The Gem Infrasound Logger: A Lightweight, Low-Power, Low-Cost, Open-Source Infrasound Logger

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Abstract

Low-frequency acoustic waves (called infrasound) are used for monitoring atmospheric disturbances including nuclear tests, volcanoes, and other powerful phenomena. Brief but focused infrasound campaigns enable the study of a wide range of sites and phenomena at low cost and with few workers. However, the cost, weight, and general inconvenience of commercial data loggers has limited past infrasound campaigns. To solve this problem, I developed an Arduino-based infrasound logger (the Gem) with a fraction of the cost, weight, and installation time. The Gem has since been adopted by several institutions for infrasound recording at volcanoes, stratospheric balloons, and river rapids.

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The Gem Infrasound Logger: a Lightweight, Low-Power, Low-Cost, Open-Source Infrasound Logger

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Limitations of Existing Infrasound Logging Systems

- Expensive data loggers with limited selection
- Recording in risky sites and platforms discouraged by high cost
- Expensive, awkward cabling needed for sensor connections
- Long installation time due to cable management, concealing
- Heavy and bulky: difficult to transport, aerial use limited to very large platforms
- Complex, error-prone installation procedure

Solution: the Gem Infrasound Logger

- Inexpensive, can be built in lab with student labor and basic tools
- Light weight and small size
- Fast, simple, cable-free setup procedure
- Lower power consumption, longer battery life than other options
- Easy to customize for specialized applications: user can modify code, enclosure, sensor, and signal conditioning parameters
- Gem described in detail in [1]; code and designs available at [2]

Designing an Infrasound Logger

Several essential components must be integrated to record any sensor to disk:

- Analog-digital converter
- Microcontroller
- Storage medium (e.g., SD card)
- Power supply
- Weatherproof enclosure

Infrasound logging in particular requires precise sample timing (±2.5 ms), moderately high resolution (±25 bps) and sample rate (±100 Hz), anti-aliasing filtering, and moderate amplification (gain ≥ 20). The following additional components are required for infrasound:

- Analog signal conditioning (low-pass filter, instrumentation amplifier)
- GPS (for precise timekeeping)
- Infrasound sensor [3]

Do-It-Yourself Electronics

User-friendly platforms like Arduino and Raspberry Pi (right) enable beginners in electronics to quickly learn to connect peripheral devices to a processor and write programs that integrate them. These education-oriented systems can often be developed into specialized and powerful research tools.

Gem vs. Best Commercial Logger (DATACUBE-3)

<table>
<thead>
<tr>
<th></th>
<th>DATACUBE-3 logger with 3 infraBSU sensors</th>
<th>3 Gem Infrasound Loggers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>Normal 2875 g; Minimum 1100 g for 1 sensor</td>
<td>Normal 1100 g; Minimum 78 g for 1 sensor</td>
</tr>
<tr>
<td>Cost</td>
<td>~$3000</td>
<td>~$1000</td>
</tr>
<tr>
<td>Time to install and take down</td>
<td>9 minutes (much longer if cables need to be concealed)</td>
<td>3 minutes, no cables to conceal</td>
</tr>
<tr>
<td>Installation steps</td>
<td>13 without confirmation, 1 with confirmation</td>
<td>6 with confirmation</td>
</tr>
<tr>
<td>Open-source?</td>
<td>No</td>
<td>Yes; hardware designs, firmware, and software are all open-source</td>
</tr>
<tr>
<td>Array size</td>
<td>Up to 15 m from center, multiples of 3 sensors</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>

A thriving ecosystem of hobbyist-oriented vendors provides easy-to-use but powerful electronic components, and online forums help provide technical support for beginning users. As beginners gain experience, they can “graduate” to more general suppliers selling parts that are less user-friendly but with better prices and selections.

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References: