ACOUSTIC USES FOR THE iPHONE

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1 INTRODUCTION

Since its introduction in 2007, Apple's iPhone has dominated the mobile phone industry. In actuality, the iPhone is a computer running a trimmed down version of the Apple's OS X operating system. When Apple introduced the iTunes Store as a medium for music downloads, the arrival of the iPhone saw an add-in to the store allowing for specific application downloads for the iPhone and iPod Touch. These "apps" were originally targeted at the games market, but in 2008 general sound level meter applications were being developed. Rapidly, the iPhone became an all round meter with applications capable of real-time analysis in octaves and third-octaves (⅓), room acoustics, signal generation, dosimetry, and sound level logging. This paper presents comparisons of the measurement performance of the iPhone 3G(S), original iPhone EDGE, and several Class 1 and Class 2 sound level meters under various conditions and environments.

2 THE iPHONE BREAKDOWN

Every incarnation of the iPhone has seen improvements; they range from increases in processing power, operating system enhancements, improved hardware, and true 3G cellular data support. The processing power in the latest generation of iPhones, the 3G(S), rivals Apple laptop computers from 2002. One of the lesser known, but significant improvements by Apple, has been done to consecutive generations of the iPhone's built-in microphone. The microphone in the iPhone 3G(S) that was released in June of 2009 has a steep high-pass filter that has been applied to it to help eliminate wind and pop noises.[1] This has been found to be true in both the built-in microphone and external microphones that plug into the 3.5 mm headset connector. This filter causes a noticeable loss of information below 200 Hz.[2] Studio Six Digital is currently developing a professional-grade external microphone that would bypass these limitations by connecting directly into the Apple "Dock" connector at the bottom of the phone. This would allow increased measurement accuracy of 30-130 dB, 20-20 kHz (±3.0 dB).[3]

Three (3) different iPhones and two (2) different sound level meter applications were used to test just how well the built-in microphones for the iPhones performed:

- One (1) Apple iPhone 3G(S)
  Model No: A1303
  Running *SignalScopePro* by Faber Acoustical
  Microphone: built-in
- One (1) Apple iPhone 3G(S)
  Model No: A1241
  Running *AudioTools* by Studio Six Digital
  Microphone: built-in
- One (1) Apple iPhone (EDGE)
  Model No: A1203
  Running *SignalScopePro* by Faber Acoustical
  Microphone: external 3.5 mm Apple headset

3 TOLERANCES AND CALIBRATION

To assess how well the iPhone performed acoustically, the previously described models were tested in both laboratory and environmental situations against the following Class 1 and Class 2 sound level meters:

- One (1) Norsonic Nor140, Class 1 sound level meter
- One (1) Norsonic Nor132, Class 2 sound level meter
- One (1) Casella CEL-414, Class 1 sound level meter
- One (1) Casella CEL-328, Class 2 sound level meter

Given that the American National Standards Institute (ANSI) and International Electrotechnical Commission (IEC) specify different precision tolerances per sound level meter class, the iPhones' results were compared against both of these limits. ANSI standards call for an average maximum deviation of ±1.0 dB for a sound level meter to be considered Class 1, and ±1.8 dB for Class 2.[4] IEC tolerance levels are higher, allowing for an average deviation of ±1.4 dB for Class 1 meters, and ±3.9 dB for Class 2.[5]

Tolerance for Sound Level Meters ANSI S1.4-1983 (R2006)		
Nominal frequency (Hz)	Tolerance limits (dB)	
	Class 1	Class 2
63	± 1.0	± 2.0
125	± 1.0	± 1.5
250	± 1.0	± 1.5
500	± 1.0	± 1.5
1000	± 1.0	± 1.5
2000	± 1.0	± 2.0
4000	± 1.0	± 3.0
8000	+ 1.5; -3.0	± 5.0
16000	± 3.0; -∞	± 5.0; -∞

Table 1 – Level tolerances for different class sound level meters as per ANSI s1.4-1983 (R2006) are stricter than IEC standards.

