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School of Engineering Science • Burnaby, BC • V5A1S6
http://www.sfu.ca/~echiua/mint • 340-2001@sfu.ca

July 13, 2001

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 340 Design Specifications: Dancing Orpheus Musical Suit

Dear Dr. Rawicz,

The attached document, *Design Specifications: Dancing Orpheus Musical Suit*, outlines the design specifications of our project for ENSC 340. Our goal is to design and implement a musical instrument that can be played while the performer dances.

We are currently in the process of designing and building a device that aims at generating music through specific user movements. Angular changes at specific body joints would be detected and would activate wireless signal transmission. In turn, received sensor signals would activate music production. The design presents a quick and flexible way that integrates both dancing and music composition.

The purpose of this document is to describe the high-level design specifications of our product regarding its two major processing units: motion detection and sensor logic transmission unit, sound generation and processing unit. Applicable design information and testing approaches required for successful project completion are provided in this document.

MiNT consists of five innovative third year engineering students – Sharon Chang, Eddy Chiu, Tony Leung, Robert Sin, and Lydia Tse. If you have any questions or concerns about our design specifications, please feel free to contact me by phone at (604) 420-3628 or by email.

Sincerely,

Eddy Chiu
MiNT, Inc.

Enclosure: *Design Specifications: Dancing Orpheus Musical Suit*

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Design Specifications:
Dancing Orpheus Musical Suit

Project Team:

Sharon Chang
Eddy Chiu
Tony Leung
Robert Sin
Lydia Tse

Contact Personnel:

Eddy Chiu
echiua@sfu.ca

Submitted to:

Dr. Andrew Rawicz – ENSC 340
Steve Whitmore – ENSC 305
School of Engineering Science
Simon Fraser University

Executive Summary

Advancements in technology have been an important factor in revolutionizing art and entertainment. Traditionally, music has been a crucial requirement for dancing. Technological development has allowed this trend to be reversed by products that detect and convert body motion into music. However, the narrow range of products available is expensive and sometimes massive. With the introduction of the *Dancing Orpheus Musical Suit*, a portable and economical device that allows a dancer to play music at the same time, composing music will become easier and more fun than ever.

The *Dancing Orpheus Musical Suit* is suitable for everyone with its exceptional flexibility and convenience in music generation. It provides an innovative way of music generation and composition. In addition, the *Dancing Orpheus Musical Suit* costs only a tiny fraction of other currently available products of the same kind.

The basic operations of the *Dancing Orpheus Musical Suit* include tracking a dancer's motions and generating sequences of musical notes. In addition, the user can also vary these notes by changing the pitch or generating flats and sharps. Additional sound generating and modifying effects are also available for selection. The prototype is designed to output to a low power speaker or an amplifier. If time is available, a computer interface will be implemented as an enhancement feature.

The development of this project spans a 13-week period, with August 24, 2001 being the scheduled completion date for a working prototype.

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1. Introduction

Music and dancing have significant impacts on human civilization, being the central part of various entertainment and cultural activities. Music provides a dancer with rhythm and theme, whereas the accompaniment of dancing steps provides graphical expression for a song.

Despite the inseparability of these two qualities, currently, among the enormously varied musical instruments from various origins, merely a few can be played by a dancer while performing. Such instruments are limited to the category of percussion; for example, drums and bells that can only generate a narrow selection of notes.

The *Dancing Orpheus Musical Suit* is a device that generates music based on a dancer's motions. Radio transmission and internal batteries avoid wire connections and thus provides the user with complete freedom of movement and portability. All musical notes as well as pitch variations are featured by the *Dancing Orpheus*, allowing it to compose music at the same level of complexity as any other sophisticated musical instrument.

The main objective for this project is to complete the assembly of a functioning device by August 2001. This document provides a high-level system overview of our product as well as a detailed discussion on various design specifications to the two major units: motion detection and sensor transmission logic unit, sound generation and processing unit.

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2. System Overview

Figure 1 shows the system overview of the *Dancing Orpheus Musical Suit*.

