Computer Engineering

Stand-Alone Device for Chord Detection

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♫ ♬ ♬ ♫ ♩ ♪ ♩ ♪ ♬ ♪

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Background

Music Theory

- Study of the components that music is comprised of
  - sound, pitch, melody, harmony, notation, rhythm, form, etc
- Studied by musicians and people who are interested in further appreciation of musical compositions

Note

- 12 different notes with many octaves
- The most basic component of western music
  -when combined build scales, chords, keys, etc.

Chord

- Harmonic structure
- Made up of a combinations of notes

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Motivation

Musician's Tool

- Musical Analysis
- Transcription
  - Manual process is tedious and time consuming
- Improvisation

Building Block

- Proof of concept to build on for bigger projects
  - Tonality Detection
  - Automated Transcription

Stand-Alone Device for Chord Detection from Auditory Input

Stand-Alone

- Definition: “able to operate without control from another system, company, etc.”(Merriam-Webster)
- For this project:
  - Not be simply a computer program
  - All Data Acquisition occurs on the machine
  - Operate independently of location, user, attachment chords

Chord Detection

- Extract and recognize the harmonic structure of a ‘chord’ from a signal

Auditory Input

- Relating to sound
- Not Amplified
- Not symbolic data (MIDI Format)

Design Requirements

Functional

- Input: Acoustic Signal
  - From microphone or AUX cable
  - Not MIDI format
- Output: Display on screen on device
- Accurate
  - Must detect chords correctly at least 75% of the time
- Operate at a meaningful rate for musicians
  - ~1-2 seconds (for music at 120bpm)
- Stand-Alone
- User Friendly ☺

Non-Functional

- Cost affordable: < $200
- Ethical: must not cause copyright infringement

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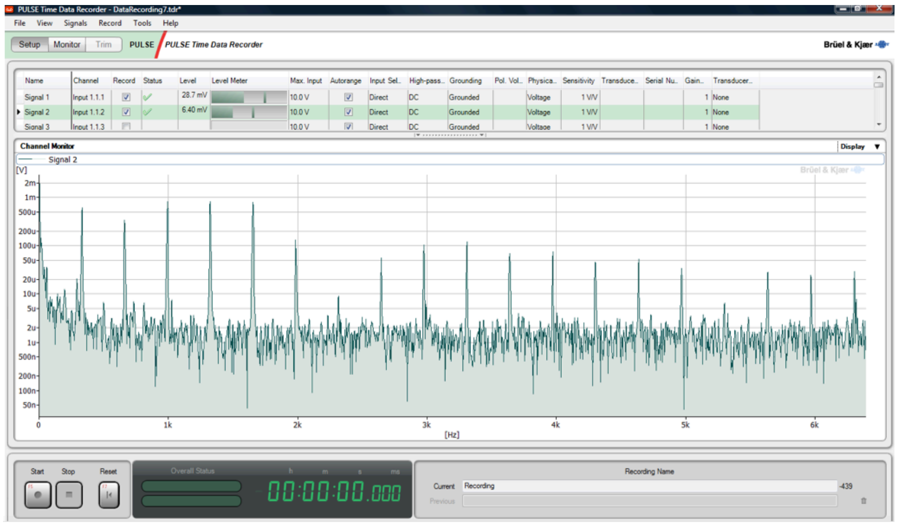
The Problem

E note (played on guitar)