All sound level meters were calibrated to 94 dB at 1 kHz with a Rion NC-74 Class 1 calibrator. The NC-74 was then set inside an anechoic chamber along with the Nor140 and all iPhones in order to calibrate the Faber Acoustical and Studio Six Digital software. The Nor140 and each iPhone, in turn, were positioned 0.34 m from the NC-74 and the iPhones were calibrated using the Nor140's reading as the target level. The process of calibrating the iPhones for both of the software applications was straightforward, but definitely not easy. Faber Acoustical's *SignalScopePro* was much more consistent with its calibration in Pascals, but cumbersome to use. Studio Six Digital's *AudioTools* suite used a dB trim in order to calibrate its software (see Figure 1). While more intuitive, *AudioTools* took a lot more effort to find the accurate calibration. Both software packages would benefit from an external microphone that could have the NC-74 attached to it in a similar fashion as the Nor140.

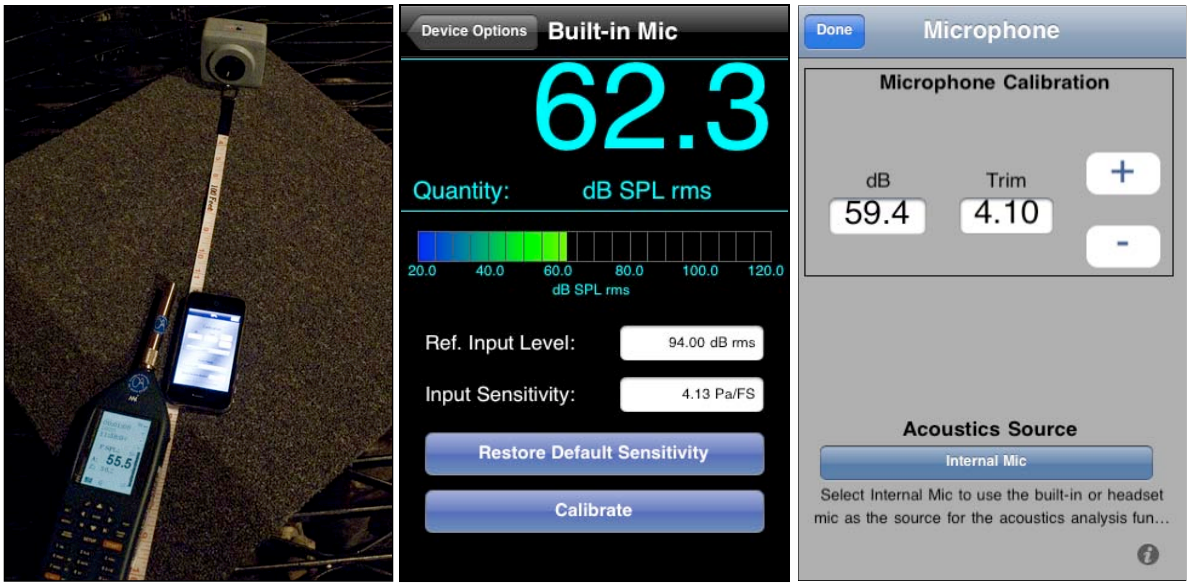

Figure 1 – The iPhone calibration process of both *SignalScopePro* (middle) and *AudioTools* (right).

4 LABORATORY TESTING

Testing of the iPhone was divided between laboratory and environmental situations. Eight (8) laboratory tests were conducted, including: measurements of background noise levels present in London South Bank University's (LSBU) anechoic chamber, reverberation room, and an empty refrigeration workshop; peak values from an impact of a steel ball on a steel plate, and the impulse of a balloon bursting; and L_{Aeq} values from an industrial fan, handheld drill, and a hair dryer.

The iPhone was compared against the Nor140 and CEL-414 Class 1 sound level meters, and a CEL-328 Class 2 sound level meter. The Nor140 measured both dB(A) and dB(Lin) values, while the CEL-414 only recorded dB(A), and the CEL-328 measured dB(Lin). Third-octave (⅓) results were recorded from the Nor140 to establish the dominant frequency of any background noise source. Multiple iPhones were used in order to measure both dB(A) and dB(Lin) values since neither Faber Acoustical or Studio Six Digital software applications allowed for the simultaneous recording of multiple weightings. Two-minute intervals were used for the L_{Aeq} recordings to compensate for any anomalies in sound levels and allow for more accurate measurements.

