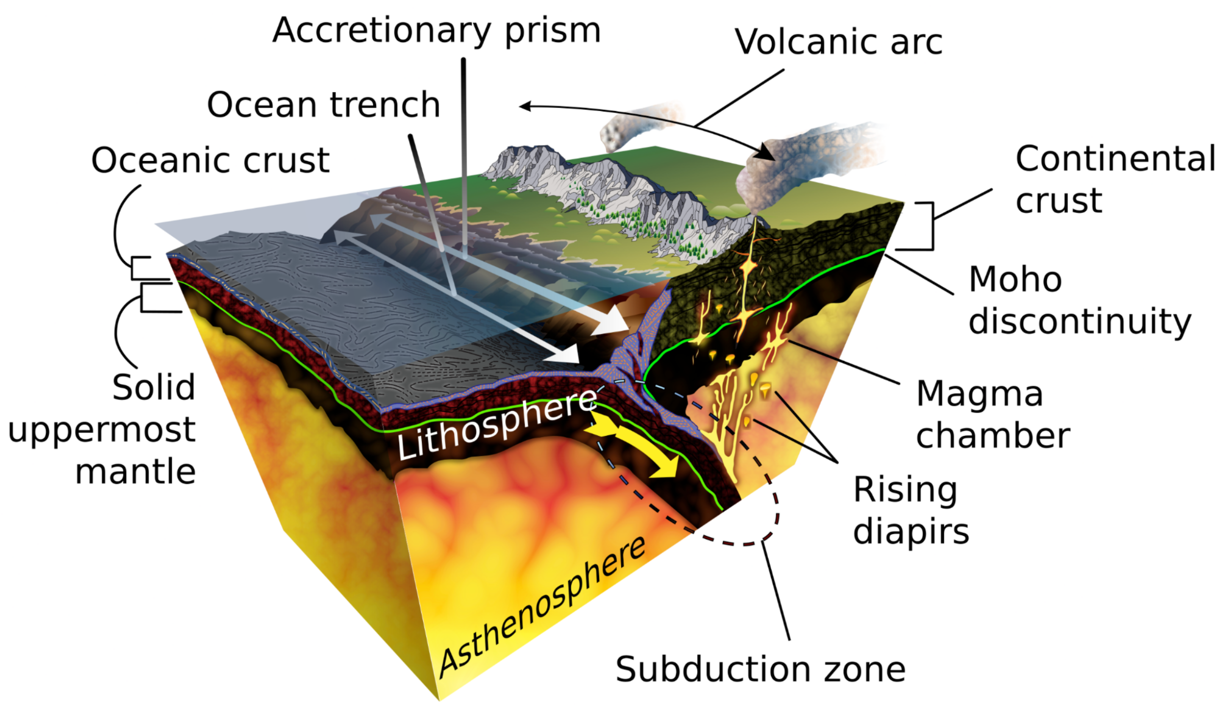
QuakeLogic MOHO-AIR Introduction and QuickStart

The Moho discontinuity is the boundary between the Earth's crust and the mantle, named after its discoverer, Croatian seismologist Andrija Mohorovičić. It is defined by a sudden change in the speed of seismic waves, which travel faster through the denser mantle than the crust above. This boundary is found at different depths, being shallower under the oceans (about 10 km) and deeper under continents (averaging about 35 km).



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Product Overview

QuakeLogic Inc. provides advanced seismometers and infrasound sensing technologies for professional and research applications. The MOHO AIR is a high-quality instrument designed for monitoring air pressure variations below 20 Hz.

The software platform provided with the system is aligned with tools used by professional geophysical observatories worldwide, ensuring reliable data acquisition and analysis.

Definitions

Infrasound: Infrasound is sound with frequencies below the range of human hearing, typically defined as below 20 Hz. Produced by both natural sources such as earthquakes and man-made sources such as explosions and aircraft, infrasound can travel long distances with minimal attenuation and may be perceived as physical vibration. It is widely used in applications such as volcanic monitoring and nuclear test detection.

Time Series: A time series is a sequence of data points collected or measured over time at regular intervals.

High Pass Filter: A high-pass filter (HPF) is an electronic filter that allows signals with frequencies higher than a selected cutoff frequency to pass through while attenuating lower frequencies. It is commonly used to remove unwanted low-frequency noise from signals.

Low Pass Filter: A low-pass filter allows signals below a defined cutoff frequency to pass through while reducing higher-frequency components. It is used to remove noise and smooth signal data.

Spectrogram: A spectrogram is a visual representation of signal frequencies over time, where time is shown on the horizontal axis, frequency on the vertical axis, and amplitude represented by color intensity.

System Functionality: The MOHO AIR system collects data at a rate of 100 samples per second. This time series data is stored locally for approximately one week, with the option to transmit and archive data externally for long-term storage.

Users can access and analyze the data through the MOHO configurator application, available on mobile devices and web browsers.

Two primary visualization tools are available:

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- **Heli view**: Displays the time series over a 12-hour period
- **Sgram view**: Displays a spectrogram representation of the data over a 12-hour period

The system collects data through one primary channel and enables the creation of three additional virtual channels. These channels allow different representations of the same data through the application of high-pass and low-pass filters.

