Audification And Sonification Of Power Grid Data

ECE 499
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Background

- Power Grid Voltage Equation:

$$V(t) = \sqrt{2}A(t)cos(2\pi f_C t + \theta(t))$$

- Audification converts V(t) Signal into an audible signal

- Sonification uses parameters of V(t) to control pitch/volume parameters of notes played on a music producing source (audio synthesizer)

Project Goals

- Generate clear representations of different types of system responses
- Generate easy to use algorithms
- Determine possible use in power systems introduction and for power grid operators
- Incorporate musical aspect to sonification approach for more pleasing playback

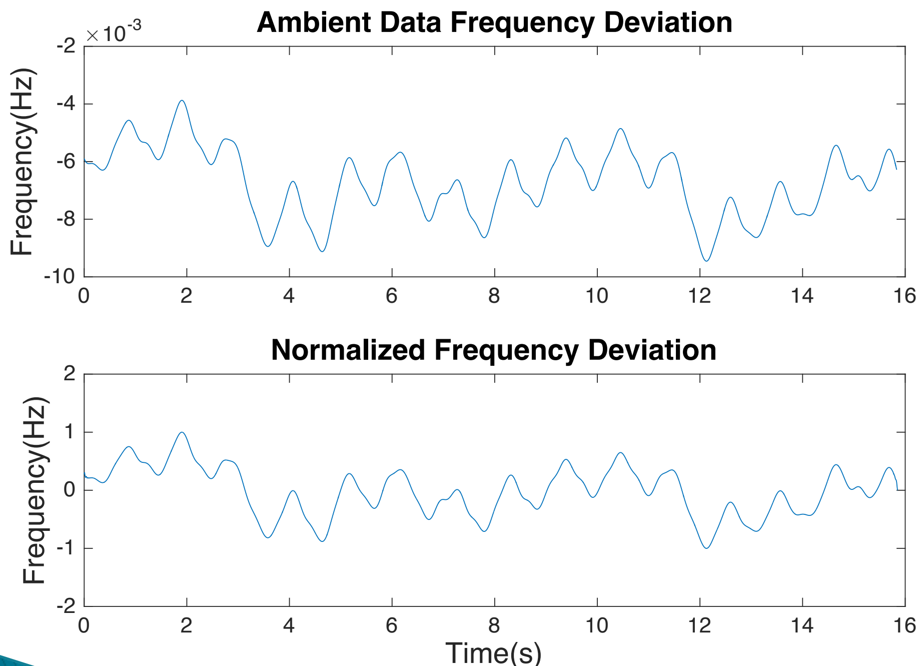
Audification Work Flow

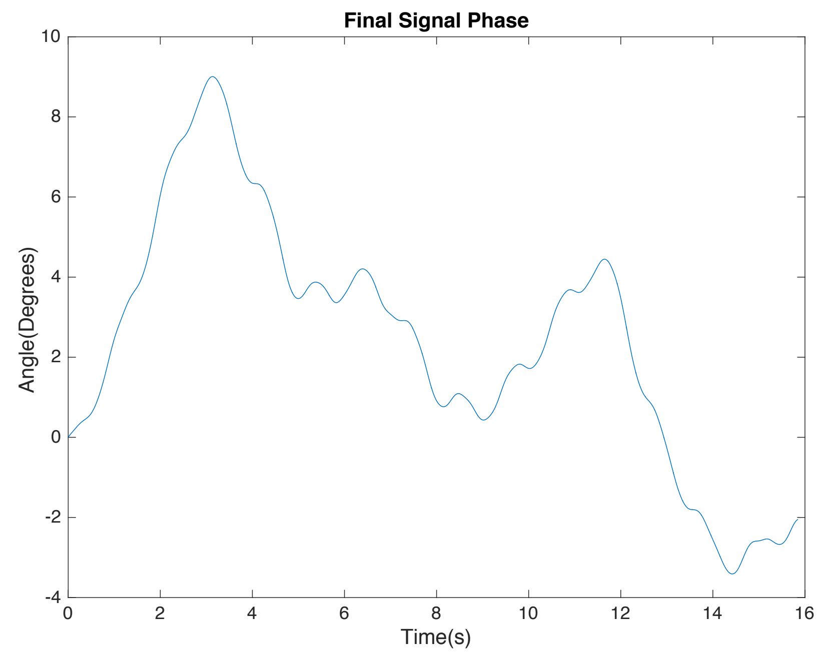
Signal Processing (MATLAB) → Voltage/ Frequency Deviation Normalization and Amplification (MATLAB) → Audio Signal Generation (MATLAB) → Audio playback (MATLAB)

