

NIOSH Sound Level Meter Application (app) for iOS devices

Hearing Loss Prevention Team

Engineering and Physical Hazards Branch

Division of Applied Research and Technology



NIOSH Sound Level
Meter



Developed in collaboration by EA LAB, Inc. under MOU agreement between NIOSH and EA LAB

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Why did NIOSH develop this app?

NIOSH estimates that 22 million workers are exposed to hazardous noise levels every year. In addition to damaging workers' quality of life, occupational hearing loss carries a high economic price to society. The NIOSH hearing loss team evaluated 192 sound measurement applications (apps) for the iOS and Android platforms to examine their suitability and accuracy in relation to professional sound measurement instruments. Of the 192 apps, 10 iOS apps met our selection criteria for functionality, features, and calibration capability, and only 4 apps met our accuracy criteria of (± 2 dB(A) mean difference from the reference type 1 sound level meter). The results were published in the Journal of Acoustical Society of America (JASA): [Evaluation of smartphone sound measurement applications, Kardous and Shaw 2014](#). A followup study on the use of smartphone with external microphones was published in JASA in 2016 ([Evaluation of smartphone sound measurement applications \(apps\) using external microphones—A follow-up study, Kardous and Shaw 2016](#)), the study revealed that apps used with external calibrated microphones show close agreement with Type 1 sound level meter (accuracy within ± 1 dB(A) of reference type 1 sound level meter).

The studies also revealed that most commercially available sound measurement apps lacked the accuracy and functionality necessary to conduct occupational and general-purpose noise measurements. As a result, NIOSH hearing loss researchers collaborated with one of the 4 app developers to develop a free sound measurement app that can be distributed to the occupational safety and health community as well as the general public. NIOSH signed an MOU agreement with EA LAB in February 2015 to develop the NIOSH Sound Level Meter app. The app was subjected to the same testing requirements that were established in the Kardous and Shaw studies.

The ubiquity of smartphones and the sophistication of current sound measurement applications present a great opportunity to revolutionize current data collection and surveillance practices for noise. Through the use of crowdsourcing techniques, workers around the world may be able to collect and share workplace (or task-based) noise exposure data using their smartphones. Scientists and occupational safety and health professionals can rely on such shared data to build job exposure databases and promote better hearing health and prevention efforts. In addition, the ability to acquire and display real-time noise exposure data raises workers' awareness about their work (and off-work) environment and allows them to make informed decisions about hazards to their hearing. A NIOSH-developed and branded occupational sound measurement smartphone app will help advance the NIOSH mission by translating knowledge of occupational sound measurement into a practical and informational product that will be available to more than 1.3 billion active iOS devices worldwide.



Figure 1. The main screen of the NIOSH SLM app (shown with an external microphone on iPhone 8)

Does this app comply with ANSI or IEC sound level meter or noise dosimeter standards?

Professional sound level meters (SLMs) must comply with national and international standards such as the American National Standards Institute (ANSI) S1.4-2014), Specifications for Sound Level Meters and International Electrotechnical Commission (IEC) 61672, Sound Level Meters: Specifications (ANSI adopted the IEC standard in 2014). ANSI/IEC standards specify acoustical, electrical, and environmental tests with indicated tolerance limits and measurement uncertainties that are specified in decibels over a wide frequency range (typically from 10 Hz – 20 kHz). Such tests must account for level linearity, directionality, time and frequency-weighting responses, tone bursts, radio frequency interference, and atmospheric and environmental conditions. The standards also specify that these tests shall be made on the complete instrument, including the microphone and pre-amplifier.

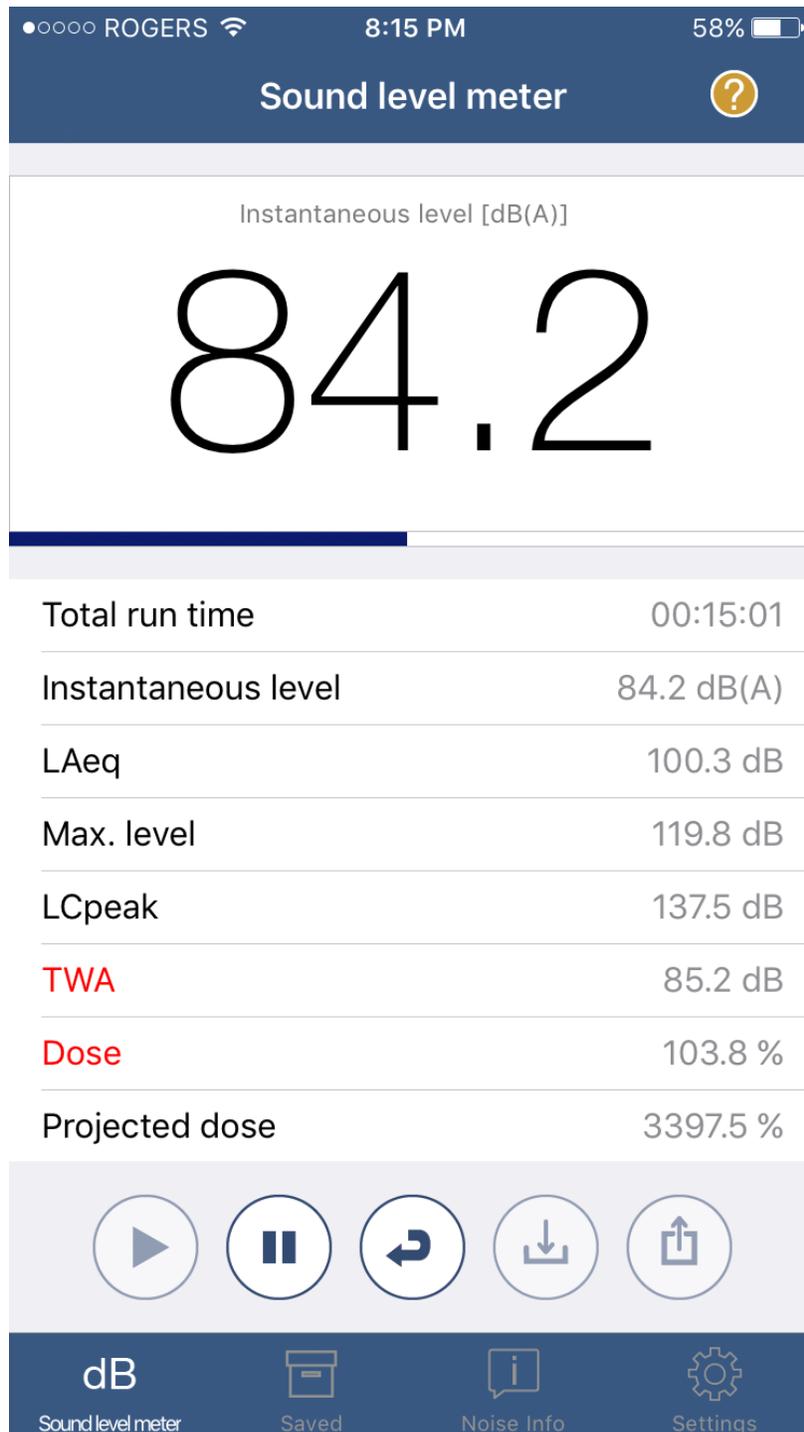
In 2018, EA LAB and NIOSH researchers evaluated the app's performance as part of a system (iPhone + external microphone) for compliance with type 2 requirements of IEC 61672/ANSI S1.4 standard: Sound Level Meters – Part 3: Periodic Tests. The results were published in the Applied Acoustics Journal [Celestina et al. 2018].