This functionality enables users to isolate specific frequency ranges and remove unwanted noise.

Infrasound Effects (Reference Data)

Infrasound effects are generally associated with frequencies below 20 Hz and high intensity levels (above approximately 100–120 dB). At lower levels, effects are typically subjective.

Examples of frequency-related observations:

- Below 1 Hz: May cause dizziness and nausea at high intensity
- 5 Hz: Potential effects on cardiac tissue at extreme levels
- 7 Hz: Associated with brainwave frequency ranges (not scientifically confirmed as harmful)
- 10 Hz: Linked to changes in cardiac rhythm at high intensity
- 18–19 Hz: May affect visual perception due to resonance effects

Using the MOHO AIR system, users can focus on specific frequency bands. For example, filters can be configured to observe data between 5 Hz and 9 Hz or below 1 Hz, depending on analysis requirements.

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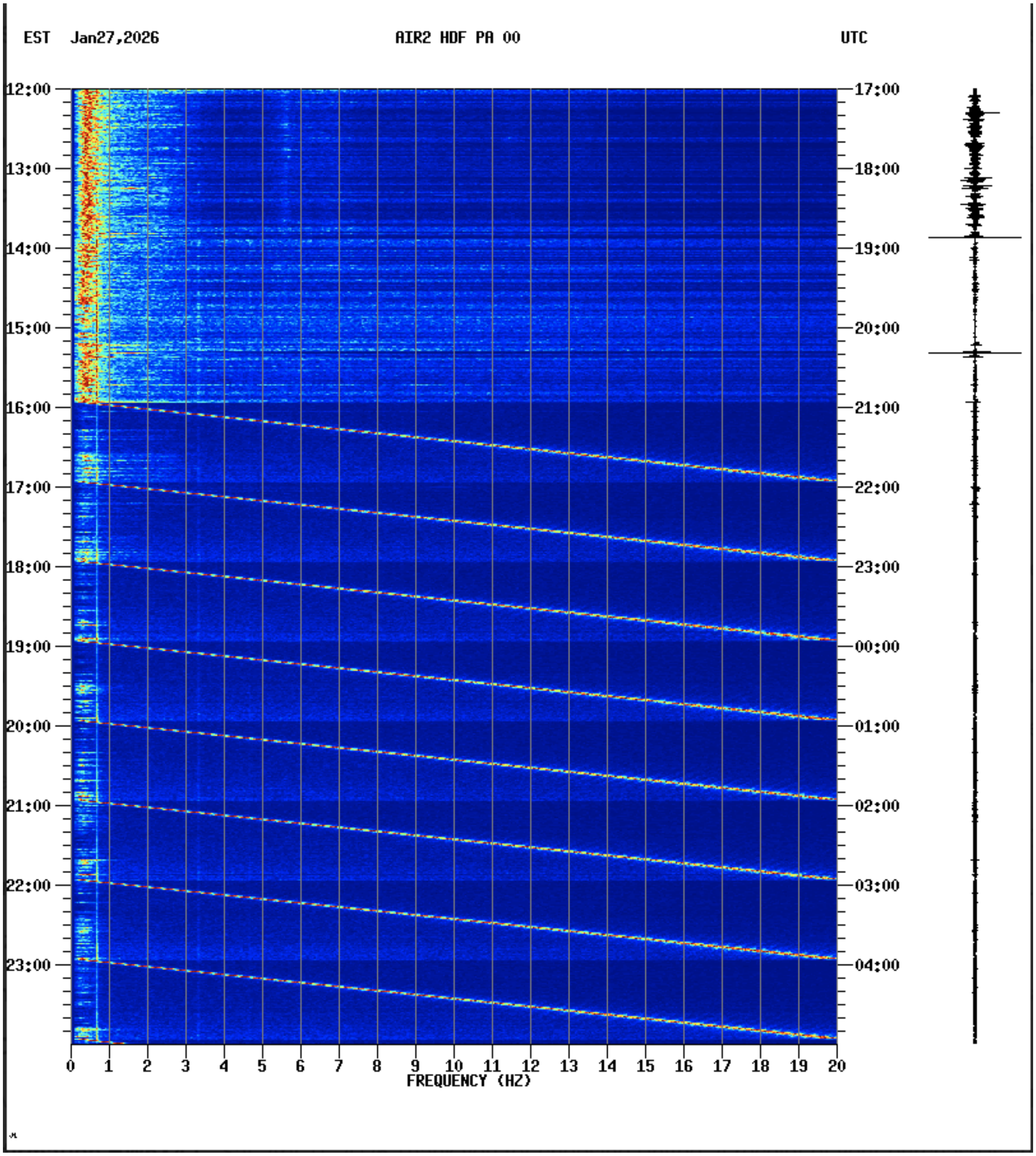
System Capability

The MOHO AIR is designed to deliver performance close to research-grade infrasound sensing systems.