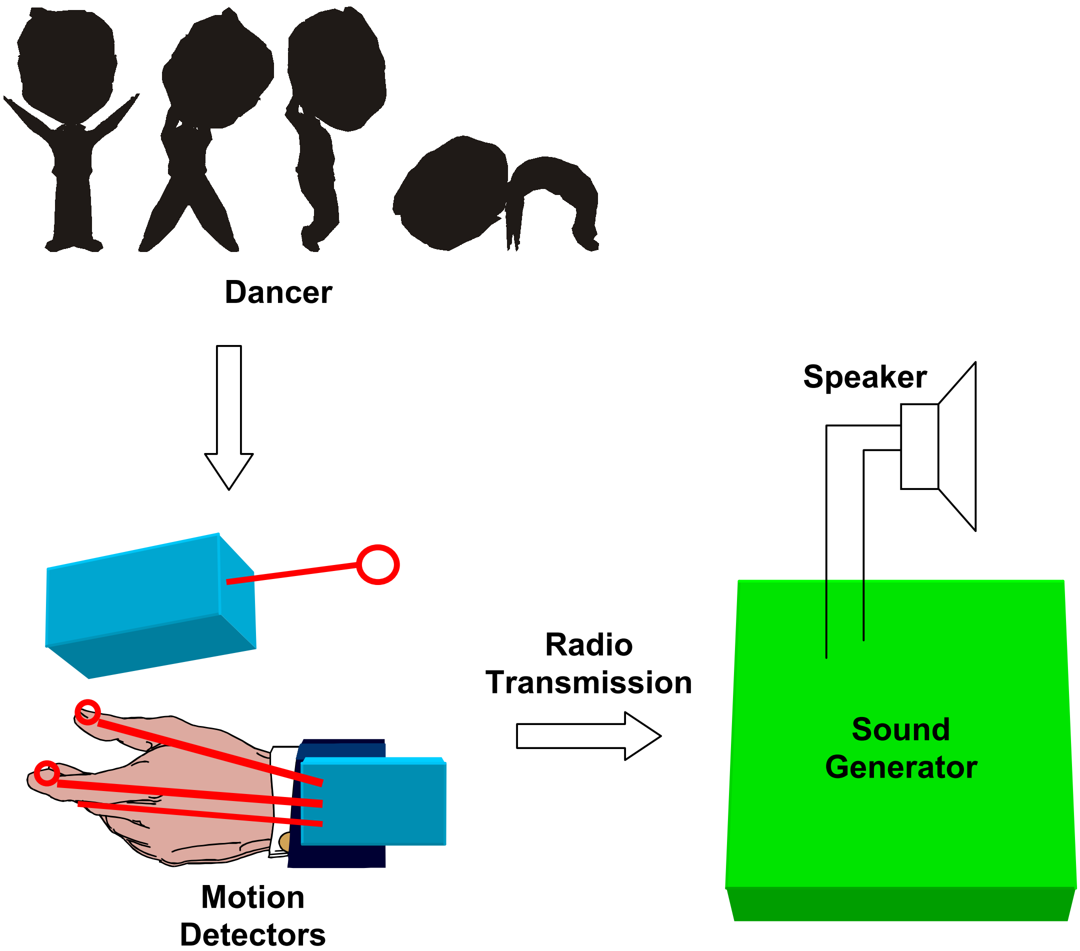

Figure 1: System Overview

The device tracks a dancer's motions and sends the data to a detached sound generator through pairs of radio transmitter and receiver.

The motion sensors are to be worn at the major body joints, each of which controls the playing of a predefined musical note or sound effect. The placement of the sensors is shown in Figure 2.

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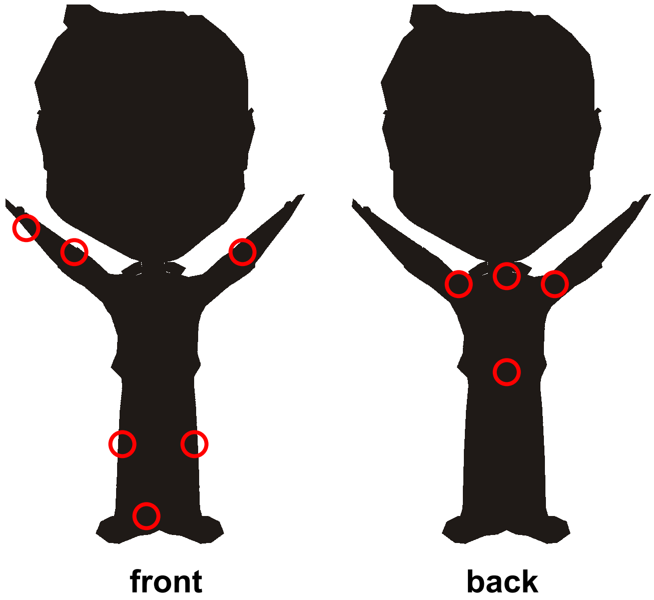

Figure 2: Sensor placement

When the sensors detect an angular movement beyond a preset threshold value, an activation signal will be generated, which causes the sound generator to produce the digitally synthesized tone.