PULSE Time Data Recorder - DataRecording7.tdr*

Name	Channel	Record	Status	Level	Level Meter	Max. Input	Autorange	Input Sel..	High-pass..	Grounding	Pol. Vol..	Physica..	Sensitivity	Transduce..	Serial Nu..	Gain..	Transducer..
Signal 1	Input 1.1.1	☑	✓	28.7 mV		10.0 V	☑	Direct	DC	Grounded		Voltage	1 V/V			1	None
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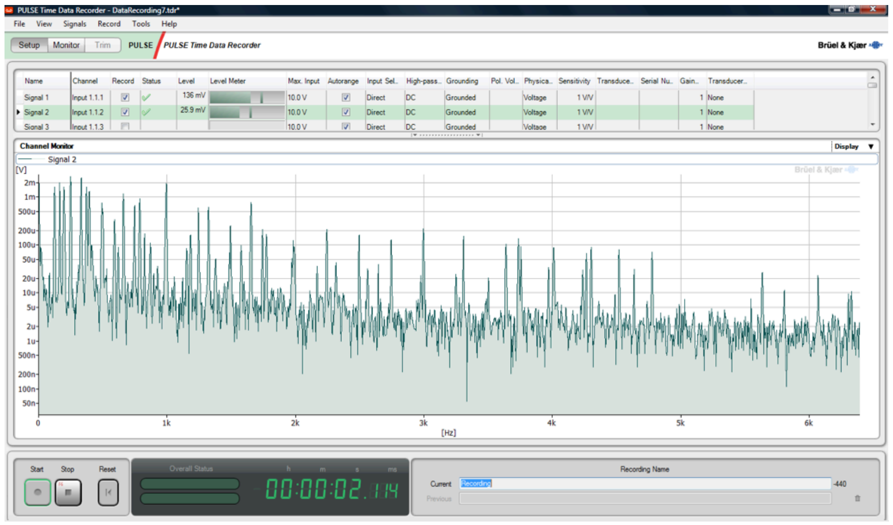
E chord (played on guitar)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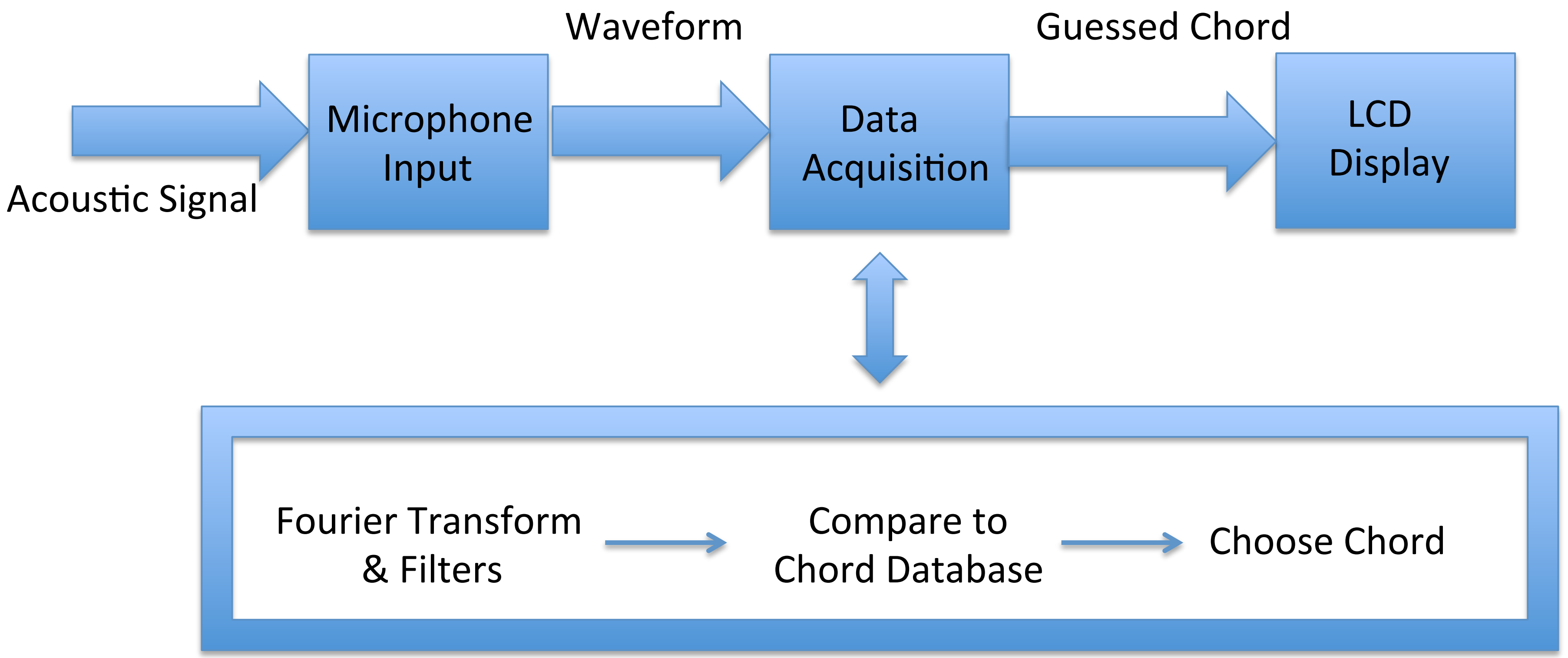
Top-Level Schematic



Design: Hardware Options

Device	Audio Input Capability	Programming Language	Operating System	Cost
Raspberry Pi	3.5 mm jack Or USB Device	Python, Java, C, C++, Scratch, or Ruby	NOOBS (New Out Of Box Software) Or Linux	~ $40
Arduino	No direct input -requires extra wiring and coding	C/C++ using open-source IDE	DuinOS	$25-$70
FPGA	Personal Experiences proved this to be difficult	VHDL Or Verilog		>$100