Frequency Deviation Normalization

$$\Delta FreqNorm(i) = 2 * \frac{\Delta Freq(i) - min(\Delta Freq)}{max(\Delta Freq) - min(\Delta Freq)} - 1$$

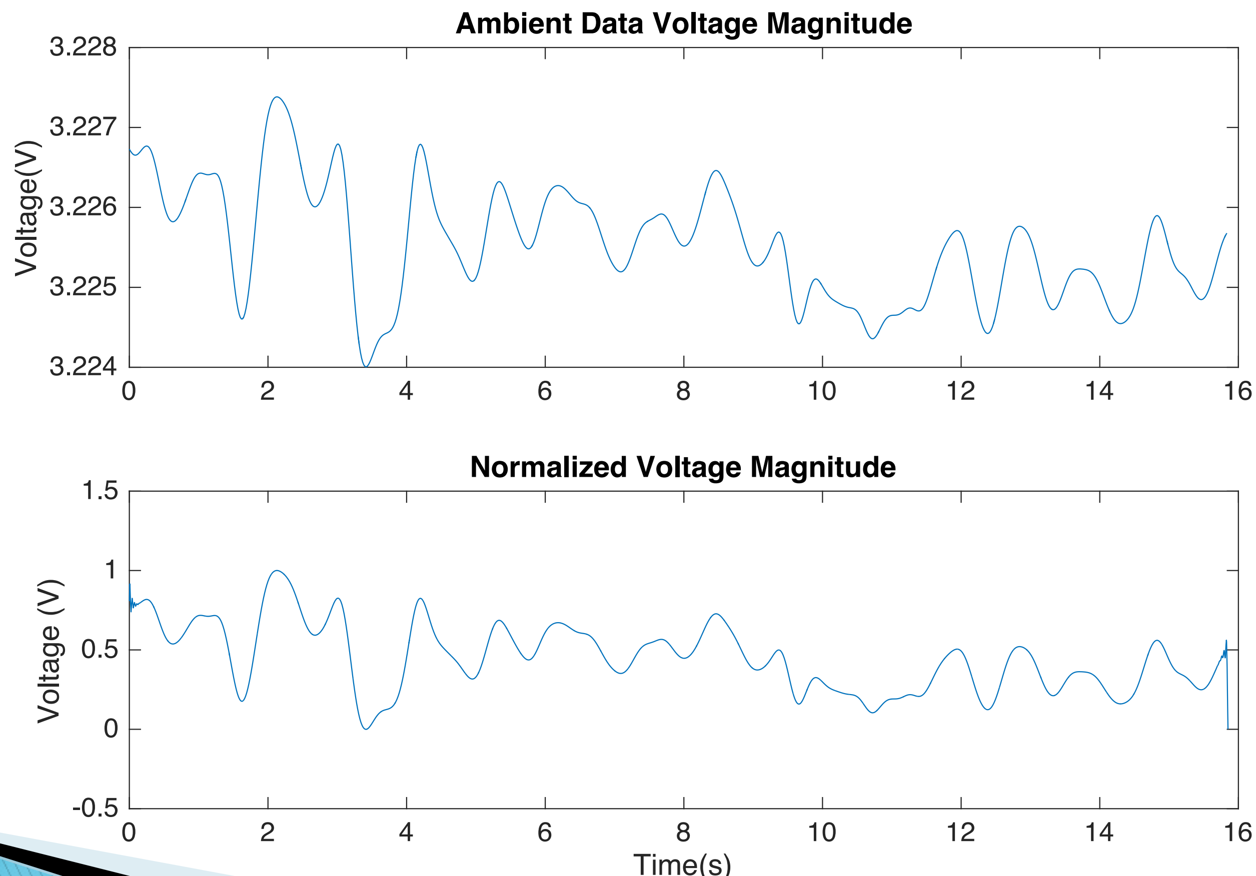
$$\Delta\theta(i) = 2\pi(Ts\Delta FreqNorm(i) + \Delta\theta(i-1))$$