Celestina, M., Hrovat, J., & Kardous, C. A. (2018). Smartphone-based sound level measurement apps: Evaluation of compliance with international sound level meter standards. *Applied Acoustics*, 139, 119-128. <https://doi.org/10.1016/j.apacoust.2018.04.011>

NIOSH and EA LAB continue to work towards achieving compliance with Part 1 and 2 or IEC 61672, but as of today, this is the only app that has shown any compliance with sound level meters standards. This app is meant to serve as a practical tool to raise awareness about noise levels in the workplace. Increased awareness could lead workers and managers to request full professional noise surveys and implement engineering controls or hearing conservation programs to reduce the risk of noise-induced hearing loss.

Main Screen (Sound Level Meter)

Once the user launches the app, they will be presented with a main screen (dB icon highlighted on the bottom left corner). The top half of the screen shows a readout of the sound level using the built-in microphone (or external microphone if used) and reports the instantaneous sound level in A, C, or Z-weighted decibels. The weighting is user-selectable and can be accessed in the Settings screen.



What are the main features of the NIOSH SLM app?

The NIOSH Sound Level Meter app has many important features: it provides a readout of the sound level using the built-in microphone (or with an external microphone) and reports the instantaneous sound level in A, C, or Z-weighted decibels. The weighting is user-selectable and can be accessed in the “Settings” screen. The app also reports the main metrics that are important for proper occupational noise measurements: run time (total time), A-weighted equivalent sound level (LAeq), maximum level measured during the current run time, C-weighted peak sound pressure level (LCpeak), time-weighted average (TWA), and dose. The app also contains basic information about noise and hearing loss prevention. In addition, the app allows the user to save and share measurement data using the smartphone other communication and media features. If location services are enabled, the app can use the GPS feature to provide an exact geospatial location of the location of the noise measurement.

- **Total run time:** Total run time for the current measurement
- **Instantaneous level:** Default sound pressure level in A, C, or Z-weighted decibels [dB(A), dB(C), dB(Z)].
- **LAeq:** Equivalent (averaged every second) continuous sound level in A-weighted decibels [dB(A)].
- **Max level:** Highest sound pressure level during a measurement period.
- **LCpeak:** Peak sound pressure level in C-weighted decibels [dB(C)].
- **TWA:** Time-weighted average is the sound level accumulated over any time period, but with its average computed over an 8-hour time period.
- **Dose:** A percentage of the maximum allowable daily noise dose. Exposures at 100% or above are considered hazardous.
- **Projected Dose:** The current noise dose, over the current measurement duration, projected forward over 8 hours (assuming the sound level remains constant over that same 8-hour period)

On the bottom of the screen, there are five major buttons: Start, Pause, and Reset:



The app will give the user a warning before reset, Save, and Upload (through email)).

A permanent bar at the bottom of the screen allows the user to switch between the main 4 screens of the app – Soundlevelmeter (dB), Saved, Noise info, and Settings.



The user can toggle back and forth between these screens and can also use the ← button at the top left of the screen to go back to the previous screen.



There is a help button that the user can select to get more information about the specific screen:

Making a noise measurement

To make a measurement, hold the phone with the microphone (typically on the bottom of the phone) pointed at the source of noise and away from the body or other objects (about an arm's length). Same if using an external microphone. The readout on the main screen will give you the instantaneous sound level and will fluctuate constantly as the ambient noise level changes. Please note that microphones are susceptible to humidity, temperature, wind, and other conditions, and as a result the accuracy of the measurement will change from day to day, and from location to location, and with the age of the smartphone. NIOSH recommends using an external microphone

Measurement

Use the start, pause and reset button to control the measurement. Tapping pause button will temporarily stop the measurement, but it can be continued by tapping the start button. Tapping reset will erase all measurement data.

Parameters

All of the measured parameters are displayed in the table, but you can pick any parameter and display it on very prominently above the table. To do so just tap the parameter, that you want to display, in the table.

Explanation of parameters

Total time: Total run time for the current measurement.
Instantaneous level: Default sound pressure level in A-weighted decibels dB(A).
LAeq: Equivalent (averaged every second) continuous sound level in A-weighted decibels dB(A).
Maximum level: Highest sound pressure level during a measurement period.
LCpeak: Peak sound pressure level in C-weighted decibels.
TWA: Time-Weighted Average is the sound level accumulated over any time period, but with its average computed over an 8-hour time period

Saving measurements

Tap the save button to save the measured results. The list of saved measurements is available in "Saved" tab.

Sharing

Tap the share button to share the measured results via email. The measurement results are presented in a nicely designed html report.

How to interpret the results or readouts of the app

NIOSH establishes recommended exposure limits (REL) for various hazards on the basis of the best available science and practice. The REL for noise is 85 decibels, using the A-weighting frequency response an 8-hour average, usually referred to as time-weighted average (TWA). Exposures at or above this level are considered hazardous. OSHA sets legally enforceable permissible exposure limits (PEL) that require employers to take actions to reduce worker exposures. The OSHA PEL for noise is 90 dB(A) as an 8-hr TWA based on a 5-dB exchange rate.

Occupational standards specify a maximum allowable daily noise dose, expressed in percentages. For example, a person continuously exposed to 85 dB(A) per NIOSH or 90 dB(A) per OSHA over an 8-hour work shift, will reach 100% of their daily noise dose. The noise dose is based on both the sound exposure level and how long it lasts (duration). This dose limit uses a 3-dB time-intensity tradeoff commonly referred to as the exchange rate or equal-energy rule: for every 3-dB increase in averaged noise exposure, the allowable exposure time is reduced by half. For example, if the exposure increases to 88 dB(A), workers should be exposed for only 4 hours. Alternatively, for every 3-dB decrease in averaged noise exposure, the allowable exposure time is doubled, as shown in the table below.