Background noise L_{Aeq} measurements proved to be troublesome for the iPhone in the presence of low noise levels. This was due to the high-pass filter applied to the built-in microphone for the iPhone. Both Faber Acoustical and Studio Six Digital applications had difficulty accurately measuring low levels and low frequencies, reporting values up to 21 dB(A) greater than either the Norsonic or Casella sound level meters. However, L_{Aeq} measurements with a constant noise source (drill, refrigeration motor, fan, hairdryer) in excess of 40 dB(A) gave close agreement in levels with both the Nor140 and CEL-414, often within ±0.5 dB (see Figure 2). When analyzed in octave bands, it was apparent that the high-pass filter in the iPhone colored results (see Figures 3 and 4).

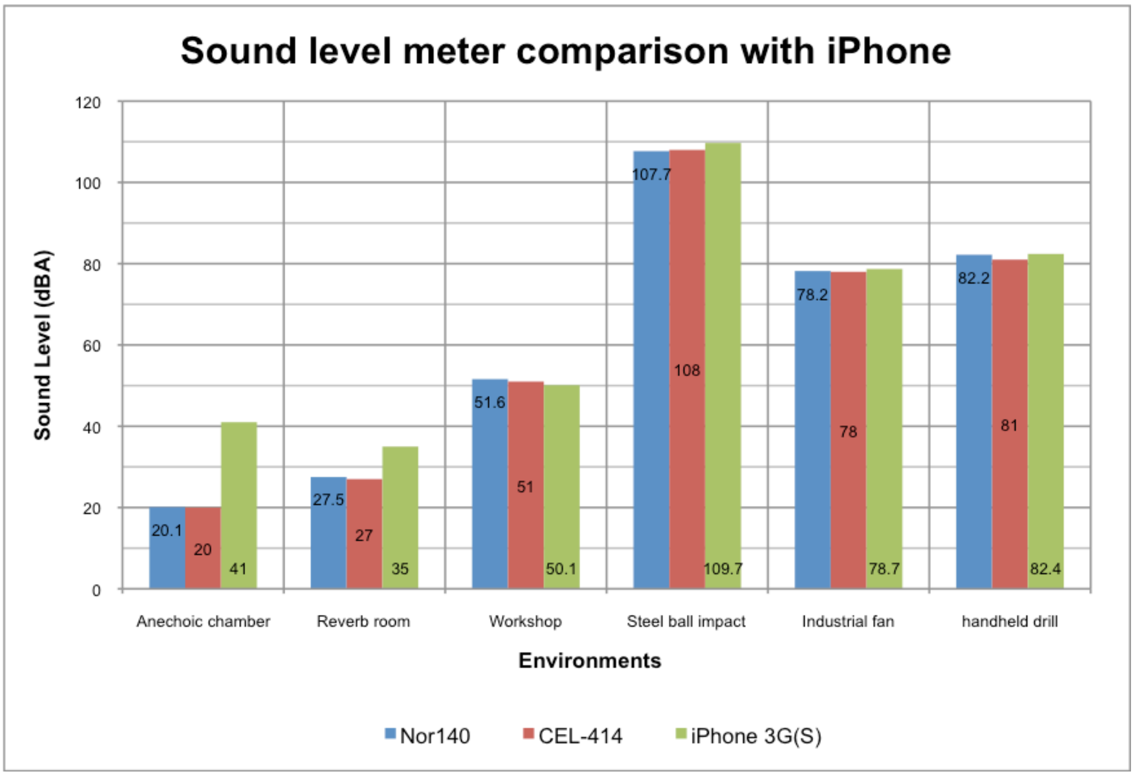

Figure 2 – Sound level meter values versus the iPhone. The iPhone performed best when conducting L_{Aeq} measurements in excess of 40 dB(A).

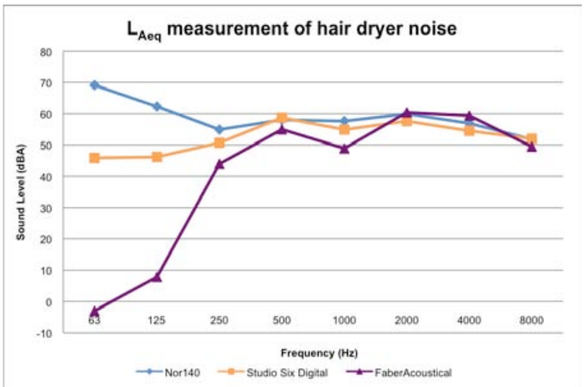

Figure 4 – Octave band comparison of the Nor140 and iPhones running Faber Acoustical and Studio Six Digital software against the broadband noise of a hair dryer.

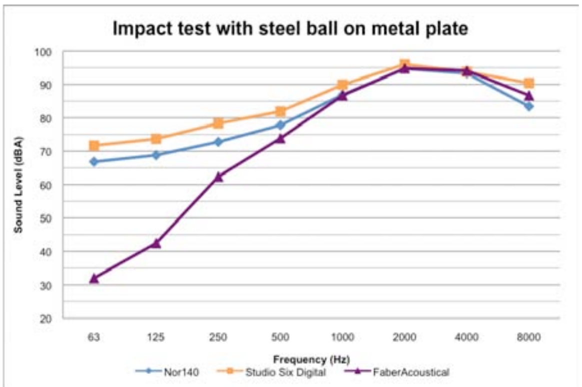

Figure 3 – The impact test showed that Studio Six Digital's software attempted to compensate for the iPhone's high-pass filter by low frequency extrapolation.

Impulsive sounds also proved difficult for the iPhone. When used to assess the peak levels of a steel ball dropping onto a steel plate from a height of 0.3 m, or the levels of a balloon bursting, the iPhone was not able to capture a true peak level. When compared to the Nor140, the iPhone, running either Faber Acoustical or Studio Six Digital software was, at times, 30 dB too low, even after repeated measurements. However, when viewing the octave band comparison of the iPhone against the Nor140, it proved again these results were biased due to the high-pass filter on the iPhone's microphone (see Figure 4). Neither software packages can accurately measure peak levels because the internal microphone clips, and both software applications register it as such. Interestingly, Studio Six Digital's *AudioTools* software compensated for this low frequency roll-off by an attempt at regression analysis.

5 ENVIRONMENTAL TESTING

The iPhone, even with its biased processing on its internal microphone and 3.5 mm headphone jack, excelled at time-averaged recordings. L_{Aeq} and single event level (SEL) measurements were all highly accurate, even in the presence of environmental conditions. Several recordings were done outdoors, in fair weather conditions, in the Elephant and Castle of South London. These recordings were time-averaged noise assessments, consisting of: a two-minute L_{Aeq} ambient noise level recording of a car park surrounded on all sides by buildings, another two-minute L_{Aeq} measurement of traffic noise alongside a busy A-road (Newington Causeway); a noise mapping survey around the parish of Borough; and a series of SEL calculations of nine (9) trains through the Elephant and Castle National Rail station.

Conducted first, were the two-minute L_{Aeq} measurements (see Figure 5). The background noise levels in the LSBU car park were recorded using the iPhone 3G(S) running Faber Acoustical, as well as the Nor140 and the CEL-414 sound level meters. Both Class 1 meters returned a reading of 54 dB(A). The majority of the sound information was contained in the low frequencies

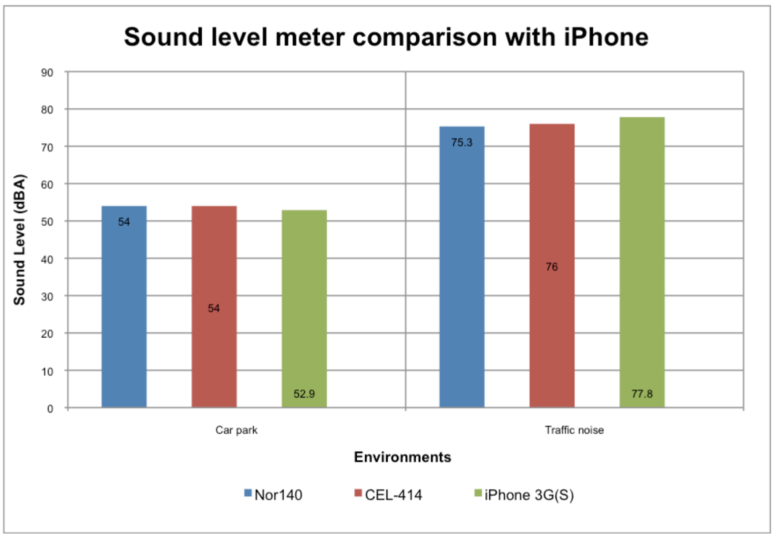

Figure 5 – The iPhone did very well in background L_{Aeq} measurements against two (2) Class 1 sound level meters, as close as -1.1 dB.