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3. Motion Detectors

3.1. Motion Detection

The *Dancing Orpheus Musical Suit* features 2 types of motion detectors. Type 1 detectors are designed to track major joint motion using a rotation gear with restoration force. Conversely, type 2 detectors are activated by bringing the finger connection pads into contact.

Figure 3 shows the system block diagram for type 1 motion detector.

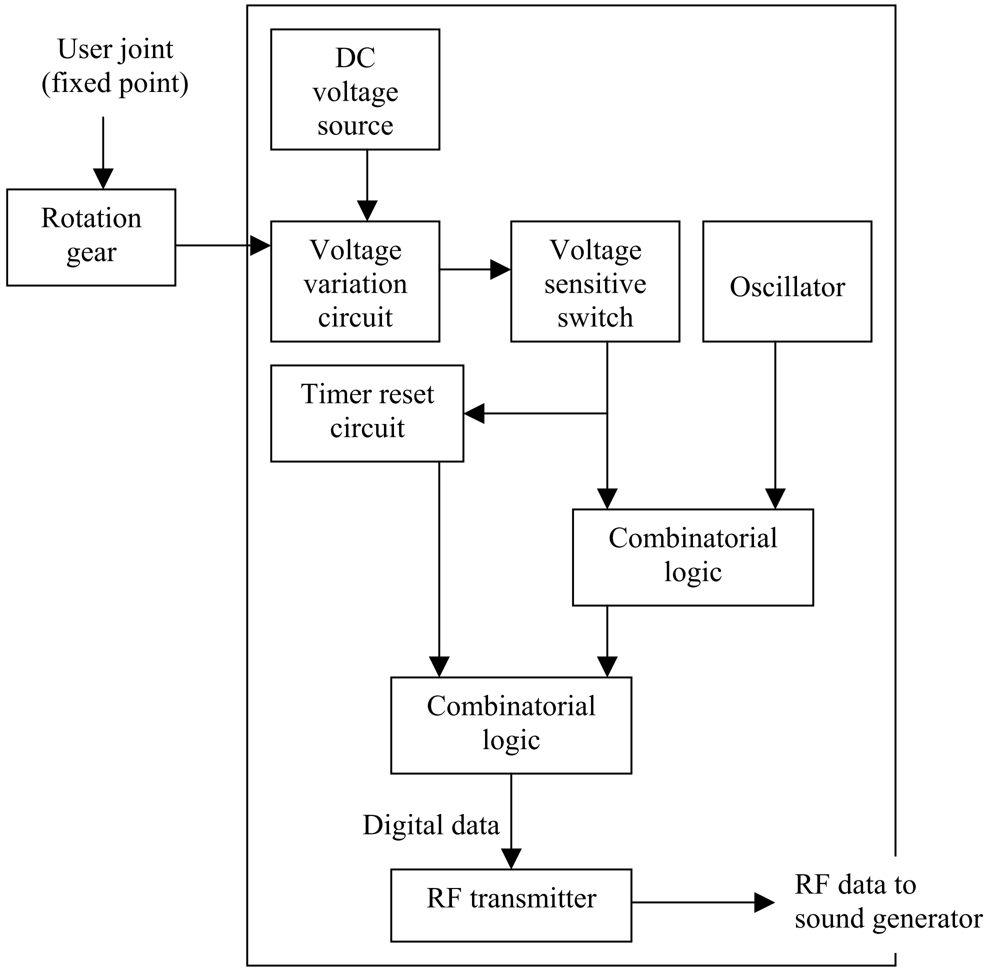

Figure 3: Type 1 Motion Detector Block Diagram

A type 1 motion detector consists of a DC voltage source[1], a rotation gear, a voltage variation circuit, a voltage sensitive switch, a timer reset circuit, some combinatorial logic, and a RF transmitter module.

[1] Power supply: 2 button cell batteries providing $6V_{DC}$.

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Each motion detector unit is attached to 2 different locations of the user's body, across a joint: a fixed reference point for movement and the main circuitry. These two parts of the detector are connected with a string attached to the rotation gear.