Time-Weighted Average (TWA)	Time to reach 100% daily noise dose
85 dB(A)	8 hours
88 dB(A)	4 hours
91 dB(A)	2 hours
94 dB(A)	60 minutes
97 dB(A)	30 minutes
100 dB(A)	15 minutes

It is important to differentiate between noise level and time-weighted average noise exposure. While noise levels describe the intensity of sounds at a given point in time, the NIOSH exposure limits are set as time-weighted average exposures over periods of time. If sound level measurements consistently exceed 85 dB(A), we recommend that you follow up with a professional such as an industrial hygienist or occupational safety and health specialist to conduct a professional noise survey at your workplace. Remember, protecting your hearing is a good health practice no matter where your ears are!

Saved measurements screen

The second screen gives the user a list of “Saved measurements” with date and time stamp and the TWA for that specific measurement. Each saved measurement is stored separately.



A detailed look at what the saved measurement contains, the report information (date, measurement time, operator, location) as well as the measured values from the mains screen.

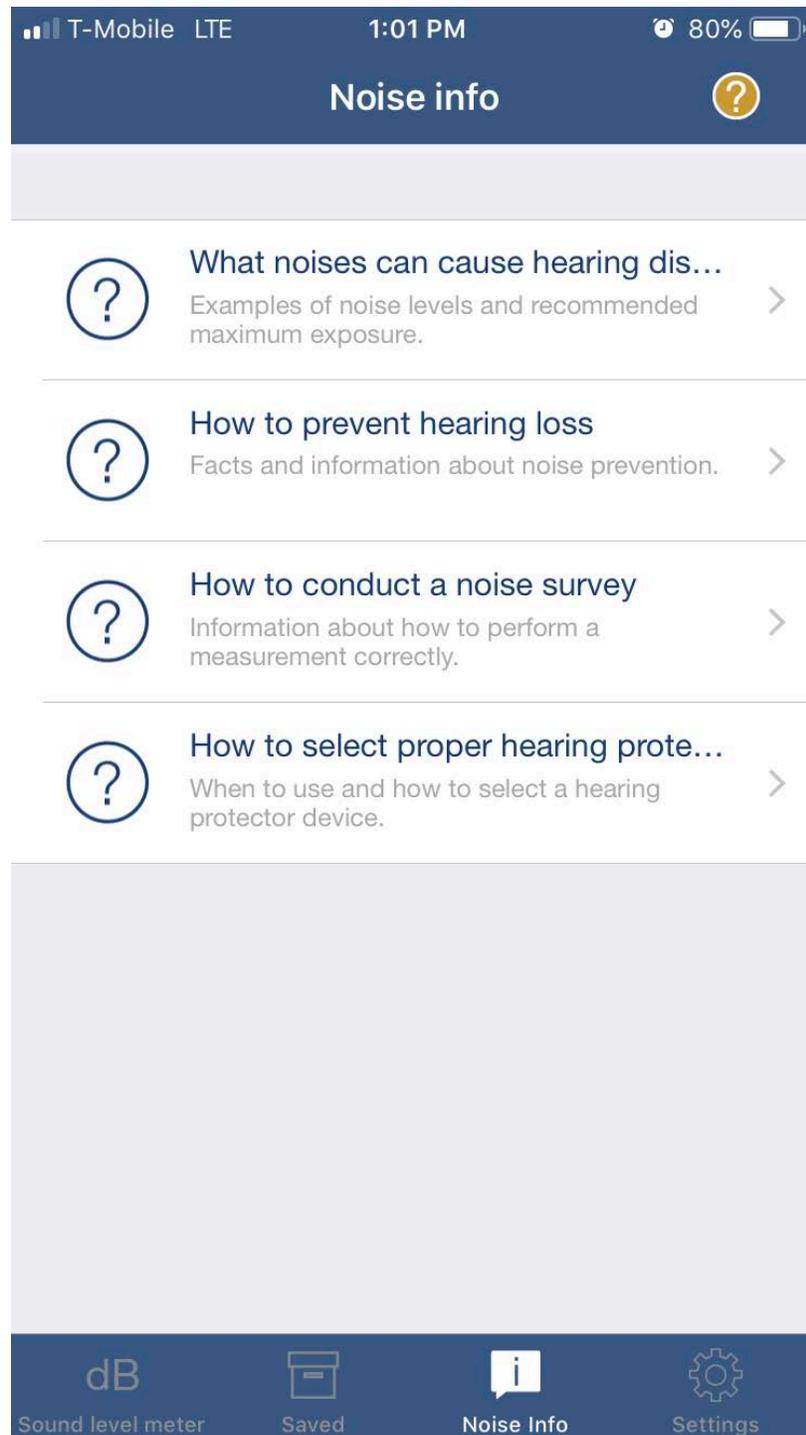
The screenshot shows a mobile application interface for a sound level meter. At the top, the status bar displays 'AT&T', signal strength, Wi-Fi, the time '10:39 AM', and battery level '95%'. Below the status bar is a dark blue header with a back arrow, the text 'All', the title 'Measurement', and an upload icon. The main content is divided into two sections: 'GENERAL' and 'MEASURED VALUES'. The 'GENERAL' section lists: Date (10/20/18, 8:22 PM), Measurement time (00:01:00), Operator (Chuck), and Location (DTW - CVG). The 'MEASURED VALUES' section lists: LAeq (82.3 dB), Max. level (83.3 dB), LCpeak (105.7 dB), TWA (55.4 dB), Dose (0.1%), and Projected dose (52.2%). At the bottom is a dark blue navigation bar with four icons: 'dB' (Sound level meter), 'Saved' (document icon), 'Noise Info' (info icon), and 'Settings' (gear icon).

GENERAL	
Date	10/20/18, 8:22 PM
Measurement time	00:01:00
Operator	Chuck
Location	DTW - CVG

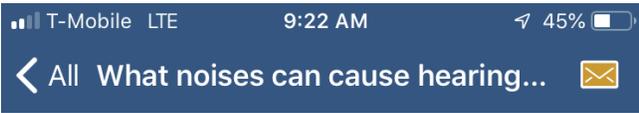
MEASURED VALUES	
LAeq	82.3 dB
Max. level	83.3 dB
LCpeak	105.7 dB
TWA	55.4 dB
Dose	0.1 %
Projected dose	52.2 %

Noise info screen

The third screen contains basic information from the NIOSH Noise and Hearing Loss Prevention Program and other NIOSH research resources:



a. What noises can cause hearing disorders

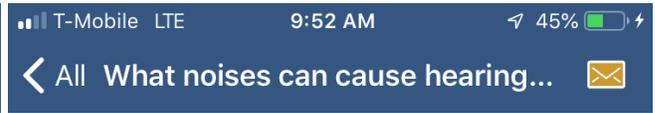


Exposure to loud sounds can cause hearing loss, tinnitus, or both. Hearing loss is often caused by prolonged exposure to loud sounds (especially when hearing protection is not used or the ear does not have enough time to rest between exposures) but it can also happen from a single very loud exposure such as that from firearm or a firecracker. The louder the sound, the shorter the amount of time it takes for hearing loss to occur. NIOSH uses a 3-dB exchange rate which is also known as "trading ratio" or "time-intensity tradeoff", it basically means that for every 3-dB increase in noise exposure, the duration must be cut in half. Conversely, for every 3-dB decrease in noise exposure, duration of exposure can be doubled.



Know which noises can cause damage. Wear hearing protection when you are involved in a loud activity.

- **85 dB(A)**
Regular and prolonged exposures to noise at or above 85 dB(A) (averaged over 8 hours per day)



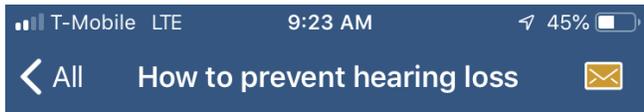
- **85 dB(A)**
Regular and prolonged exposures to noise at or above 85 dB(A) (averaged over 8 hours per day) are considered hazardous.
- **100 dB(A)**
Regular and prolonged unprotected exposure of more than 15 minute per day risks permanent hearing loss.
- **110 dB(A)**
Regular and prolonged unprotected exposure of more than 1.5 minutes per day risks permanent hearing loss.

Examples of noise levels

- **194 dB** Loudest possible tone
- **180 dB** Rocket launch
- **165 dB** 12-gauge shotgun
- **140 dB** Jet engine at takeoff
- **120 dB** Ambulance siren
- **119 dB** Pneumatic percussion drill
- **114 dB** Hammer drill
- **108 dB** Chain saw
- **108 dB** Continuous miner
- **105 dB** Bulldozer, spray painter
- **103 dB** Impact wrench
- **98 dB** Hand drill
- **96 dB** Tractor
- **93 dB** Belt sander
- **90 dB** Hair dryer/power lawn mower



b. How to prevent hearing loss

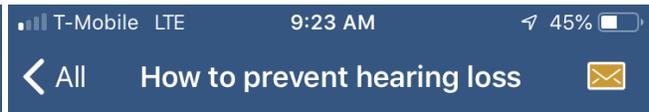


The obvious best prevention strategy is to avoid loud noise and activities. Prolonged exposures above 85 A-weighted, decibels (dBA) without protection, can harm your hearing. A single high-level exposure (e.g., firearm or fireworks) can reach over 150-170 dB and can cause immediate mechanical damage to the inner ear. If you need to shout to be heard, the noise is too loud and may be dangerous. Noise-induced hearing loss is irreversible, but 100% preventable.

There several ways to protect your hearing, whether at work or at play. Know which noises can cause damage - if the app average reading is consistently above 85 dB, you are at risk. The single most important thing to protect your hearing is to walk away. Some other proven tips:

- Avoid loud, noisy activities and places.
- If you use headsets for work, or listen to music often, turn the volume down or use noise-cancelling headsets that can block ambient noise.
- Take breaks from noisy activities so your ears can rest.
- Use hearing protection.
- Get your hearing tested if you are exposed to loud noise often.

In the workplace, NIOSH's [Criteria Document](#) and the [Practical Guide - Preventing Occupational Hearing Loss](#) describe the attributes of successful hearing loss prevention programs. The main components of such a program are:



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In the workplace, NIOSH's [Criteria Document](#) and the [Practical Guide - Preventing Occupational Hearing Loss](#) describe the attributes of successful hearing loss prevention programs. The main components of such a program are:

1. Noise exposure monitoring
2. Engineering and administrative controls
3. Audiometric evaluation
4. Hearing protection devices
5. Education and motivation
6. Record keeping
7. Program evaluation
8. Program audit



c. How to conduct a noise survey

Noise surveys are usually conducted to identify which workers/individuals are exposed to harmful noise levels and to provide appropriate information to take corrective action such as noise control, or enrollment in a hearing conservation program. Some suggested tips:

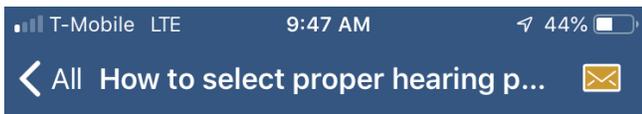
- If feasible, we recommend using an external microphone that can be calibrated with acoustical calibrator.
- If an external microphone is not available or cannot calibrate to known source prior to measurement, several repeated measurements may be required to get a representative sample.
- Hold the smartphone with internal (or external microphone) at about 10 - 12" (~25-30 cm) from your "hearing zone" (sphere around your head).
- The microphone should be pointed directly at the source of noise, preferably at 30° - 45° angle.
- If the noise source is constant, you only need a 30 second to 1 minute measurement.
- If the noise source is varying, longer periods of measurements are desired, to try to capture all the variations. Suggest at least 15 minutes.
- Take precautions not to touch the microphone, tap, or rub with your fingers as this can introduce artifacts into the measurement.
- Do not use in high wind conditions, use windscreen if you are using external microphone (some come equipped with windscreens).
- Avoid measuring within 1 meter of large noise

More detailed information, instructional videos, a user manual, and how to interpret specific results can be found in the NIOSH SLM webpage:
<https://www.cdc.gov/niosh/topics/noise/app.html>

Useful measurement standards:

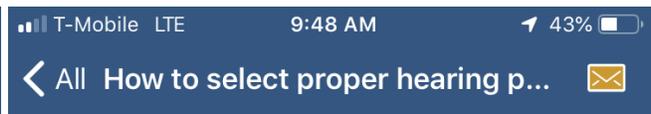
- ANSI S12.19-1996 (R2006) - Measurement of Occupational Noise Exposure
- CSA Standard Z107.56-2013 (R2018) - Procedures for the Measurement of Occupational Noise Exposure

d. How to select proper hearing protection



Hearing damage can occur by prolonged exposure to noise at or above 85 decibels, A-weighted (dBA). Hearing protectors are designed to reduce the amount of hazardous noise reaching the inner ear. Most countries require the manufacturer to provide a label to indicate the amount of attenuation that a hearing protector provides:

- In the U.S., the EPA requires a Noise Reduction Rating (NRR) label to be used on packaging. The NRR range is from 0 to about 35 decibels and provides a mean attenuation over seven test frequencies (from 125 Hz through 8000 Hz) when worn properly, however, NIOSH and OSHA recommend a de-rating scheme since most people are unlikely to attain the full attenuation indicated by the NRR. Most recently, NIOSH recommends fit-testing (measure noise reduction for the individual workers using fit-testing systems) over de-rating method.
- In Canada, the Canadian Standards Association specifies different Classes for hearing protectors - Class A offer highest protection and be used up to a TWA 105 dBA, Class B up to 95 dBA, and Class C up to 89 dBA. They also specify the suffix "L" for hearing protectors that have at least 20 dB of protection at low frequency (125 Hz).
- In most of Europe, the European Union specifies a rating called Single Number Rating (SNR) based on tests conducted at independent laboratories. The SNR is a single value that provides an



To get the best protection from your soft foam earplugs, remember to **roll**, **pull**, and **hold** when putting them in. Use clean hands to keep from getting dirt and germs into your ears!