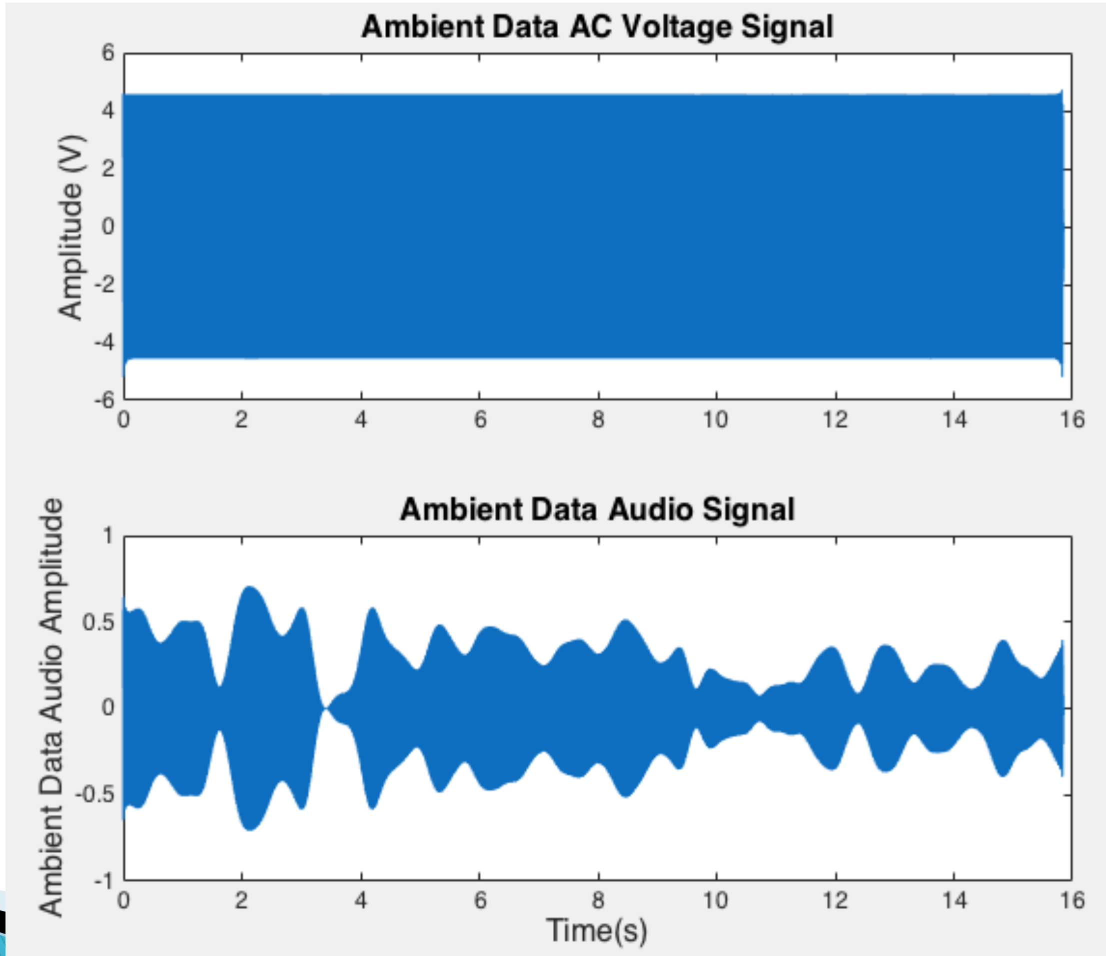
Voltage Magnitude Normalization

$$VmagNorm(i) = \frac{Vmag(i) - min(Vmag)}{max(Vmag) - min(Vmag)}$$

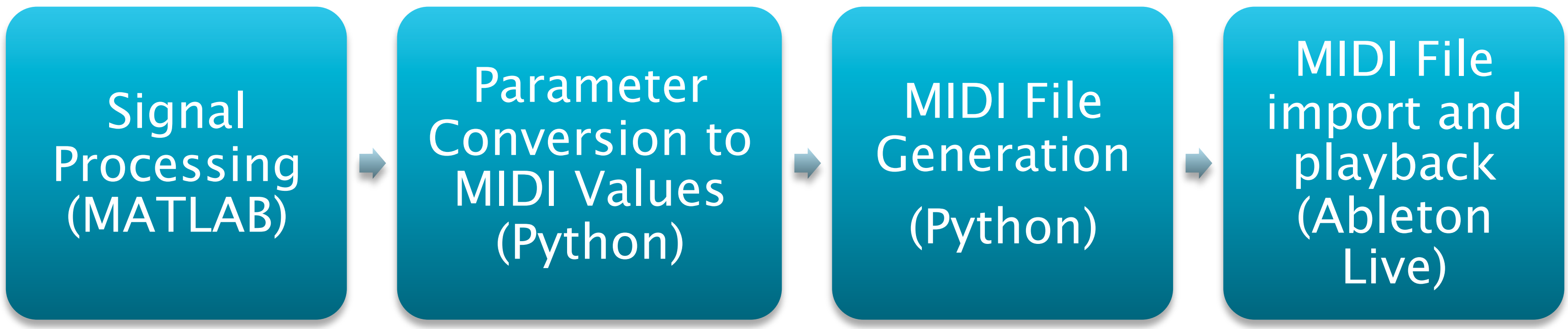


Audio Signal Generation