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Factory Default Filters

Filter	Channel	Type	Cutoff	Poles	Description
1	1	HP	0.005	2	Removes very low-frequency drift
2	2	HP	0.05	2	Passes frequencies above 0.05 Hz
3	3	HP	0.5	2	Passes frequencies above 0.5 Hz
4	4	HP	1.0	2	Passes frequencies above 1 Hz

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CONVERSION OF MOHO-AIR DATA TO PASCAL AND G-WEIGHTED DECIBELS (dBG)

Comprehensive Technical Guide for Infrasound Monitoring and Human Impact Assessment

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Abstract

Infrasound sensors are indispensable instruments for the detection and quantification of low-frequency atmospheric pressure waves produced by natural phenomena such as volcanic eruptions, avalanches, severe weather, and earthquakes, as well as anthropogenic sources including industrial machinery, blasts, and wind turbines. Sensor digitizers record raw integer counts which, by themselves, carry no physical meaning. To support quantitative analysis, regulatory comparison, and human-impact assessment, these counts must be converted into physical pressure (Pascals), into unweighted sound pressure levels (dB SPL), and — for infrasound — into G-weighted sound pressure levels (dBG) per ISO 7196:1995.

This document provides a complete and self-consistent engineering procedure for performing those conversions on data from the QuakeLogic MOHO-AIR system. It includes the calibration derivation, the full conversion workflow, the ISO 7196 G-weighting filter specification, a human-impact interpretation table aligned with the standard, reference-grade Python pseudocode, and reporting best practices.

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1. Introduction

The MOHO-AIR system measures atmospheric pressure fluctuations in the infrasound band. Throughout this document, infrasound is taken to mean acoustic pressure variations with frequencies below the conventional human audible threshold of 20 Hz. The lower bound of interest depends on the sensor and application: the MOHO-AIR sensor responds usefully from approximately 0.1 Hz upward, while the ISO 7196 G-weighting characteristic — used for human perception assessment — is defined over the band 1 Hz to 20 Hz.

The system records signals as signed integer counts. These counts must be converted into:

- **Pressure (Pa)** — the underlying physical quantity used for waveform analysis, source characterization, and event detection.
- **Sound Pressure Level (dB SPL)** — the unweighted logarithmic representation of acoustic pressure, useful for comparing event amplitudes against reference values.
- **G-weighted Sound Pressure Level (dBG)** — the perceptually relevant level for infrasound, used for human-impact and regulatory assessment.

This document presents the complete engineering procedure for performing each conversion, together with the underlying assumptions, the calibration derivation, and the interpretation criteria recommended for reporting.

2. System Overview

2.1 Sensor Characteristics

The MOHO-AIR sensor is a differential-pressure microbarometer configured for infrasound monitoring. Its principal nominal characteristics are summarized below.

Parameter	Nominal Value
Measurement type	Differential atmospheric pressure
Frequency response (useful band)	≈ 0.1 Hz to 20 Hz
Sensor sensitivity, S	3.5 mV / kPa (= 3.5 μV / Pa)
System calibration factor, K	0.000602 Pa / count
Reference acoustic pressure, p_0	20 μPa = 2×10^{-5} Pa

2.2 Measurement Chain

The complete measurement chain consists of three stages: the differential pressure transducer, the analog signal-conditioning section (instrumentation amplifier, anti-alias filter), and the digitizer (analog-to-digital converter). The system calibration factor K folds the response of all three stages into a single linear scaling that converts digitizer counts directly into Pascals.

2.3 Calibration Factor Derivation

The calibration factor K (in Pa per count) is determined by the sensor sensitivity, the analog gain of the conditioning electronics, and the digitizer's least-significant-bit (LSB) voltage:

$$K = V\_LSB \,/\, (S \times G)$$

where:

- *V_LSB* is the digitizer LSB voltage (V/count), determined by the ADC full-scale range and resolution;
- *S* is the sensor sensitivity (V/Pa) — here 3.5×10^{-6} V/Pa;
- *G* is the dimensionless gain of the analog signal-conditioning chain.

For the MOHO-AIR system the combined chain yields K ≈ 0.000602 Pa/count. As a consistency check, this implies an effective input-referred LSB of $K \times S = 0.000602 \times 3.5 \times 10^{-6} \approx 2.11$ μV per count, consistent with a 24-bit ADC operating at a moderate analog gain.

Important: The factor K is a system-level calibration. If the sensor, gain, or digitizer is replaced or reconfigured, K must be re-derived or re-measured before the equations in this document are applied.

3. Conversion: Counts → Pressure (Pa)

3.1 Linear Conversion

The recorded digital signal is converted to physical pressure using the system calibration factor:

$$p(t) = K \times Counts(t) = 0.000602 \times Counts(t) \quad [Pa]$$

where:

- *p(t)* is the instantaneous pressure time series, in Pascals;
- *Counts(t)* is the recorded digitizer time series, in raw counts;
- *K* = 0.000602 Pa/count is the system calibration factor (see §2.3).

