

1. PROBLEM

The theremin is one of the first electronic musical instruments ever made. A Russian physicist, Leon Theremin, invented it in 1919. The theremin is played by moving one's hands closer or farther away from two antennas. The proximity of the player's hand to the pitch antenna creates a capacitance that is used to control the frequency of a variable oscillator circuit. The output of this circuit is combined with the output of a fixed frequency oscillator. These oscillators both operate at supersonic frequencies. After the outputs of both of the circuits have been mixed, the signal is filtered to extract a beat frequency created by the difference in frequency between the oscillators. The volume antenna also creates a capacitance which is used to control an amplifier circuit that the filtered signal is fed through before being output to a speaker.

The theremin is a truly unique instrument. It is the only known instrument to be played without touching it [2]. It has a relatively wide range of pitches, usually ranging about five octaves, allowing it to play music from the basso to the high soprano range and everything in between. The timbre of the theremin is somewhat like a violin, very rich in harmonics and complex. It has what is usually described as a "spooky" or "ethereal" sound.

Despite being one of the earliest electronic musical instruments, the theremin is also one of the least used or well known. The very qualities that set it apart from other instruments introduce problems that have prevented it from becoming very popular. It has traditionally been a difficult instrument to learn because it lacks any physical reference for the performers, forcing them to rely heavily on their ears in determining what notes they are playing [3]. Most novice musicians' ears are not very well developed, leading to a frustrating experience for those trying to learn to play the theremin, discouraging casual players, who are not already experienced with music or sorely determined to learn it, from taking it up. Clara Rockmore, one of the most widely known theremin virtuosos, once said in an interview "One should not learn to play the theremin as his first instrument," [1] explaining that the fundamentals of music should be learned first on another instrument before the theremin is learned. Those beginners that do choose to endure the difficulties in learning the theremin as their first instrument are further hindered by the inherent problems in self-study caused by the aforementioned limitations: that is, with no tactile or visual reference and a less-than-perfect sense of pitch, the students may have difficulty in ascertaining whether their performance is in tune or otherwise acceptable without guidance from a teacher. This is an unfortunate problem, because the fact that the theremin is such a rarely played instrument leads to difficulty in finding teachers, making self-instruction an all but necessary element in learning.

Our group proposes to address these problems by building a theremin that is geared toward making learning to play easier, even for those with no prior musical experience. Our theremin will be designed with an LCD display that shows the note that is being output and how closely in tune it is. This provides visual feedback to the performers, giving them a more reliable reference than their ears as to the accuracy of their

performance. Our theremin will also have a MIDI compatible output that will be used to interface the instrument with a computer. This will allow the users to study the theremin with the aid of software that we will write to aid them. The software will evaluate and rate their playing, according to exercises it provides for them to play. This software is what will set our theremin apart from other MIDI theremin models, as it will provide the students with an objective, accurate method of evaluating their playing ability and a more effective way of practicing. The software will be designed such that exercises can be added to it as needed, allowing for greater challenges to be introduced as the user's playing ability grows.

These improvements will make the theremin an easier instrument to learn to play and improve the quality and effectiveness of theremin pedagogy in general. This will the theremin more accessible and attractive to a broader group of musicians and opening it up as less opposing challenge for those who lack musical training on another instrument. In addition to these improvements, the theremin will be designed for a lower cost than currently available models, which can typically range from \$370 to \$3500, further widening the prospective user-base by making it more attractive to casual users. Providing a usable instrument with better tools and methods for learning to play at a lower cost than existing models will make the theremin less of a challenge to adopt and may allow the theremin to finally obtain the popularity and mainstream acceptance that have eluded it for almost the entire eighty years of its existence.

2. OBJECTIVES

The three main issues that we intend to focus on in designing our theremin are ease of use, ease of learning, and cost. In order for it to be accessible to a broader range of people, the theremin will need to be easy to set up and play. Along with making it easy to use, the cost of the theremin will need to be minimized by making certain considerations in its design. These include reducing the octave range and choosing the lowest costing components as possible. In order to make the theremin easy to learn, computer software will be created that is compatible across a broad range of PC's along, and an onboard LCD interface will be included to display the pitch being played. The following is a list of what will be needed to accomplish our objectives.