1. Roll the earplug up into a small, thin "snake" with your fingers. You can use one or both hands.



2. Pull the top of your ear up and back with your opposite hand to straighten out your ear canal. The rolled-up earplug should slide right in.



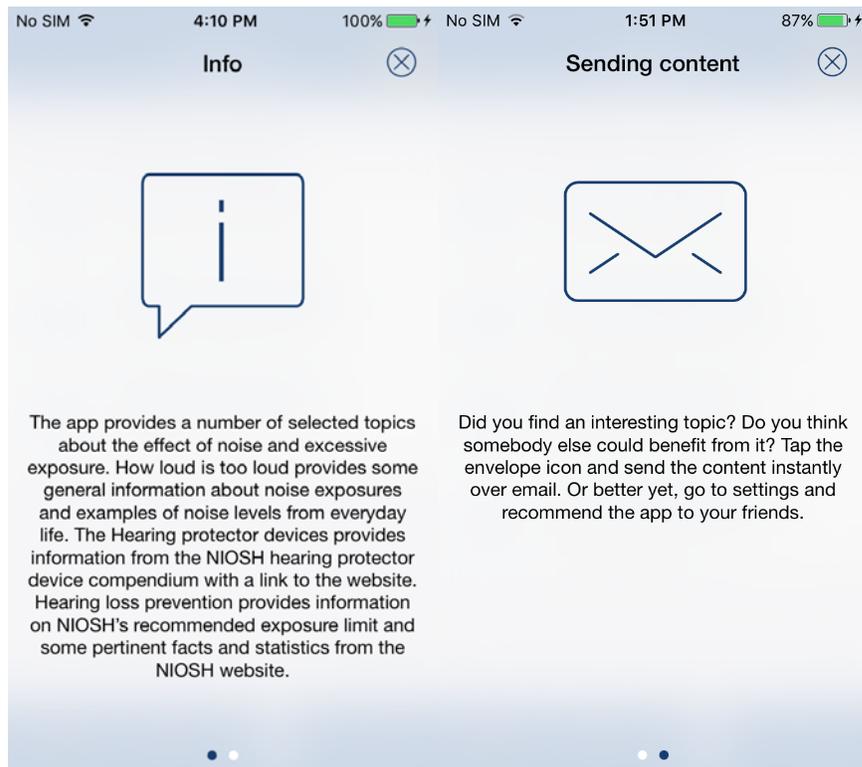
3. Hold the earplug in with your finger. Count to 20 or 30 out loud while waiting for the plug to expand and fill the ear canal. Your voice will sound muffled when the plug has made a good seal.

Additional resources:

- NIOSH Personal Protective Equipment (PPE) <https://www.cdc.gov/niosh/topics/noise/reducenoise>
- Hearing protection - OSH WIKI https://oshwiki.eu/wiki/Hearing_protection
- Best practice bulletin: Hearing protection-emerging trends: Individual Fit Testing <https://c.ymcdn.com/sites/www.hearingconservation>
- The EPA labeling standard is defined in Code of Federal Regulations (CFR) 40, Part 211, Subpart B - Hearing Protective Devices.
- Canada Class is defined in Canadian Standards Association Z94.2-02 Hearing Protection Devices

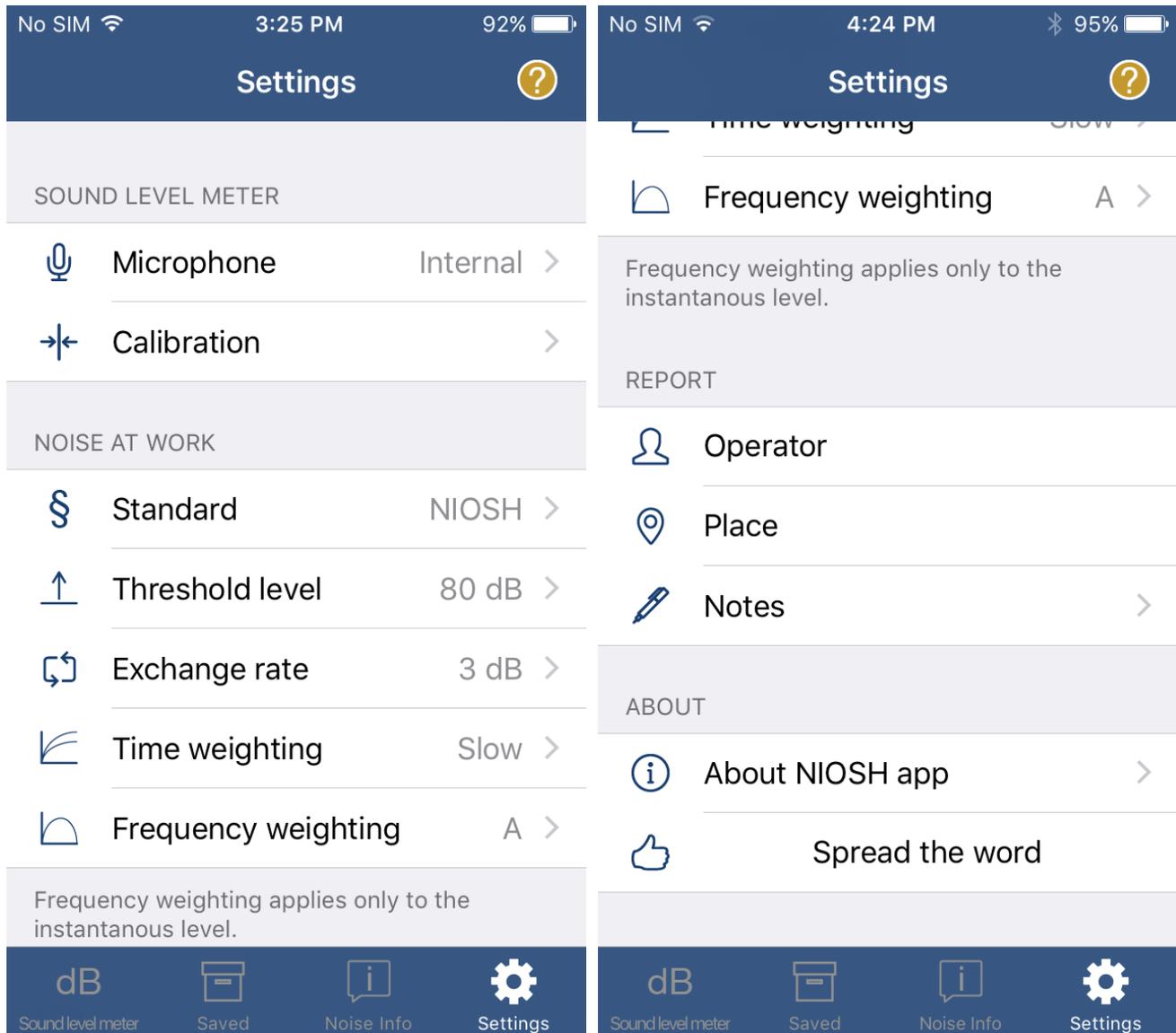


There are two “help” screens for such as for Info, and Sending content from the Noise info screens.