3.2 Baseline (DC) Correction

Microbarometer outputs typically contain a slowly varying offset arising from atmospheric trends, sensor self-heating, and electronics drift. To isolate the dynamic (acoustic) component, subtract the mean of the segment under analysis:

$$p\_corr(t) = p(t) - mean(p(t))$$

For long records, a simple mean subtraction may be insufficient — slow trends remain. In that case, subtract a running mean or apply a high-pass filter with a corner well below the lowest frequency of interest (typically 0.05 Hz to 0.1 Hz for infrasound work). The corrected signal p_corr(t) is the input for all subsequent analysis.

Note: Detrending should always be performed on the pressure-domain signal (Pa), never on the raw count series, so that the subtracted offset has a physical interpretation.

4. Conversion: Pressure → Sound Pressure Level (dB SPL)

Unweighted sound pressure level (dB SPL) is defined relative to the conventional reference pressure for airborne sound, p_0 = 20 μPa:

$$L\_p = 20 \cdot \log_{10} (p\_rms / p_0) \quad [dB\ SPL]$$

$$with \quad p_0 = 20 \times 10^{-6}\ Pa$$

where p_rms is the root-mean-square of the baseline-corrected pressure signal over the analysis window of length N samples:

$$p\_rms = \sqrt{((1/N) \cdot \Sigma\, p\_corr(t)^2)}$$

Important — parenthesization. The denominator inside the logarithm is the full reference value (20×10^{-6} Pa). It is essential to enclose the reference in parentheses; writing the formula as 20 $\log_{10}(p\_rms / 20 \times 10^{-6})$ is ambiguous and, by standard precedence, evaluates incorrectly as 20 $\log_{10}((p\_rms / 20) \times 10^{-6})$.

Note that dB SPL is a physical quantity. For sound at audible frequencies it correlates well with perceived loudness, but for infrasound it does not — see §6 and §7.

5. Infrasound Fundamentals

5.1 Definition

Infrasound is acoustic energy at frequencies below the conventional human audibility threshold. There is no single universally adopted lower bound, but the following definitions are used consistently in this document:

- **Physical definition:** acoustic pressure waves with frequencies below ~20 Hz. Practical lower bounds for atmospheric infrasound studies are typically 0.01 Hz to 0.1 Hz, set by sensor response.
- **ISO 7196 measurement band:** the G-weighting characteristic for human-perception assessment is defined for the band 1 Hz to 20 Hz. Energy outside this band is heavily attenuated by the standard G filter.

Throughout this guide, references to the "infrasound" perception threshold and to dBG values apply within the ISO 7196 band of 1 Hz to 20 Hz unless explicitly stated otherwise.

5.2 Perception Characteristics

Infrasound differs from audible sound in three important ways. First, the threshold of perception rises steeply as frequency decreases — far more rapidly than the equal-loudness contours suggest at higher frequencies. Second, the dynamic range between threshold and discomfort is compressed: only about 20 dB separates just-perceptible from very loud levels in the 1–20 Hz band, compared with 60 dB or more at speech frequencies. Third, perception below the audibility threshold is increasingly mediated by tactile and vestibular pathways rather than the auditory system, manifesting as pressure sensations or vibration.

ISO 7196 reports the threshold of perception as approximately 100 dB re 20 μPa at 10 Hz, rising further at lower frequencies. Levels below approximately 90 dBG are not normally significant for human perception.

6. G-Weighted Decibels (dBG)

6.1 Purpose

G-weighting, defined in ISO 7196:1995, is a frequency-weighting characteristic intended to approximate the human response to infrasound in the 1 Hz to 20 Hz band. It de-emphasizes frequencies where humans are insensitive and emphasizes those near the perception peak around 16–20 Hz. The result, expressed in dBG (sometimes written dB(G) or L_G), is the appropriate metric for infrasound human-impact assessment, regulatory compliance, and wind-turbine noise studies.

6.2 Filter Specification

The G-weighting filter has three defining characteristics per ISO 7196:

- Reference gain of **0 dB at 10 Hz**.
- Approximate slope of **+12 dB/octave** between 1 Hz and 10 Hz; the response then peaks broadly near 16–20 Hz.
- Sharp roll-off of **−24 dB/octave** below 1 Hz and above 20 Hz, suppressing energy outside the perceptual band.

The full transfer function is the product of a fourth-order high-pass section (corner near 1 Hz) and a fourth-order low-pass section (corner near 20 Hz), with appropriate gain normalization to give 0 dB at 10 Hz. Exact pole/zero locations are specified in ISO 7196:1995, which should be consulted for compliance work.

Tabulated G-Weighting Response

The following values are representative of the ISO 7196 G-weighting at 1/3-octave centres. They are sufficient for engineering verification of a digital implementation; for legally required measurements, refer to the tolerance limits given in the standard.

Frequency (Hz)	G-weighting (dB)	Region
0.25	**−88**	Stop band (deep attenuation)
0.5	**−64**	Stop band
1.0	**−33**	Lower edge of pass band
2.0	**−22**	Rising response (≈12 dB/oct)
4.0	**−14**	Rising response
8.0	**−3**	Approaching reference
10.0	**0**	Reference frequency (definition)
12.5	**+4**	Pass band peak region
16.0	**+7.7**	Pass band peak region
20.0	**+9**	Upper edge of pass band
25.0	**−4**	Falling response (>20 Hz)
31.5	**−14**	Roll-off (≈−24 dB/oct)
63.0	**−42**	Stop band

Note: Values are approximate, expressed relative to the 10 Hz reference (positive numbers indicate gain above reference). Exact values and tolerance limits are specified in ISO 7196:1995.

