Monitoring Sound Levels in LAPPD Lab

B. Chockalingam, J. Judge, and G. Nathan

The University of Chicago

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Abstract

The sound levels in the LAPPD lab are continuously monitored to identify disturbances to the Margherita tile production facility. Clear differences in sound levels between daytime and nighttime are apparent: average sound level ranges from 12.88mV during off-hours to 13.25mV during busy hours. Laboratory disturbances (entering or exiting, objects falling) register as sound level peaks greater than 300mV. Since microphone sensitivity fluctuates depending on background noise, the microphone is calibrated to quiet nighttime conditions. During nighttime hours (22:00 - 08:00) an object falling from the Margherita cart will produce a measurement of 250mV $\pm$ 50mV and the laboratory door opening and closing will produce a measurement of 400mV $\pm$ 50mV and 500mV $\pm$ 50mV, respectively. Thus, any entry into or presence in the lab is detectable.

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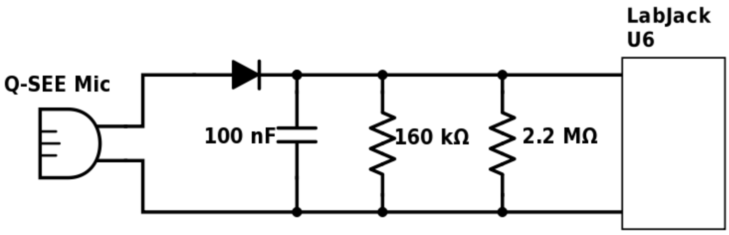

Figure 1: Schematic for audio circuit

1 Equipment & Setup

To monitor sound levels in the laboratory, this project implements a microphone, a half-wave rectifier, and a low-pass filter to produce a varying DC signal that the LabJack U6 [1] can detect.

An indoor microphone [2] is powered by a 12 V DC (0.5 A) wall-wart, with an analog AC audio output signal of amplitude 4 V p-p. After half-wave rectification via a diode and then low-pass filtration with a time constant of 0.016 s ± 0.004 s, the variable DC signal is readable on the Labjack [3] as a single-ended measurement, returning a voltage from 0 - 800 mV.

The choice of a time-constant of 0.016 s is based partially on the target frequency spectrum of mechanically-produced disturbances, in the 150 Hz to 400 Hz range. A second consideration takes precedence. The circuit should reserve enough time-resolution so that its baseline would quickly reset via a rapid decay, thus maintaining constant sensitivity when measuring short, minimally-spaced disturbances. The change in voltage due to the circuit is described by the following equation:

$$V(t) = V_0 e^{-\frac{t}{\tau}} \tag{1}$$

Then, for the desired circuit,

$$V_{max} * e^{(-f_{disturbances/s}/2\pi(RC))} = V_{decay} \tag{2}$$

$$1 * e^{(20/2\pi(RC))} = 0.20 \tag{3}$$

Hence, for the voltage to decay to a 20 % of its maximum value within a tenth of a second,

$$RC = 0.02s \tag{4}$$

The low-pass filter with this time-constant uses a capacitor value of 0.1 μF and a resistor value of 160 kΩ. In implementation, the time constant is slightly shorter at RC = 0.016 s. Additionally, a 2.2 MΩ resistor, in the form of a 1 MΩ passive probe in series with a 1.2 MΩ resistor to the circuit, was included. This additional resistance helped mitigate complications related to making single-ended measurements on the Labjack U6. This 2.2 MΩ load is added in parallel with the 160 kΩ resistor as shown in Fig. 1, and hence does not significantly affect the value of the time-constant.

[1] LabJack U6 product information: https://labjack.com/products/u6

[2] Q-SEE Model QSPMIC, product information: https://q-see.com/products/qspmic-powered-indoor-microphone-with-cable

[3] LabJack U6 product information: https://labjack.com/products/u6

Time Interval	Average Sound Level (mV)	Standard Deviation (mV)
24 h (0:01 - 23:59)	12.93	19.98
Morning Before Work (0:01 - 8:00)	12.88	15.91
Working Hours (8:00 - 16:00)	12.94	24.89
Working Hours (16:00 - 18:00)	13.07	17.90
After Working Hours (18:00 - 23:59)	12.95	16.12
Busy Hours, 3+ people (10:00 - 11:00)	13.25	22.85

Figure 2: Average Sound Levels on February 7, 2017. The standard deviation in this case does not represent precision of the sound monitor's measurements, but rather, shows the variation of levels of sound within the laboratory. As expected, the standard deviation is greater during working hours (24.89 mV and 17.90 mV) than it is during off hours (15.91 mV). A plot for the audio data from this same day can be found in Fig. 5.

2 Calibration

Despite frequency-dependence and saturation affecting the microphone's sensitivity, the sound-level monitor is adequate to measure activity level in the lab.

In Fig. 3, sine-wave tones ascending in 20 Hz steps from 200 Hz to 400 Hz reveal frequency-dependent sensitivity despite amplitude being held constant. The interval was small enough such that defects in the speakers was negligible. Moreover, the shape of each tone in the graph is an exponential decay, suggesting saturation. A saturating microphone's diaphragm, when subject to loud sound, becomes deformed to its maximum and temporarily loses its ability to respond normally to changes in air pressure. Only after a recovery period of at least 4 seconds of silence does the diaphragm free itself from this taut, pinned state, and regain its flexibility. This phenomenon explains why in-lab, workday disturbances are not normally higher than off-hour, hallway disturbances, as apparent in Fig. 4.

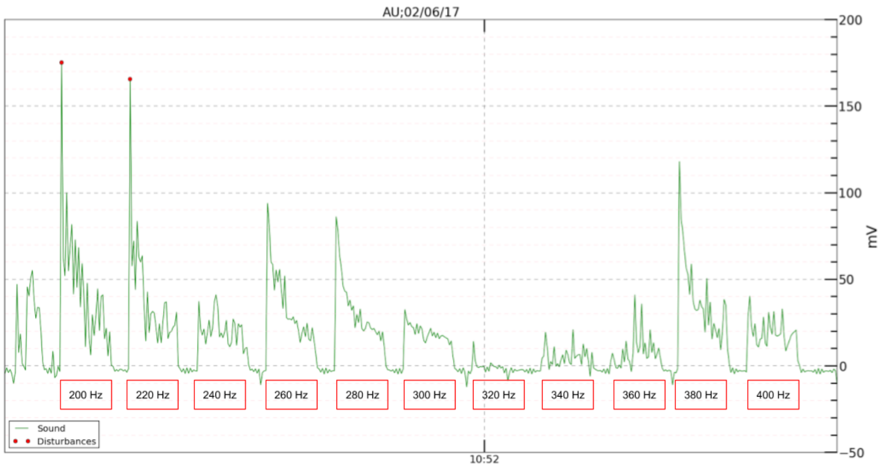

Figure 3: Calibration tests aimed at determining bandwidth and sensitivity to frequency (target range 200-400 Hz). The sensitivity drops in later frequency measurements. Rather than frequency domination, the decreasing sensitivity of the microphone to depend on saturation. The shape of the separate pulses each follow exponential decay, suggesting microphone saturation.

Nevertheless, saturation does not preclude the microphone's usefulness as an activity monitor. Calibration aimed at quiet "nighttime" conditions suggest that distrubances over 400 mV may be of concern, especially if several occur in a short period during the night. A 300 mV $\pm$ 50 mV spike might be attributed to a sharpie falling from the cart, while 450 mV $\pm$ 50 mV spike would be associated with the door opening or closing (Fig. 4. Hallway disturbances such as slamming the door and elevator noise are to be expected from 8:00-22:30 each workday, and can contribute up to 750 mV disturbances. Distinguishing between in lab and hallway disturbances, therefore, will have to incorporate some deductive reasoning based on time of day and the strength of the disturbance.

3 Future Operation of Sound Level Monitor

Despite saturation and frequency-dependence, the sound level monitor adequately approximates mechanical activity and disturbances in the lab. The circuit targets the 200-400Hz range. Visual inspection of plots over several hours reveals distinct periods of the day: in-lab activity, empty-lab hallway periods, and night-time conditions. Moreover, during night-time conditions of heightened sensitivity, disturbances over 300 mV, especially if recurring, suggest potential disturbance in the lab. Short bursts of 600 mV suggests door-related disturbances in the hallway. If these larger, isolated spikes give way to smaller peaks whose separation is on the order of a minute, the lab has likely been entered.

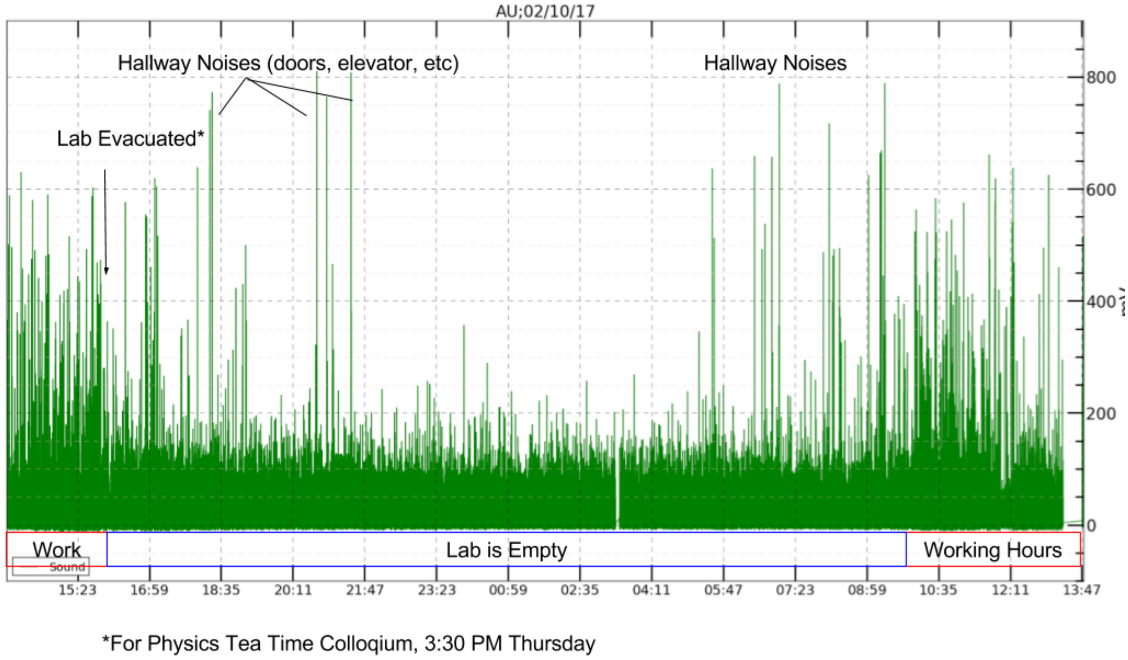

Figure 4: Audio sound levels from Thursday, Feb. 9 to Friday, Feb. 10. After the lab emptied for the Physics Tea Time Colloqium at 15:30, sparse hallway noises persisted throughout the afternoon, registering high as the silent conditions increased the microphone's sensitivity. The lab stayed empty until about 08:00 the following day.

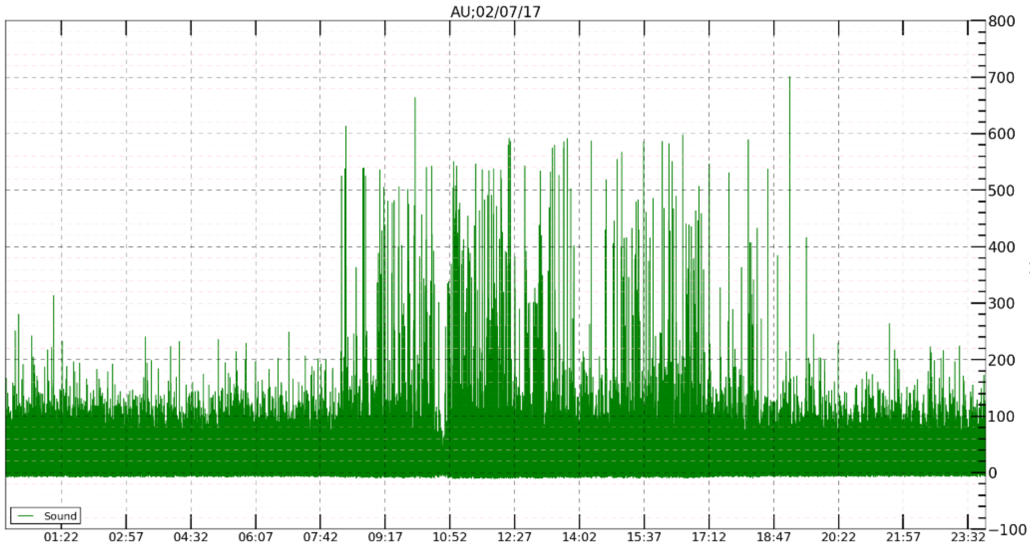

Figure 5: Audio sound levels over the course of Tuesday, Feb. 7. For this typical workday, nighttime conditions end at 08:00 and start at 20:00. During these nighttime hours, neither hallway nor in-lab disturbances were observed, for a door-related disturbances would be expected to register at 400 mV or higher.