(100 Hz dominant), due to the traffic noise from the nearby Elephant and Castle roundabout. Although *SignalScopePro* reported that the dominant frequency was 630 Hz (again, a poor assessment of low frequencies due to the built-in high-pass filter), it still reported an L_{Aeq} value of 52.9 dB(A). Leaving the LSBU campus, a two-minute recording was undertaken by the Elephant and Castle roundabout, at the roadside of Newington Causeway. This recording was conducted with traffic flowing. The iPhone 3G(S) running *SignalScopePro* returned a +2.5 dB deviation from the Nor140, and a +1.8 dB difference from the CEL-414.

A short noise mapping survey was undertaken around the parish of Borough using one-minute L_{Aeq} measurements. Using Studio Six Digital's *AudioTools* to carry out these findings, the iPhone 3G(S) did exceedingly well. Over the 11 individual measurements, the average difference between the Nor140 and the iPhone was only 0.3 dB. The only reading where the iPhone gave a difference of over 1.0 dB was when it was stationed within 3 m of roadworks (see Figure 6).

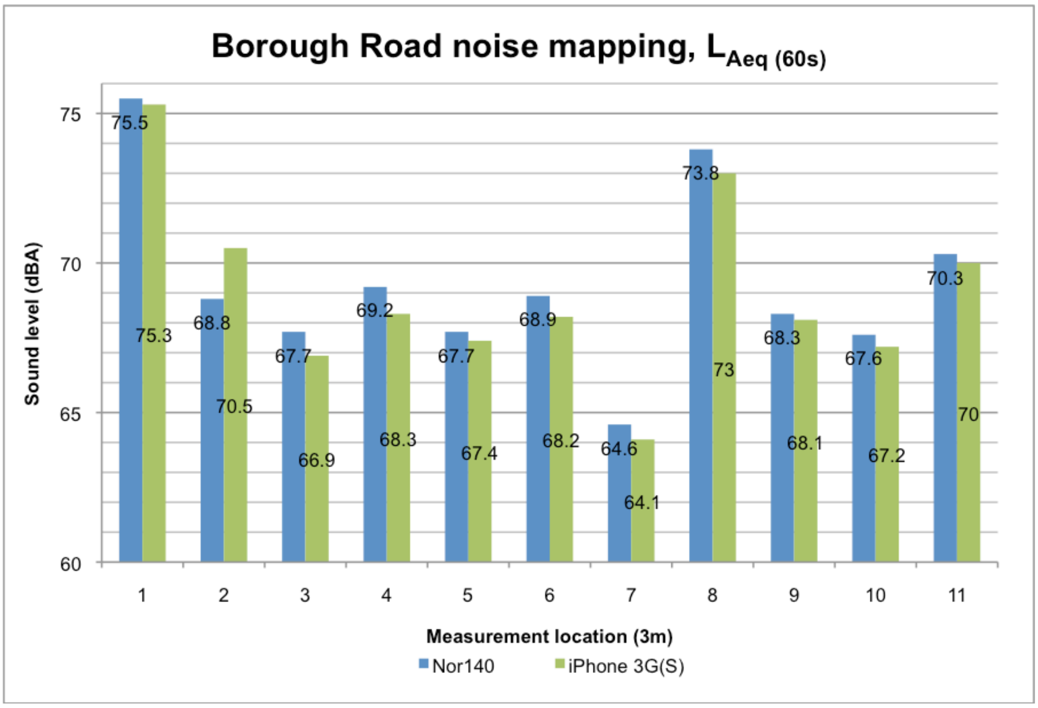

Figure 6 – The iPhone did well on L_{Aeq} measurements along a 33 m stretch of a busy road, being an average of 0.3 dB within the Class 1 Norsonic Nor140.

The last environmental test conducted was an extensive test of two (2) Norsonic sound level meters and three (3) iPhones documenting SEL and L_{Aeq} train events at the Elephant and Castle National Rail station. All sound level meters were positioned on the central train platform, 3 m from any platform edge or façade. As the three (3) iPhones and the Nor132 obtained individual L_{Aeq} measurements, another 3 m down the platform the Nor140 recorded a single L_{Aeq} measurement for the full 30-minute duration.