6.3 Why dBG, Not dB SPL or dBA

Three weightings are commonly encountered in acoustic measurement, but only one is appropriate for infrasound:

- **dB SPL (unweighted, also called dBZ):** the physical pressure level. Required for waveform analysis and physical comparisons, but overstates the perceptual significance of low-frequency content.
- **dBA (A-weighting):** designed for audible-range loudness assessment. The A-curve attenuates low frequencies very aggressively (e.g. ≈ −50 dB at 10 Hz), making it inappropriate — and often misleading — for infrasound assessment.
- **dBG (G-weighting):** defined specifically for the 1–20 Hz band. The correct metric for infrasound human-impact and regulatory work.

7. Complete Conversion Workflow: Counts → dBG

The following five-step procedure produces a G-weighted sound pressure level from raw MOHO-AIR digitizer counts. Each step is summarized; the underlying equations are given in §3, §4, and §6.

Step 1 — Counts to Pressure

Apply the system calibration factor:

$$p(t) = 0.000602 \times Counts(t) \quad [Pa]$$

Step 2 — Baseline (DC) Correction

Remove the DC offset and any slow drift over the analysis window:

$$p\_corr(t) = p(t) - mean(p(t))$$

For long records (minutes to hours), use a high-pass filter (corner well below the lowest frequency of interest) instead of a single mean subtraction.

Step 3 — Apply the G-Weighting Filter

Pass the corrected pressure signal through the ISO 7196 G-weighting filter:

$$p\_G(t) = G[\, p\_corr(t) \,]$$

Implementation options include: (a) a digital IIR filter realising the ISO 7196 transfer function, designed once at the recording sample rate; (b) FFT-domain weighting, applying the G-weighting magnitude response bin-by-bin; (c) one-third-octave band analysis followed by energy-summation with G weights. Method (a) is preferred for time-domain output; method (b) is convenient when computing dBG from a pre-computed power spectrum.

Step 4 — RMS of the Weighted Signal

Compute the root-mean-square of the G-weighted signal over the analysis window:

$$p\_G,rms = \sqrt{(1/N) \cdot \Sigma\, p\_G(t)^2}$$

Choose the window length according to the integration time required by the application. ISO 7196 references both "slow" (1-second time constant) and longer integration times. For regulatory compliance, the equivalent-continuous level over the prescribed averaging period (L_Geq) is typically required.

Step 5 — Convert to dBG

Convert the weighted RMS pressure to a logarithmic level relative to 20 μPa:

$$L\_G = 20 \cdot \log_{10} \left(p\_G,rms \,/\, (20 \times 10^{-6}) \right) \quad [dBG]$$

The result is the G-weighted sound pressure level for the analysis window. For continuous monitoring, repeat steps 2–5 for successive windows to obtain a time series of dBG values.

7.1 Workflow Summary Diagram

Raw Counts
Counts(t) — signed integers from digitizer

▼ **× K = 0.000602 Pa/count**

Pressure
p(t) [Pa]

▼ **subtract mean / high-pass**

Detrended Pressure
p_corr(t) [Pa]

▼ **ISO 7196 G filter**

G-weighted Pressure
p_G(t) [Pa]

▼ **RMS over window**

RMS Pressure
p_G,rms [Pa]

▼ **$20 \cdot \log_{10}(\cdot / 20\mu Pa)$**

L_G (dBG)
G-weighted sound pressure level

8. Interpretation of dBG Levels

The following interpretation is consistent with ISO 7196:1995, which states that just-perceptible infrasound in the 1–20 Hz band yields G-weighted sound pressure levels close to 100 dB, that levels below approximately 90 dBG are not normally significant for human perception, and that very loud infrasound is on the order of 120 dBG.

dBG Level	Classification	Expected Human Response
< 85 dBG	**Not perceptible**	Well below the perception threshold; no human response expected. Below the 85 dBG night-time guideline used in some wind-turbine assessments.
85–95 dBG	**Sub-threshold**	Below average perception threshold; possibly noticeable to highly sensitive individuals under quiet conditions. Approximate threshold zone.
95–100 dBG	**At perception threshold**	Approximately the average threshold of perception per ISO 7196. Typical listeners begin to perceive a pressure or vibration sensation.
100–110 dBG	**Clearly perceptible**	Sound is reliably detected. Sensation of pressure or low-frequency vibration; possible mild annoyance with prolonged exposure.
110–120 dBG	**Loud / disturbing**	Strongly perceptible. Annoyance and disturbance are likely; sleep disturbance possible at residential receivers.
> 120 dBG	**Very loud / extreme**	Approaching the upper bound discussed in ISO 7196. Potential discomfort and physiological response at sustained levels.

Caveat: Individual perception thresholds vary considerably (typically by 10–15 dB across listeners). The bands above describe average response; sensitive individuals may perceive levels below the nominal threshold, and some listeners may be tolerant of higher levels.

9. Frequency-Dependent Perception Threshold

The threshold of perception in dBG is approximately constant across the 1–20 Hz band by design — the G-weighting filter compensates for the strong frequency dependence of the underlying physical (unweighted) threshold. Expressed in unweighted dB SPL, the threshold rises sharply with decreasing frequency.

Frequency	Approximate Threshold	Notes
20 Hz	≈ 80 dB SPL	Just below conventional audibility limit
10 Hz	≈ 100 dB SPL	ISO 7196 reference frequency; classical threshold ≈ 100 dB
5 Hz	≈ 110 dB SPL	Steeply rising threshold
2 Hz	≈ 120 dB SPL	Perception increasingly tactile rather than auditory
1 Hz	≈ 130 dB SPL	Lower edge of ISO 7196 G-band

Source: Threshold values are rounded summaries based on ISO 7196:1995 (≈100 dB at 10 Hz) and supporting psychoacoustic literature (e.g., Møller & Pedersen). Individual thresholds vary by 10–15 dB.

10. dBG Impact Zones for Reporting

For environmental reporting and regulatory communication, the dBG levels in §8 are commonly consolidated into three impact zones. The boundaries below are aligned with ISO 7196 and with regulatory guidance used in wind-turbine assessment (e.g., 85 dBG night-time and 90 dBG daytime guidelines proposed in the European literature).

Zone	dBG Range	Recommended Action / Interpretation
Green	**< 90 dBG**	Below significance threshold. No expected human response.
Yellow	**90–105 dBG**	Approaching / at perception threshold. Possible perception by sensitive listeners; adopt as a precautionary threshold for residential receivers.
Orange	**105–115 dBG**	Clearly perceptible. Annoyance and possible sleep disturbance at residential receivers; likely to require investigation.
Red	**> 115 dBG**	Loud to extreme. Strong perception, probable annoyance and discomfort. Investigate source and apply mitigation.

Interpretation of dBG levels — human impact

G-weighted decibels (dBG) for infrasound assessment, per ISO 7196:1995

ISO 7196 reference points
Threshold of perception ≈ 100 dBG · Very loud ≈ 120 dBG · Compressed dynamic range ≈ 20 dB
Below ~90 dBG: not normally significant for human perception

dBG range	Human perception	Typical sources / environments	Guidance
< 90 dBG BELOW THRESHOLD	Not perceptible No expected response	Atmospheric background, distant weather, ocean swells	No action required Below significance threshold
90 – 100 dBG SUB-THRESHOLD	At / near threshold Sensitive listeners may detect	Distant industry, residential wind-turbine receivers	Monitor Check trends over time
100 – 110 dBG PERCEPTIBLE	Clearly perceptible Pressure / vibration sensation	Heavy industry, near-field wind turbines, distant blasts	Investigate Annoyance possible
110 – 120 dBG DISTURBING	Loud and disturbing Annoyance very likely	Compressors at range, pile driving, large blasts	Mitigate Sleep disturbance likely
> 120 dBG EXTREME	Very loud / extreme Physiological response possible	Close-range industry, blasts, severe atmospheric events	Act immediately Investigate and mitigate

Key takeaway

- Average perception threshold in the 1–20 Hz band is ≈ 100 dBG (ISO 7196:1995).
- Dynamic range from threshold to "very loud" is only ≈ 20 dB — much narrower than at audible frequencies.
- Individual thresholds vary by ±10–15 dB. Sensitive listeners may perceive levels below the population threshol

Unweighted perception thresholds — dB SPL, by frequency

These are unweighted thresholds. After G-weighting, the threshold is approximately constant near 100 dBG across 1–20 Hz.

20 Hz	10 Hz	5 Hz	2 Hz	1 Hz
~80 dB SPL	~100 dB SPL	~110 dB SPL	~120 dB SPL	~130 dB SPL

Why dBG, not dB SPL or dBA
dB SPL overstates infrasound perceptual impact at low frequencies.
dBA strongly attenuates low frequencies (≈ −70 dB at 10 Hz) and is unsuitable for infrasound.

Counts → Pa → dBG: worked reference table

MOHO-AIR system, 10 Hz sinusoid (G-weighting = 0 dB at the 10 Hz reference)

Assumptions

K = 0.000602 Pa/count · p_ref = 20 µPa · p_peak = K × counts_peak · p_rms = p_peak / √2

Peak counts	Peak Pa	RMS Pa	dB SPL	dBG @ 10 Hz	Zone
100	0.060	0.043	66.6	66.6	Below threshold
500	0.301	0.213	80.5	80.5	Below threshold
1,000	0.602	0.426	86.6	86.6	Below threshold
1,500	0.903	0.639	90.1	90.1	Sub-threshold
2,000	1.204	0.851	92.6	92.6	Sub-threshold
3,000	1.806	1.277	96.1	96.1	Sub-threshold
5,000	3.010	2.128	100.5	100.5	Perceptible
10,000	6.020	4.257	106.6	106.6	Perceptible
20,000	12.04	8.514	112.6	112.6	Disturbing
30,000	18.06	12.77	116.1	116.1	Disturbing
50,000	30.10	21.28	120.5	120.5	Extreme
100,000	60.20	42.57	126.6	126.6	Extreme
200,000	120.4	85.14	132.6	132.6	Extreme

ISO 7196 reference checkpoints

- ~ 1,486 peak counts → 0.894 Pa peak → 0.632 Pa RMS → 90 dBG (significance threshold)
- ~ 4,698 peak counts → 2.828 Pa peak → 2.000 Pa RMS → 100 dBG (perception threshold)
- ~ 46,984 peak counts → 28.28 Pa peak → 20.00 Pa RMS → 120 dBG (very loud)

Important caveats

1. This table assumes a pure 10 Hz sinusoid. dBG = dB SPL only at the 10 Hz reference; at other frequencies subtract the G-weighting attenuation (e.g. ≈ −22 dB at 2 Hz, ≈ −33 dB at 1 Hz, +9 dB at 20 Hz).
2. Counts shown are PEAK values of a sinusoid. RMS counts (= peak / √2) would map directly without the √2 factor.
3. Real signals are broadband — apply the G-weighting filter to the time series first, then compute RMS, then convert.
4. Baseline (DC) correction must be applied before any RMS or dB calculation.

11. Health and Environmental Considerations

Reported responses to infrasound include annoyance, disturbance of sleep, and perceptions of pressure or vibration. The following observations from the peer-reviewed literature should inform the interpretation of dBG measurements:

- **Threshold variability:** Individual perception thresholds vary by 10–15 dB. A small minority of listeners may perceive infrasound at levels well below the population-average threshold.
- **Levels around wind farms:** Multiple studies have found that L_Geq levels measured in residential settings near operating wind turbines are typically below 90 dBG, i.e., below the conservative perception threshold.
- **No consistent severe health effects below threshold:** Current peer-reviewed evidence does not establish severe physiological harm from infrasound exposure at typical environmental levels. Annoyance and sleep disturbance, however, are documented at perceptible levels.
- **Reporting in dBG, not dBA:** For sources whose energy is concentrated below 20 Hz, dBA values significantly understate perceptual relevance. Report dBG alongside dBA when assessing infrasound from such sources.

12. Best Practices for Data Reporting

12.1 Required Reporting Quantities

For every infrasound dataset, report at minimum:

- **Pressure time history (Pa)** — the baseline-corrected p_corr(t) traces.
- **Sample rate (Hz)** and the analysis window length used for RMS computation.
- **dB SPL (unweighted, L_p)** — for physical comparison with other measurements.
- **dBG (G-weighted, L_G)** — for human-impact and regulatory interpretation.
- **Frequency band of analysis** — explicitly state the band over which dBG is reported.

12.2 Recommended Additional Reporting

- **L_Geq, T** — equivalent-continuous G-weighted level over averaging period T (e.g. 10 minutes, 1 hour).
- **Spectral content** — one-third octave spectrum or FFT-derived spectrum to identify dominant tones.
- **Background level** — ambient L_G measured with the source of interest absent.
- **Wind/weather metadata** — wind speed and direction, temperature, and pressure at the time of measurement.

12.3 Avoid

- **dBA for infrasound sources.** A-weighting attenuates 10 Hz by ≈ 70 dB, which makes it unsuitable for reporting infrasound.
- **Reporting peak counts.** Always convert to engineering units before reporting.
- **Single-sample statistics.** RMS and dBG should be computed over a meaningful analysis window, not from instantaneous samples.

13. Implementation Notes

13.1 Reference Python Pseudocode

The following pseudocode illustrates a complete implementation of the workflow in §7. It is intended as a reference; production code should add input validation, calibration metadata tracking, and proper handling of multi-channel data.

```
import numpy as np
from scipy import signal

# --- 1. System constants ---------------------------------------------
K        = 0.000602          # Pa per count (MOHO-AIR calibration)
P_REF    = 20e-6             # Reference pressure, 20 µPa
FS       = 100               # Sample rate (Hz) - example

# --- 2. Counts -> Pressure -------------------------------------------
def counts_to_pa(counts):
    return K * counts.astype(float)

# --- 3. Detrend ------------------------------------------------------
def detrend_dc(p):
    return p - np.mean(p)

# --- 4. ISO 7196 G-weighting filter ----------------------------------
# Realisation: 4th-order high-pass (~1 Hz) cascaded with
# 4th-order low-pass (~20 Hz), with gain normalisation to 0 dB at 10 Hz.
# Exact pole/zero locations: ISO 7196:1995.
def design_g_filter(fs):
    # Approximate Butterworth implementation of the G-weighting
    # mask. Replace with the exact ISO 7196 transfer function for
    # compliance work.
    sos_hp = signal.butter(4, 1.0,  btype='highpass', fs=fs, output='sos')
    sos_lp = signal.butter(4, 20.0, btype='lowpass',  fs=fs, output='sos')
    sos    = np.vstack([sos_hp, sos_lp])
    # Normalise gain so that |H(10 Hz)| = 1
    w, h = signal.sosfreqz(sos, worN=[10.0], fs=fs)
    return sos, 1.0 / np.abs(h[0])

def apply_g_weighting(p, fs):
    sos, k = design_g_filter(fs)
    return k * signal.sosfiltfilt(sos, p)

# --- 5. RMS and dBG --------------------------------------------------
def rms(x):
    return np.sqrt(np.mean(np.square(x)))
```

```
def to_db(p_rms):
    return 20.0 * np.log10(p_rms / P_REF)

# --- 6. Full pipeline -----------------------------------------------
def counts_to_dbg(counts, fs=FS):
    p       = counts_to_pa(counts)
    p_corr  = detrend_dc(p)
    p_g     = apply_g_weighting(p_corr, fs)
    return to_db(rms(p_g))    # dBG
```