Settings Screen

The settings screen provides the user with the proper controls and settings to make accurate measurements.



Under **SOUND LEVEL METER**, there are two control settings:

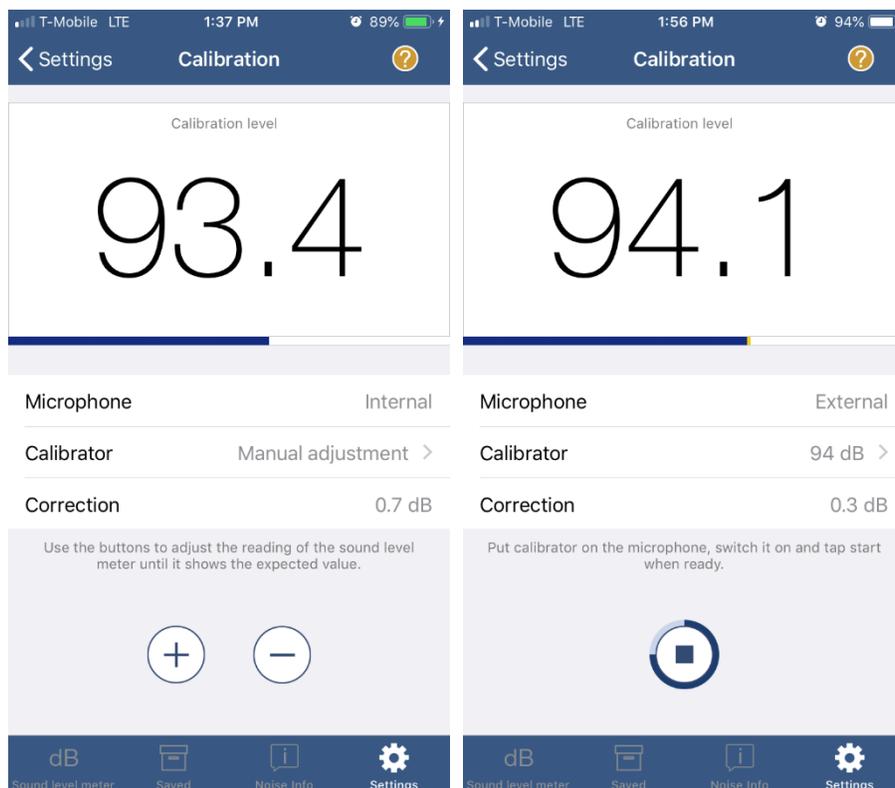
1. **Microphone:** Allows the user to select between the built-in internal microphone or an external microphone connected to lightning port or a headset jack.
2. **Calibration:** Allows the user to calibrate the app before each use, either manually or automatically. The process of calibration is used to adjust the reading of the app (which might not be always correct because of differences in microphone sensitivity, effects of environmental conditions, or possible damage from mishandling or manufacturer defect) to match a known sound source. Calibration is recommended before and after each measurement. The app offers two forms of calibrations, manual (for internal microphones) and automatic (for external microphones):

a. **Manual Calibration:**

The user can manually adjust the reading on the calibration screen by pressing the plus (+) or minus (-) buttons on the screen to match the reading of a known reference, such as a calibrated sound level meter. The level can be adjusted in 0.1 dB increments.

b. **Automatic Calibration**

The automatic adjustment feature is best used for calibrating the app with external microphones. This is an advanced feature aimed at more professional sound measurements since it requires access to an acoustical calibrator as well. The users places the acoustical calibrator on the microphone as shown, most acoustical calibrators can generate a calibration tone of 94 dB or 114 dB (sound pressure level). The user presses the Play button and the app will adjust the level automatically to either 94 dB or 114 dB.

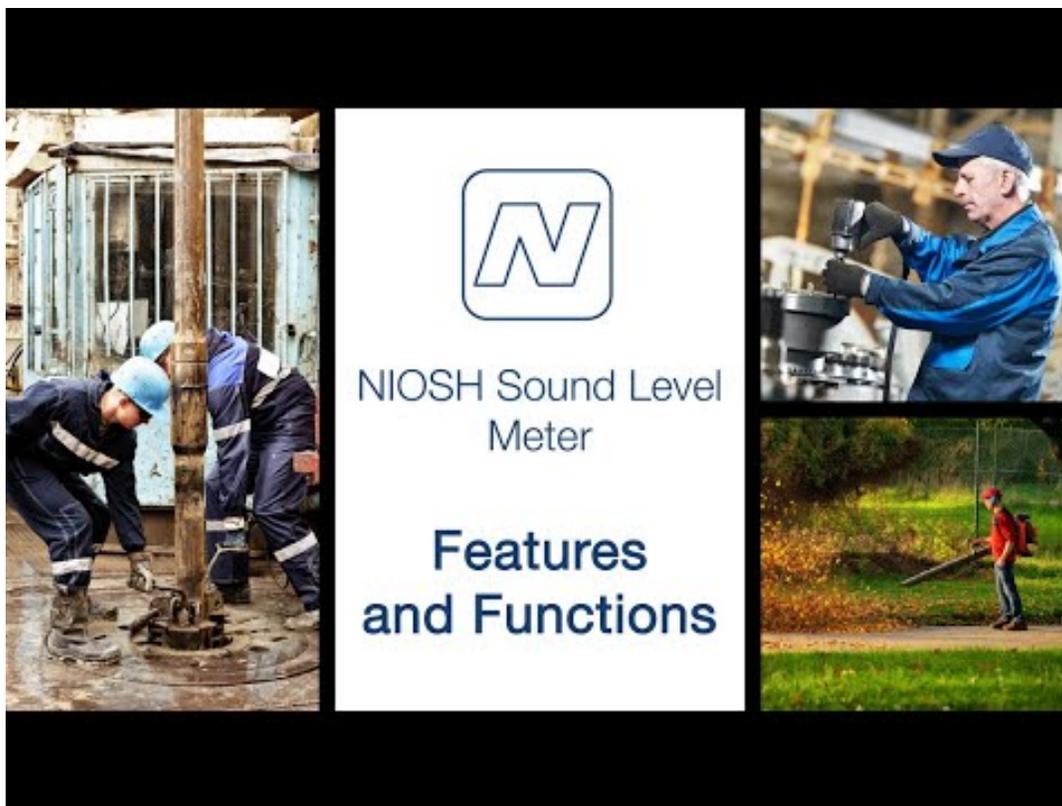


The image below shows how to calibrate the app with an external microphone using an acoustical calibrator:

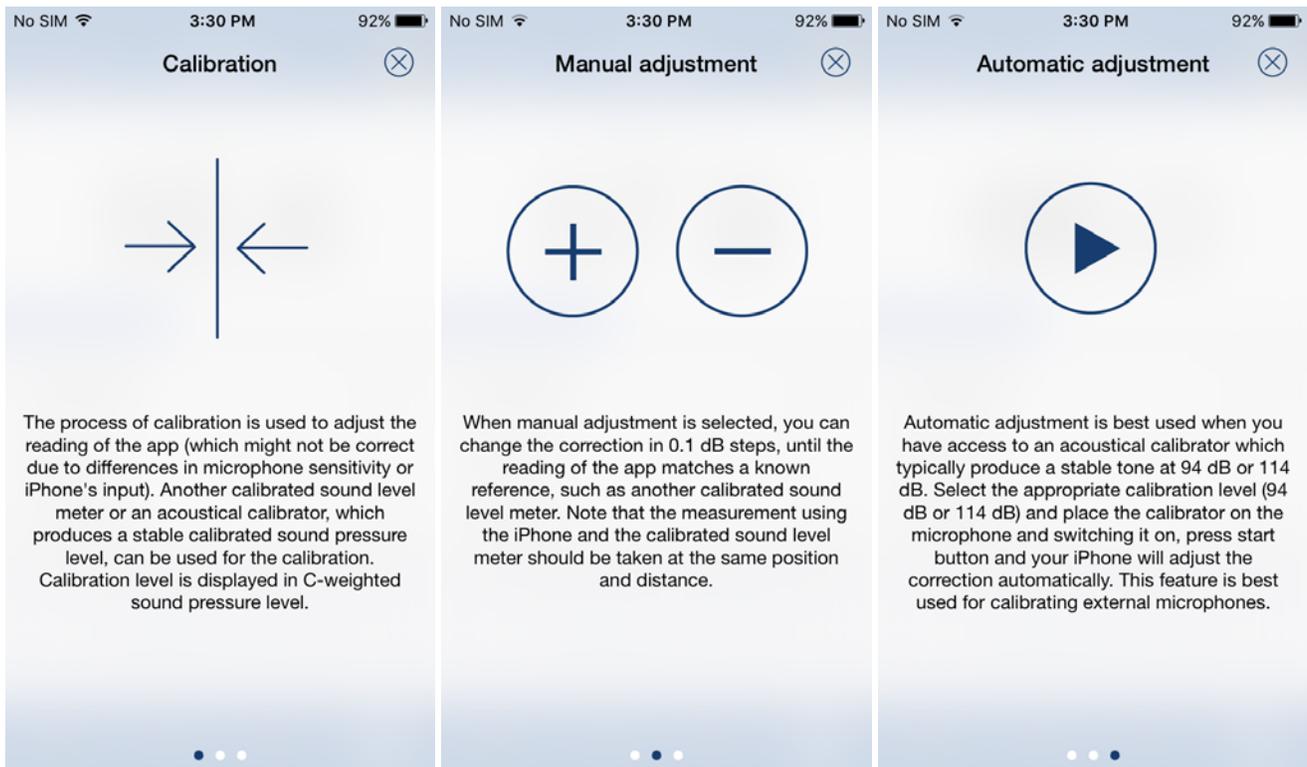


We also show how calibration is done with an external microphone in this informational video at the 4:04 mark:

https://www.youtube.com/watch?v=zK07tLj_SDs



There are also three “help” screens that can guide the user in conducting an accurate calibration as shown below:



Occupational exposure standards were established to protect workers against the health effects of exposures to hazardous substances and agents when certain values (or limits) are reached. NIOSH established recommended exposure limits (RELs) on the basis of the best available science and practice. The REL for noise is 85 decibels, using the A-weighting frequency response and a 3-dB exchange rate as an 8-hour TWA; exposures at or above this level are considered hazardous. OSHA sets legally enforceable permissible exposure limits (PELs) that require employers to take actions to reduce worker exposures. The OSHA PEL for noise is 90 dB(A) as an 8-hr TWA based on a 5-dB exchange rate. NIOSH uses the 80 dB(A) threshold level for calculating the REL. OSHA uses a 90 dB(A) threshold for calculating the PEL and an 80 dB(A) threshold for calculating the Action level.

Under **NOISE AT WORK**, there are four settings:

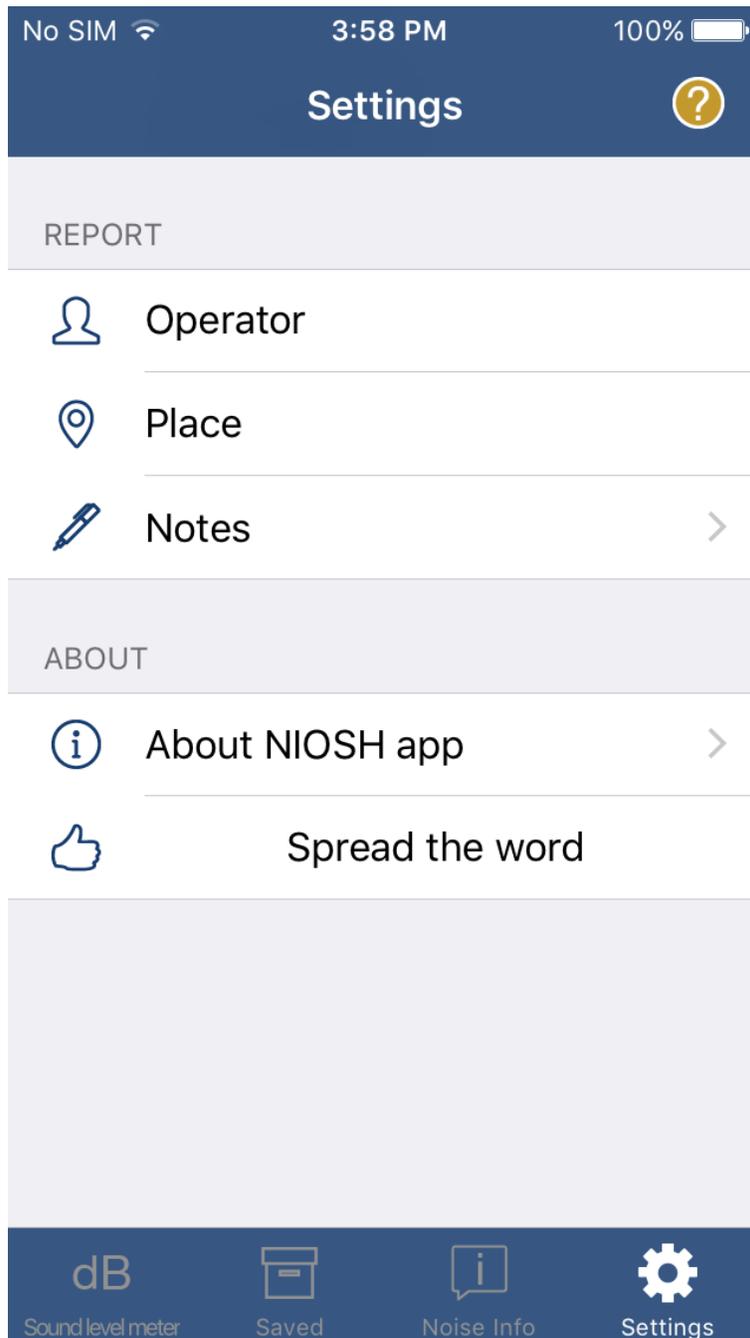
1. Standard: Allows the user to select between NIOSH or OSHA measurement criteria.
2. Threshold level: Threshold levels are automatically set to 80 dB(A) for NIOSH, or 80/90 dB(A) for OSHA AL/PEL.
3. Exchange rate: Exchange rates are automatically set to 3-dB for NIOSH or 5-dB for OSHA.
4. Time weighting: Allows the user to select the time constant, SLOW (1 second average) or FAST (1/8th of a second average). Most occupational guidelines specify SLOW time-weighting for measurements.
5. Frequency weighting: Allows the user to select the appropriate frequency-weighting response (A/C/Z)* as specified in sound level meter and noise dosimeter standards. The default is to use A-weighting which reflects human ear response to low level sounds over the 20 Hz – 20 kHz frequency range. A-weighting is mandated by occupational and environmental guidelines to assess potential hearing damage and other health effects from exposure to noise. C-weighting reflects the human ear response at higher sound levels and is often used to measure peak sound levels and evaluate hearing protection. Z-weighting, or flat, provides no adjustment to the noise over the 20 Hz – 20 kHz frequency range and is often used to measure very high-level impulses and low-frequency noise.