Both Faber Acoustical and Studio Six Digital's sound level meter applications for the iPhone showed strength in their single L_{Aeq} measurements, their SEL calculations, and by being able to change their time duration for L_{Aeq} recordings easily with few steps (see Figure 7). In contrast, the Nor132 took too many steps to alter its recording times and missed some measurements. Because of this, the L_{Aeq} total from the Nor132 of the nine (9) individual readings was lower than all others (see Figure 8). In comparison to the Nor140, all iPhones performed very well, being within ±2 dB. *AudioTools* by Studio Six Digital was +0.7 dB compared to the Nor140, and Faber Acoustical's *SignalScopePro* was -1.5 dB.

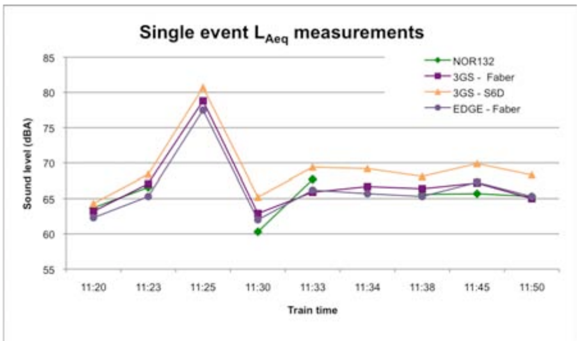

Figure 7 – Results of the three (3) iPhones and the Nor132 for each trains' L_{Aeq}. Due to train speed, the Nor132 was unable to capture the 11:25 or 11:34 train.

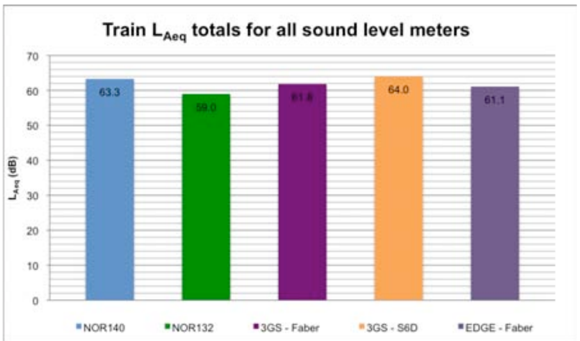

Figure 8 – All iPhones performed well with the time-averaged train assessments. The iPhone 3G(S) running *AudioTools* was +0.7 dB within the Class 1 Nor140.

6 CONCLUSIONS

With its processing power, sophisticated operating system, and modern hardware, the Apple iPhone is quite a competent and capable sound level meter in its own right, even with its built-in microphone. The results of the laboratory and environmental experiments showed the iPhone excelled in time-averaged sound level measurements, and performed within ±0.7 dB compared to a Class 1 sound level meter. Given that ANSI standards allow for tolerances of maximum expanded uncertainty to be ±1.0 dB for Class 1 sound level meters, and IEC standards as ±1.4 dB, the iPhone was easily within this range for typical noise sources.

The sound level meter applications for the iPhone do need further development; neither Faber Acoustical's nor Studio Six Digital's acoustic applications can offer the true flexibility of options or strength that a professional sound level meter can. As they stand, it is hard to justify either application as truly conforming to IEC standards, as they lack the ability to measure multiple weighting factors at once, are cumbersome to calibrate at best, do not process peak hold values well, and under-range conditions are not displayed.[6] Though, both Faber Acoustical and Studio Six Digital are branching out further to offer advanced acoustic processing applications that can do impulse response measurement and fast Fourier transform (FFT) analysis, it would be most beneficial that the main sound level meter applications were further developed to rival professional software interfaces.

Ultimately, though, everything comes back to the integrated microphone and 3.5 mm jack of the iPhone having a steep high-pass filter applied to it. Without an external microphone that completely bypasses this filtering mechanism allowing for proper calibration, accurate octave and third-octave (⅓) measurements of peak and impulse sounds, and proper low frequency background noise assessments, it cannot be considered either a valid Class 1 or Class 2 sound level meter.[7] As it stands, those types of measurements all suffer when dependent on the shipping hardware configuration of the iPhone. The inclusion of a dependable, external microphone that could plug into the iPhone's "Dock" connector to bypass the high-pass filter on the internal microphone and 3.5 mm jack would make the iPhone an ideal sound level meter for both accuracy and affordability.

7 REFERENCES

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