dB	
	X-Talk	-51		-51	

Sony Experia Z2

		Left		Right	
		Vrms	dB	Vrms	dB
High-Z	THD+N @ Max Level	0.29	-84	0.29	-84
	THD+N @ 1 Vrms	n/a	n/a	n/a	n/a
	THD+N @ Best Level	0.196	-84	0.196	-84
		uVrms		uVrms	
	Noise	17.7		17.7	
		dB +/- Deviation		dB +/- Deviation	
	Frequency Response	0.4		0.4	
		Deg. Rel. to L			
	Phase	0			
		dB		dB	
	X-Talk	-108		-108	
		Left		Right	
		Vrms	dB	Vrms	dB
30 Ω	THD+N @ Max Level	0.237	-49	0.245	-49
	THD+N @ 100 mVrms	0.107	-64	0.111	-61
	THD+N @ Best Level	0.076	-75	0.078	-73
		uVrms		uVrms	
	Noise	15		15	
		dB +/- Deviation		dB +/- Deviation	
	Frequency Response	0.4		0.4	
		Deg. Rel. to L			
	Phase	0			
		dB		dB	
	X-Talk	-35		-35	

Samsung Galaxy S5

		Left		Right	
		Vrms	dB	Vrms	dB
High-Z	THD+N @ Max Level	0.42	-85	0.423	-85
	THD+N @ 1 Vrms	n/a	n/a	n/a	n/a
	THD+N @ Best Level	n/a	n/a	n/a	n/a
		uVrms		uVrms	
	Noise	3.76		3.24	
		dB +/- Deviation		dB +/- Deviation	
	Frequency Response	0.01		0.01	
		Deg. Rel. to L			
	Phase	0			
		dB		dB	
	X-Talk	-97		-96	
		Left		Right	
		Vrms	dB	Vrms	dB
30 Ω	THD+N @ Max Level	0.394	-83	0.397	-82
	THD+N @ 100 mVrms	0.088	-83	0.088	-82
	THD+N @ Best Level	n/a	n/a	n/a	n/a
		uVrms		uVrms	
	Noise	3.56		3.08	
		dB +/- Deviation		dB +/- Deviation	
	Frequency Response	0.01		0.01	
		Deg. Rel. to L			
	Phase	0			
		dB		dB	
	X-Talk	-35		-35	

Apple iPhone 5S

		Left		Right	
		Vrms	dB	Vrms	dB
High-Z	THD+N @ Max Level	1.02	-93	1.02	-93
	THD+N @ 1 Vrms	n/a	n/a	n/a	n/a
	THD+N @ Best Level	0.481	-97	0.481	-97
		uVrms		uVrms	
	Noise	6		6	
		dB +/- Deviation		dB +/- Deviation	
	Frequency Response	0.09		0.09	
		Deg. Rel. to L			
	Phase	0			
		dB		dB	
	X-Talk	-79		-79	
		Left		Right	
		Vrms	dB	Vrms	dB
30 Ω	THD+N @ Max Level	0.92	-89	0.92	-89
	THD+N @ 100 mVrms	0.082	-92	0.082	-92
	THD+N @ Best Level	0.29	-97	0.29	-97
		uVrms		uVrms	
	Noise	3		3	
		dB +/- Deviation		dB +/- Deviation	
	Frequency Response	0.09		0.09	
		Deg. Rel. to L			
	Phase	0			
		dB		dB	
	X-Talk	-41		-41	

Tables 1–8: Each table shows the results obtained from tests on each of the eight smartphones: the Vivo 3S, the Sony Experia Z2, the HTC One M8, the Samsung Galaxy S5, the Apple iPhone 5s, the Apple iPod Classic, the Vivo X5 Max and the Apple iPhone 6.

The Vivos and the iPhones are the cream of the crop, displaying excellent performance in our tests and all of them will provide excellent playback quality, although the Vivos might be preferable over the iPhones when driving a high-impedance source such as an audio power amplifier.