$$Vaudio(t) = \sqrt{2}VmagNorm(t)cos((2\pi * 261.6))t + G\Delta\theta(t))$$



Sonification Work Flow



Data Conversion To MIDI Parameter Values

$$notes = [0, 2, 4, 5, 7, 9, 11]$$

$$KeyNotes = notes + keyIndex$$

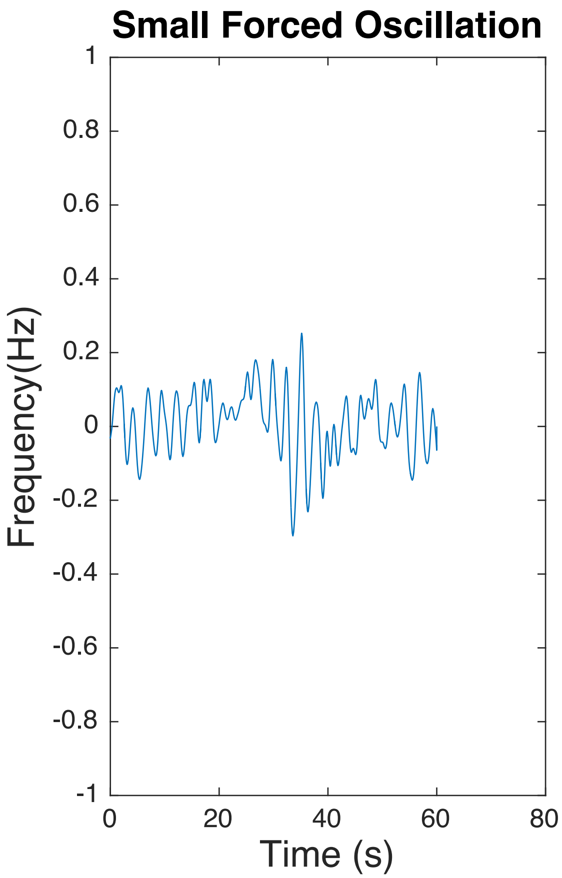