2. **MIDI compatibility:** The product will be able to connect to the computer for use with the learning software. A MIDI signal output will be used for this purpose.
2. **3-octave range:** The theremin's musical range will be three octaves. These octaves will be:
 - a. 1st octave: from 130.81 Hz to 246.94 Hz
 - b. 2nd octave: from 261.63 Hz to 493.88 Hz
 - c. 3rd octave: from 523.25 Hz to 987.77 Hz

3. **Pitch detection:** The theremin will be able to detect the pitch being played. The accuracy will be within 5% of actual note as defined by:

a. 1st octave:

| | |
|---------|-----------|
| C3 | 130.81 Hz |
| C#3/Db3 | 138.59 Hz |
| D3 | 146.83 Hz |
| D#3/Eb3 | 155.56 Hz |
| E3 | 164.81 Hz |
| F3 | 174.61 Hz |
| F#3/Gb3 | 185.00 Hz |
| G3 | 196.00 Hz |
| G#3/Ab3 | 207.65 Hz |
| A3 | 220.00 Hz |
| A#3/Bb3 | 233.08 Hz |
| B3 | 246.94 Hz |

b. 2nd octave:

| | |
|---------|-----------|
| C4 | 261.63 Hz |
| C#4/Db4 | 277.18 Hz |
| D4 | 293.66 Hz |
| D#4/Eb4 | 311.13 Hz |
| E4 | 329.63 Hz |
| F4 | 349.23 Hz |
| F#4/Gb4 | 369.99 Hz |
| G4 | 392.00 Hz |
| G#4/Ab4 | 415.30 Hz |
| A4 | 440.00 Hz |
| A#4/Bb4 | 466.16 Hz |
| B4 | 493.88 Hz |

c. 3rd octave:

| | |
|---------|-----------|
| C5 | 523.25 Hz |
| C#5/Db5 | 554.37 Hz |
| D5 | 587.33 Hz |
| D#5/Eb5 | 622.25 Hz |
| E5 | 659.26 Hz |
| F5 | 698.46 Hz |
| F#5/Gb5 | 739.99 Hz |
| G5 | 783.99 Hz |
| G#5/Ab5 | 830.61 Hz |
| A5 | 880.00 Hz |

| | |
|---------|-----------|
| A#5/Bb5 | 932.33 Hz |
| B5 | 987.77 Hz |

4. **Audio specifications:** The theremin will have a preamp voltage of 2V and a pitch drift of at most 2% of the expected pitch.
5. **Power supply:** The power will be supplied externally.
6. **Speaker jack:** There will be standard 3.5mm jack to be used by external speakers.
7. **Teaching Software:** The software will have lessons for Beginner, Intermediate, and Advanced Musicians and will be developed for the Windows API. It will be compatible with Windows 98® or higher and the Sound Blaster® sound card.
8. **Weight:** The theremin will weigh less than 15 lb.
9. **Cost:** The theremin will cost less than \$200.
10. **Interface:** An LCD screen will be used as an interface.
11. **Size:** The theremin will be no larger than 1.5 ft by 1 ft by .5 ft.
12. **Power consumption:** The theremin will consume under 50W of power.
13. **Suitable for most ages:** The final product will be suitable for use by ages eight or older.

Low cost, easy setup, and PC software will make our theremin more appealing than current designs. Meeting these objectives will improve the marketability of our theremin. We hope to create a design that will allow a broad range of players to enjoy the theremin

References

- [1] "In Clara's Words: An Interview with Clara Rockmore", <http://www.maxiespages.com/theremin/rockmore.shtml>,
- [2] "Learn - What's a Theremin?", <http://www.thereminworld.com/learn.asp>, ThereminWorld, 2002.
- [3] S. J. Aldrich, "The History and Significance of the Theremin", <http://www.stanford.edu/~aigeanta/theremin/>, Stanford University, 2000