13.2 Validation Checks

Before deploying any G-weighting implementation, verify:

- **0 dB at 10 Hz:** Inject a 10 Hz sinusoid of known amplitude; the output RMS should equal the input RMS to within 0.1 dB.
- **Slope between 1–10 Hz:** Inject sinusoids at 2.5 Hz and 5 Hz; output should drop by approximately 12 dB per octave (≈ 12 dB across that range).
- **Roll-off above 20 Hz:** Inject 40 Hz; output should be attenuated by ≈ 24 dB or more relative to 20 Hz.
- **Calibration consistency:** Inject a known pressure (e.g., 1 Pa peak at 10 Hz); the resulting dBG level should equal $20 \cdot \log_{10}(1/\sqrt{2} / 20\mu Pa) \approx 91$ dBG.

13.3 Common Implementation Pitfalls

- **Detrending after weighting.** Always detrend before applying the G filter; otherwise DC content can saturate the filter or bias subsequent calculations.
- **Insufficient sample rate.** A sample rate of at least 50–100 Hz is required to capture the upper edge of the G band without aliasing.
- **Filter transient at window edges.** Use sosfiltfilt (zero-phase) or discard the first/last seconds of each segment to avoid edge artefacts.
- **Wrong reference pressure.** Always use 20 μPa for airborne sound; 1 μPa applies to underwater acoustics and is not appropriate here.
- **Confusing peak with RMS.** dBG and dB SPL are defined in terms of RMS pressure; do not substitute peak amplitude.

14. Nomenclature

Symbol	Units	Definition
Counts(t)	—	Raw digitizer output, signed integer per sample
K	Pa/count	System calibration factor (MOHO-AIR: 0.000602 Pa/count)
S	V/Pa	Sensor sensitivity (3.5 µV/Pa)
G	—	Analog signal-conditioning gain (dimensionless)
V_LSB	V/count	Digitizer least-significant-bit voltage
p(t)	Pa	Instantaneous pressure
p_corr(t)	Pa	Baseline-corrected pressure
p_G(t)	Pa	G-weighted pressure
p_rms	Pa	RMS pressure (unweighted)
p_G,rms	Pa	RMS pressure (G-weighted)
p_0	Pa	Reference pressure for airborne sound, 20×10^{-6} Pa
L_p	dB SPL	Unweighted sound pressure level
L_G	dBG	G-weighted sound pressure level
L_Geq, T	dBG	Equivalent-continuous L_G over averaging period T
N	—	Number of samples in analysis window
f_s	Hz	Sample rate

15. References and Standards

- **ISO 7196:1995** — Acoustics — Frequency-weighting characteristic for infrasound measurements. International Organization for Standardization, Geneva.
- **IEC 61672-1:2013** — Electroacoustics — Sound level meters — Part 1: Specifications. International Electrotechnical Commission.
- **IEC 61400-11:2012** — Wind turbines — Part 11: Acoustic noise measurement techniques.
- **ISO 226:2003** — Acoustics — Normal equal-loudness-level contours.
- **Møller, H. and Pedersen, C. S. (2004).** Hearing at low and infrasonic frequencies. Noise & Health, 6(23), 37–57.
- **Hansen, C. H., Doolan, C. J., and Hansen, K. L. (2017).** Wind Farm Noise: Measurement, Assessment and Control. Wiley.

16. Summary

The MOHO-AIR system enables accurate monitoring of infrasound through a single linear calibration that converts digitizer counts directly into Pascals. Complete and correct interpretation of the recorded data requires three conversions, applied in order:

1. Counts → Pressure (Pa) using the system calibration factor K = 0.000602 Pa/count, followed by baseline (DC) correction.
2. Pressure → Sound Pressure Level (dB SPL), referenced to 20 μPa, for physical comparison.
3. Pressure → G-weighted Sound Pressure Level (dBG), per ISO 7196:1995, for human-impact and regulatory assessment.

When these steps are followed and the results are reported with proper context (frequency band, integration time, calibration metadata), the output supports scientific analysis, regulatory compliance, and meaningful communication of infrasound impact.

17. Support

For technical support, calibration verification, or questions regarding the methodology in this document, contact:

QuakeLogic Technical Support

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