$$lowestNote = 60 - numOctaves * 12$$

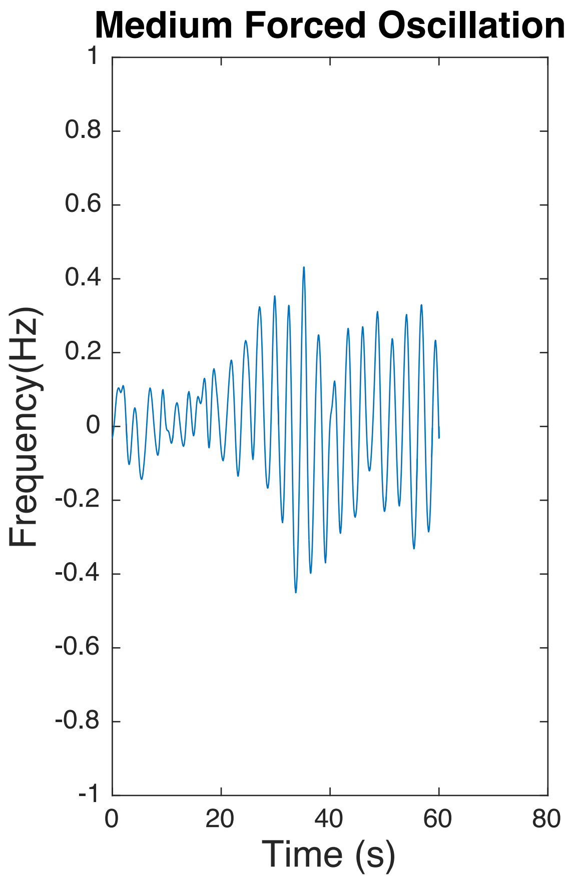
$$allNotes = lowestNote + notes + i * 12$$

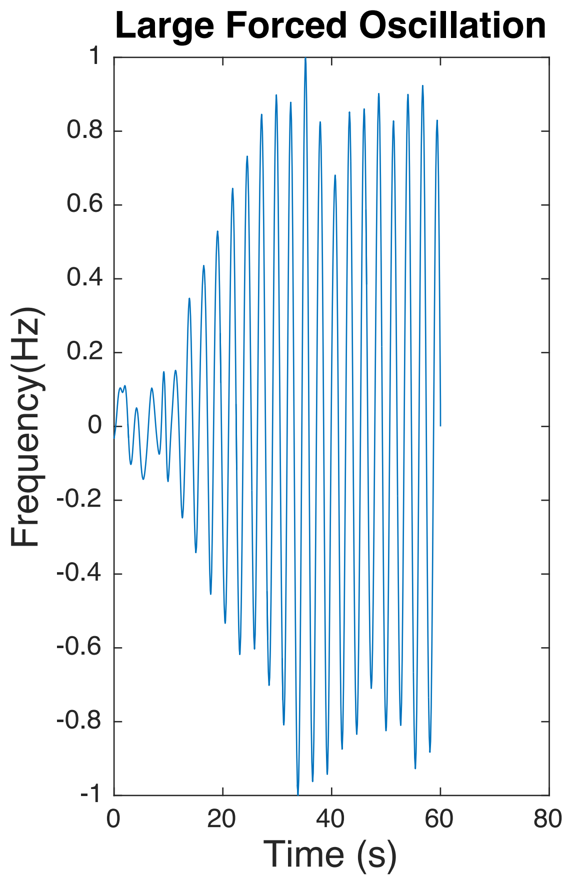
$$fStep = \frac{freqRange}{numberOfNotes} \qquad vStep = \frac{vRange}{128}$$