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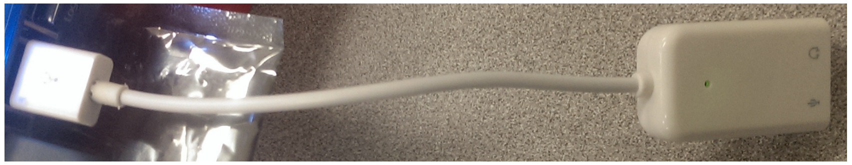
Hardware

Raspberry Pi Model B+

- Used for Data Acquisition
- Tying all components together

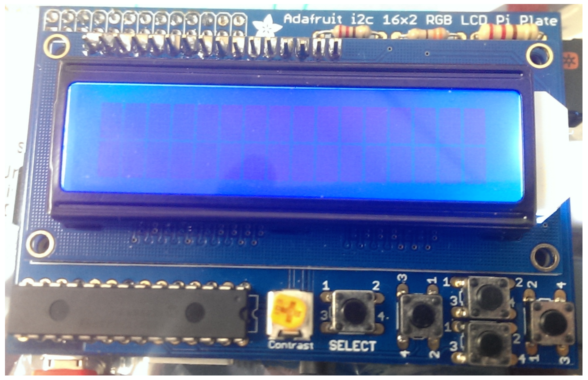
USB Sound Card

- Used for getting auditory input
- 3.5mm jack for input/output



LCD Screen

- 16x2 character display with keypad
- Used for display
- Used for controlling recording



Software/Algorithm

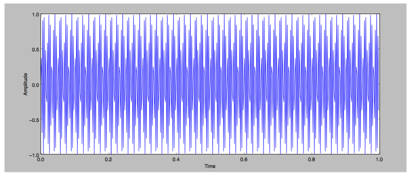
Software

- Raspbian (debian distro of Linux)
- Python

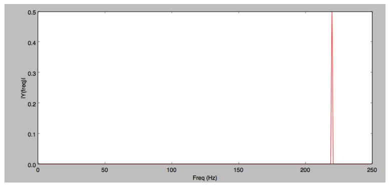
Algorithm Overivew

1. Take in data as waveform
2. Transfer data to frequency domain using Fourier Transform
3. Extract note information from frequencies
4. Create pitch-class set (set of length 12, one for each note)
5. Compare pitch-class set to chord templates to detect chord
6. Display guessed chord

1.)



2.)



3.)

4.)

[C, C#\Db, D, D#\Eb, E, F, F#\Gb, G, G#\ Ab, A, A#\Bb, B]

5.)

6.)

Design

Sampling

- Trade off between time and sampling rate
- Decided on 12000Hz

Transform & Array Manipulation

- Fourier Transform
- Change from bin values → frequency values for index
- Add up each note's intensity from corresponding frequency across all octaves

  -Forms Pitch-Class Set and then normalize it
- Take the 3 max values (assuming triad) and compare to chord templates
- Display 'guessed chord' or if no chord found, display highest note intensity

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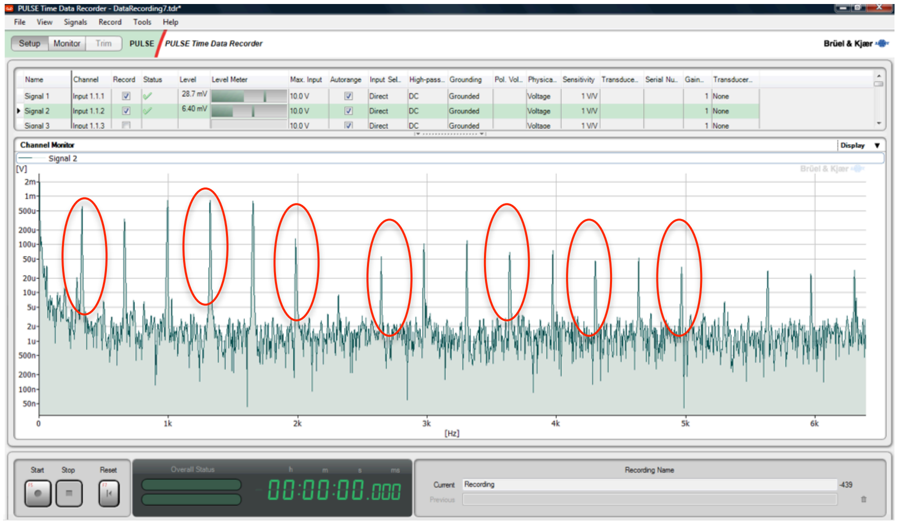
The Solution