HTC One M8

		Left		Right	
		Vrms	dB	Vrms	dB
High-Z	THD+N @ Max Level	1.03	-79	1.03	-79
High-Z	THD+N @ 1 Vrms	n/a	n/a	n/a	n/a
High-Z	THD+N @ Best Level	0.651	-92	0.649	-92
		uVrms		uVrms	
High-Z	Noise	10.2		10.1	
		dB +/- Deviation		dB +/- Deviation	
High-Z	Frequency Response	0.7		0.7	
		Deg. Rel. to L			
High-Z	Phase	0			
		dB		dB	
High-Z	X-Talk	-93		-95	
		Left		Right	
		Vrms	dB	Vrms	dB
30 Ω	THD+N @ Max Level	0.96	-78	0.96	-78
30 Ω	THD+N @ 100 mVrms	0.096	-81	0.096	-81
30 Ω	THD+N @ Best Level	0.382	-90	0.382	-90
		uVrms		uVrms	
30 Ω	Noise	9.5		9.6	
		dB +/- Deviation		dB +/- Deviation	
30 Ω	Frequency Response	0.7		0.7	
		Deg. Rel. to L			
30 Ω	Phase	0			
		dB		dB	
30 Ω	X-Talk	-41		-41	

Vivo X5 Max

		Left		Right	
		Vrms	dB	Vrms	dB
High-Z	THD+N @ Max Level	0.63	-102	0.63	-102
High-Z	THD+N @ 1 Vrms	n/a	n/a	n/a	n/a
High-Z	THD+N @ Best Level	n/a	n/a	n/a	n/a
		uVrms		uVrms	
High-Z	Noise	2.4		2.4	
		dB dB +/- Deviation		dB dB +/- Deviation	
High-Z	Frequency Response	0.02		0.02	
		Deg. Rel. to L			
High-Z	Phase	0			
		dB		dB	
High-Z	X-Talk	-103		-88	
		Left		Right	
		Vrms	dB	Vrms	dB
30 Ω	THD+N @ Max Level	0.53	-101	0.53	-99
30 Ω	THD+N @ 100 mVrms	n/a	n/a	n/a	n/a
30 Ω	THD+N @ Best Level	n/a	n/a	n/a	n/a
		uVrms		uVrms	
30 Ω	Noise	2		2	
		dB +/- Deviation		dB +/- Deviation	
30 Ω	Frequency Response	0.02		0.02	
		Deg. Rel. to L			
30 Ω	Phase	0			
		dB		dB	
30 Ω	X-Talk	-40		-41	

Apple iPod Classic

		Left		Right	
		Vrms	dB	Vrms	dB
High-Z	THD+N @ Max Level	0.96	-88	0.95	-87
High-Z	THD+N @ 1 Vrms	n/a	n/a	n/a	n/a
High-Z	THD+N @ Best Level	0.483	-89	0.48	-88
		uVrms		uVrms	
High-Z	Noise	20.5		21.5	
		dB +/- Deviation		dB +/- Deviation	
High-Z	Frequency Response	0.1		0.1	
		Deg. Rel. to L			
High-Z	Phase	0			
		dB		dB	
High-Z	X-Talk	-94		-94	
		Left		Right	
		Vrms	dB	Vrms	dB
30 Ω	THD+N @ Max Level	0.77	-26	0.77	-26
30 Ω	THD+N @ 100 mVrms	0.101	-83	0.102	-83
30 Ω	THD+N @ Best Level	179	-86	180	-85
		uVrms		uVrms	
30 Ω	Noise	17		18	
		dB +/- Deviation		dB +/- Deviation	
30 Ω	Frequency Response	0.1		0.1	
		Deg. Rel. to L			
30 Ω	Phase	0			
		dB		dB	
30 Ω	X-Talk	-41		-42	

Apple iPhone 6

		Left		Right	
		Vrms	dB	Vrms	dB
High-Z	THD+N @ Max Level	0.26	-92	0.26	-92
High-Z	THD+N @ 1 Vrms	n/a	n/a	n/a	n/a
High-Z	THD+N @ Best Level	n/a	n/a	n/a	n/a
		uVrms		uVrms	
High-Z	Noise	3.4		3.3	
		dB +/- Deviation		dB +/- Deviation	
High-Z	Frequency Response	0.04		0.04	
		Deg. Rel. to L			
High-Z	Phase	0			
		dB		dB	
High-Z	X-Talk	-64		-64	
		Left		Right	
		Vrms	dB	Vrms	dB
30 Ω	THD+N @ Max Level	0.23	-92	0.23	-92
30 Ω	THD+N @ 100 mVrms	0.11	-90	0.11	-60
30 Ω	THD+N @ Best Level	n/a	n/a	n/a	n/a
		uVrms		uVrms	
30 Ω	Noise	2.2		2.1	
		dB +/- Deviation		dB +/- Deviation	
30 Ω	Frequency Response	0.04		0.04	
		Deg. Rel. to L			
30 Ω	Phase	0			
		dB		dB	
30 Ω	X-Talk	-41		-40	