$$Notelength = \frac{Tempo(BPM)}{SamplingRate(Hz) * \frac{60seconds}{minute}}$$

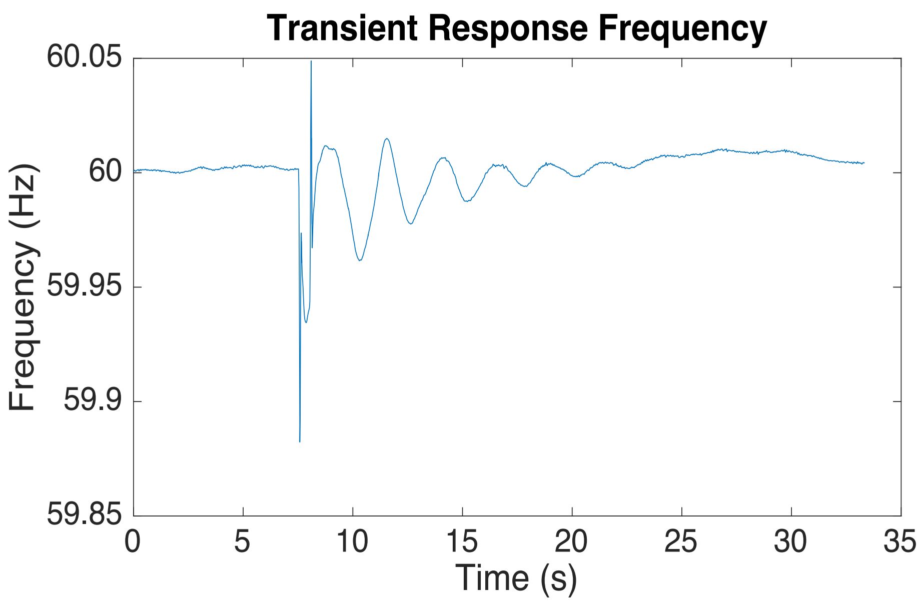
Forced Oscillation Audification

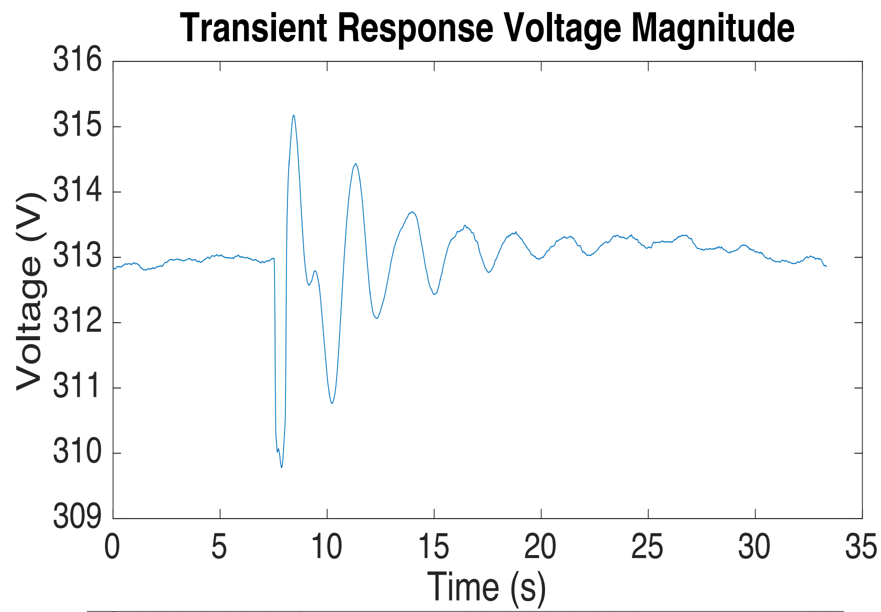


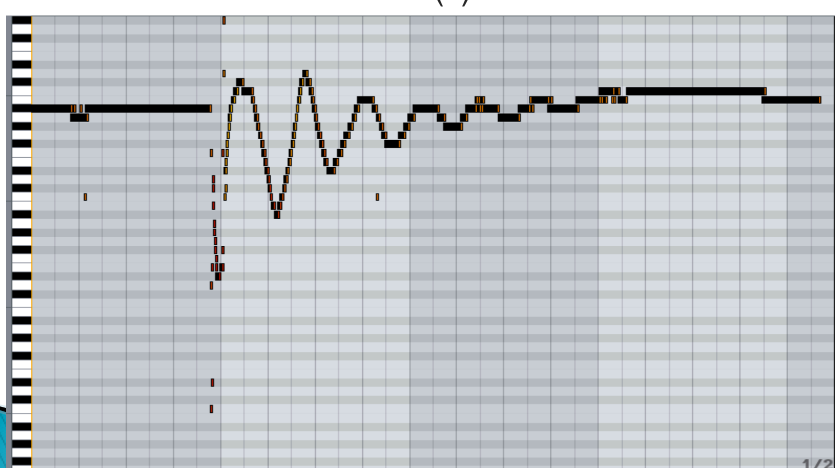




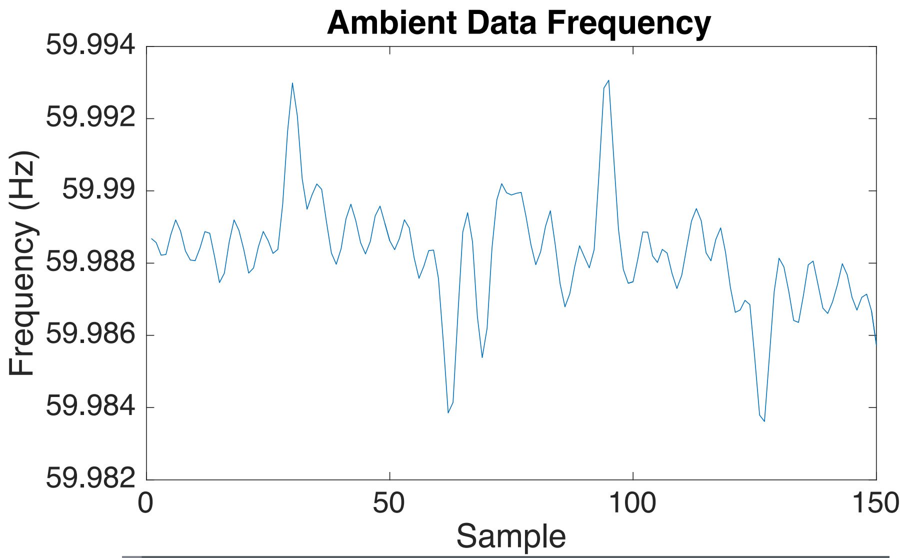
Sonification of Transient Reponse

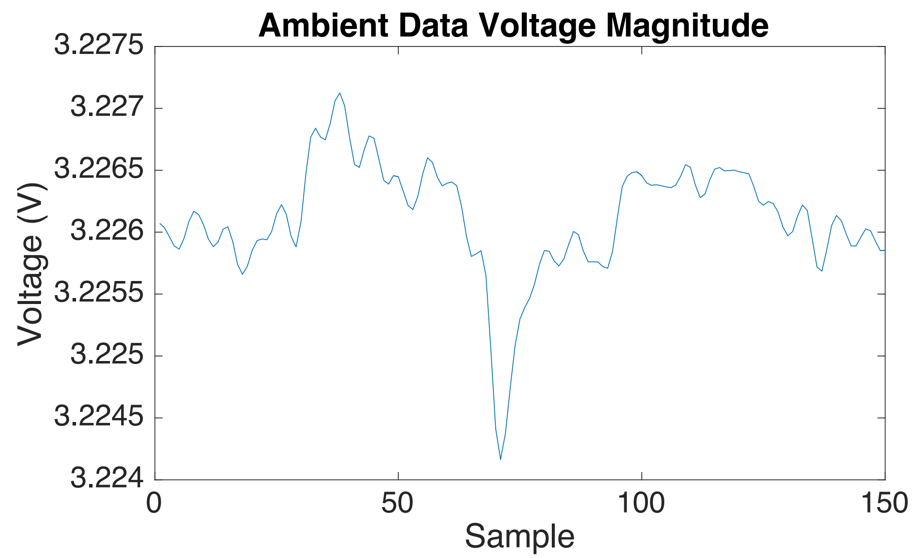