*Note that LAeq, maximum sound level, and TWA are always measured in dB(A). LCPeak is always measured in dB(C). If Z-weighting is selected, it only applies to the instantaneous sound level.

As mentioned, the NIOSH SLM app is automatically set up to make measurement according the NIOSH REL measurement criterion. There is no need to make any adjustments to the above parameters unless you are interested in making measurements according to the OSHA PEL or AL measurement criterion.

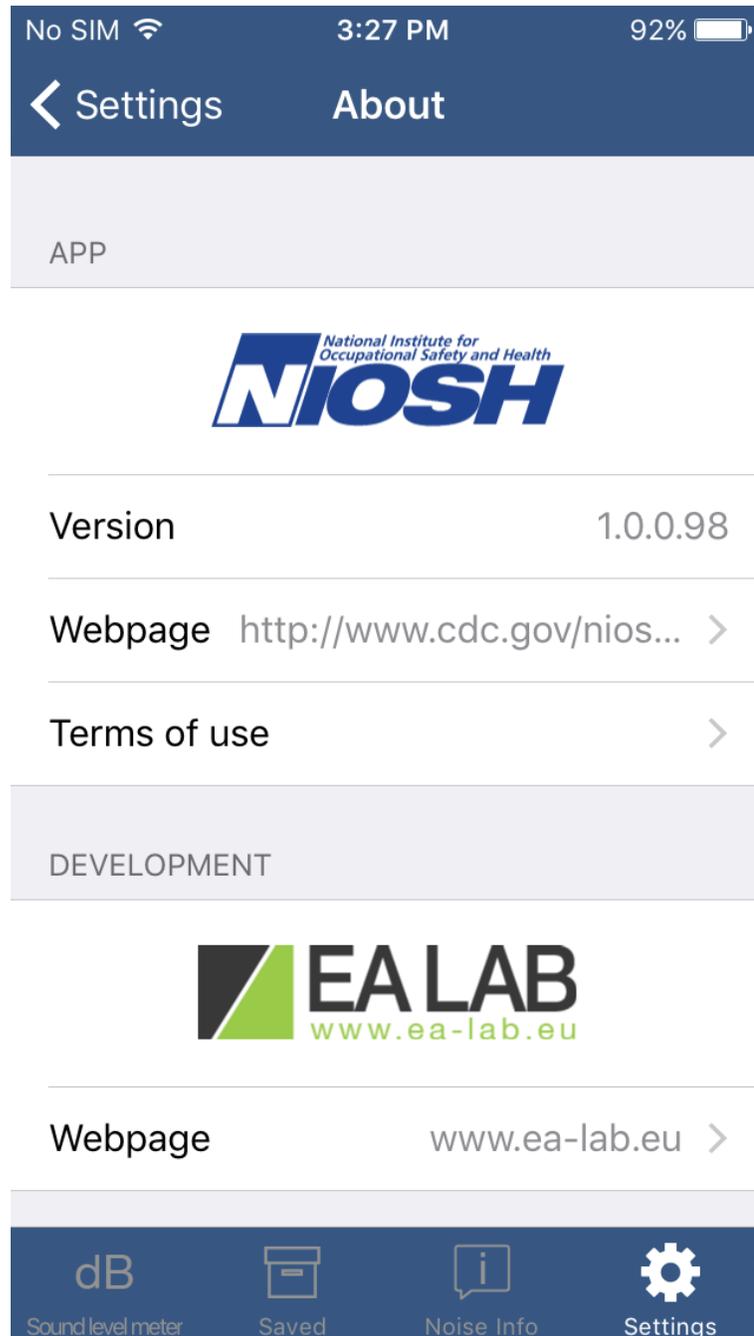
Under **REPORT**, there are three settings:

1. **Operator:** Allows the user to input the name or number related to the operator of the app.
2. **Place:** Allows the user to input the location of the measurement, which can either be typed in manually or automatically generated by selecting the GIS location icon to use the phone's location service.
3. **Notes:** Allows the user to enter additional notes up to 500 characters related to the measurement.



Under **ABOUT**, there are two settings:

1. About NIOSH app (contains information about NIOSH, version, terms of use; and EA LAB - the developer of the app).
2. Spread the word: Allows the user to share the app via social media or email messaging platforms.



Relevant smartphone studies

Kardous and Shaw (2014). [Evaluation of smartphone sound measurement applications](#) – Journal of Acoustical Society of America.

Kardous and Shaw (2014). [So how accurate are these smartphone sound measurement apps?](#) – NIOSH Science Blog.

Kardous and Shaw (2016). [Evaluation of smartphone sound measurement applications \(apps\) using external microphones – A follow-up study](#) – Journal of Acoustical Society of America.

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