E note (played on guitar)



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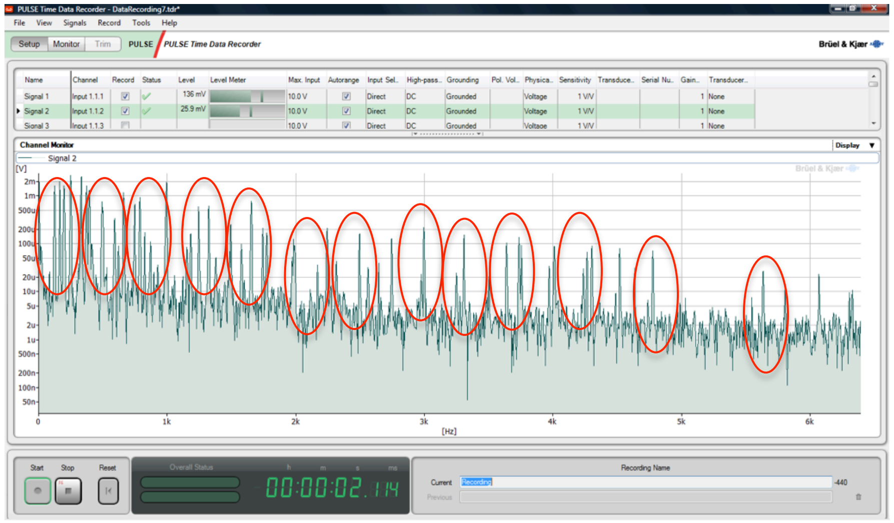
E chord (played on guitar)



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[0.13551649, 0.17193301, 0.13968407,0.1583991, 0.76749613, 0.25365, 0.16233895, 0.16606936, 0.23051037, 0.23438108, 0.1207705,0.27780134]

[0.04241156, 0.05910824, 0.11698372, 0.14734106, 0.70756931, 0.12755939, 0.12580443, 0.4603361, 0.15432546, 0.09964817, 0.07407452, 0.44640032]

[0, 0, 0, 0, 1, 0, 0, 0 ,0 ,0 ,0]

[C, C#, D, D#, E, F, F#, G, G#, A, B]

[0, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 1]

(E)

(E) (G) (B)

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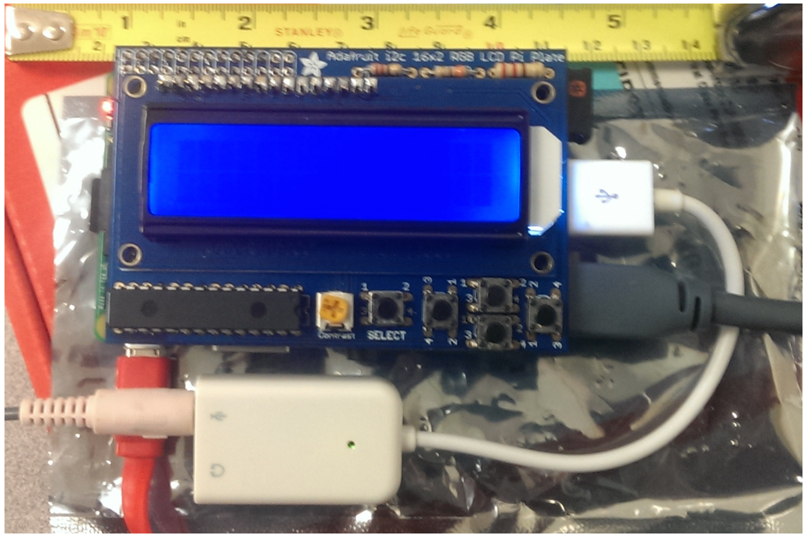
Results

Device

- Portable
- Easy to use
- Stand-Alone
- Input: Microphone/Auxiliary Chord
- Output: Display on Device



Software

- Accurately detect the 12-notes in the 12-tone western music system
- Accurately detect 12 basic major chords
- Accurately detect 12 basic minor chords
- Executes algorithm quickly

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Future Work

Device

- Make a housing for the device
- Add a battery pack so doesn't need to be plugged into wall
- Obtain a more suitable microphone

  -current one being used is from a head-set

Software

- Add functionality for chords with embellishments

  -7^{ths}s, Diminished, Augmented

- Add functionality so don't need to press a button before detection
- Add more filtering
- Test capabilities of device more thoroughly

The End

Questions?

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