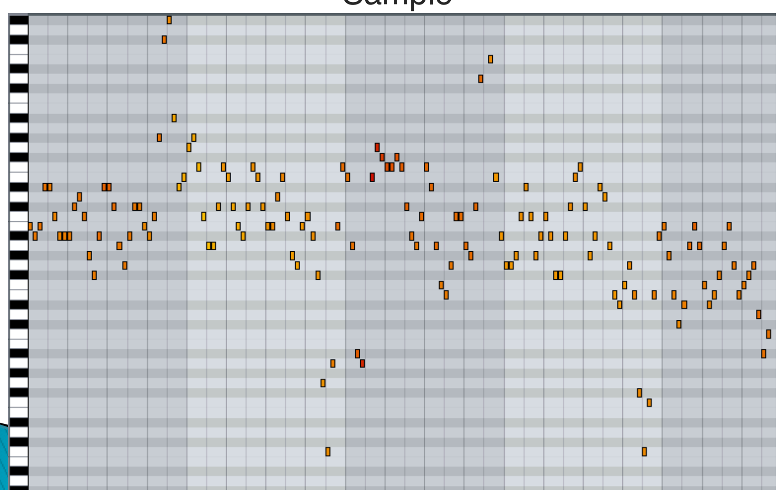


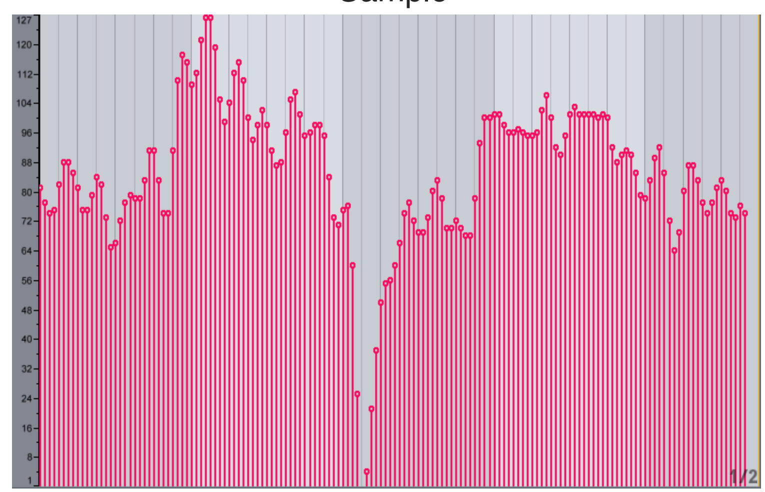


Ambient Data Sonification









Survey Results

	Detection Rate	Est. Start Time (seconds)
Ambient	20%	21 ± 12
Small Forced	73.33%	30 ± 10
Medium Forced	93.33%	25 ± 5
Large Forced	100%	12 ± 2

- Actual oscillation start time: 10s
- Participants preferred sonification playback in musical key versus chromatic and with randomized note lengths

Future Work

- Increase survey sample size for determination of use in power systems analysis/education
- Determine if minute forced oscillations can be heard that are not detectable in time domain analysis and how this can be used for detection algorithm improvement
- Multi-channel Sonification

Questions?