When the user makes a movement, the distance between the reference point and the main circuitry module varies. In effect, the string will turn the gear as shown in Figure 4.

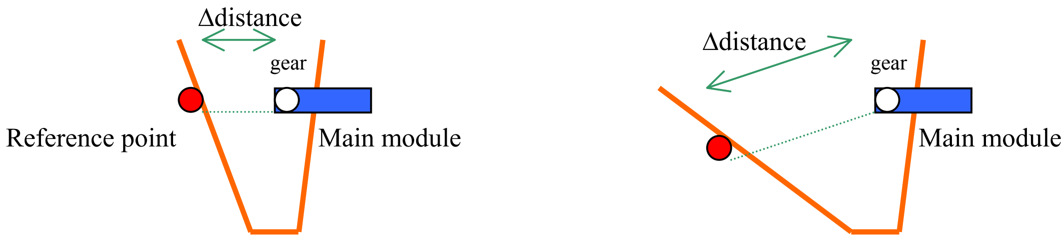

Figure 4: Angular Motion Detection by Gear with Restoration Force

Rotation of the gear excites the voltage variation circuit and gradually activating the voltage sensitive switch. This output signal is then combined with an oscillatory signal[2] and fed at the data input of the transmitter module. The timer reset circuit is activated simultaneously and would reset the transmission after 2 seconds.

On the other hand, the design of type 2 motion detectors is greatly similar to that of type 1 detectors discussed above. The system block diagram of type 2 detectors is shown in Figure 5.

[2] Refer to section 3.2 for details on the application of the oscillatory signal.

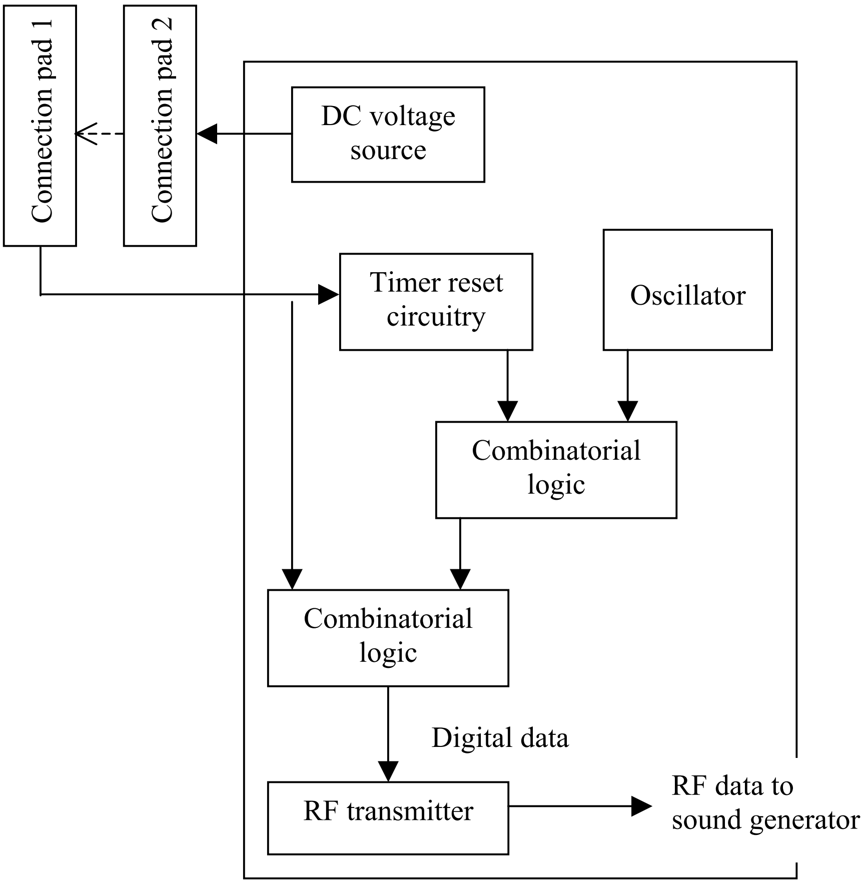

Figure 5: Type 2 motion detector block diagram

A type 2 motion detector consists of a DC voltage source[3], 2 connection pads, a timer reset circuit, some combinatorial logic, and a RF transmitter module.

The main circuitry of the type 2 detectors is placed at the back of the hands with the connection pads attached to the finger tips. When connection pads 1 and 2 come into contact, they generate an activation signal that is combined with an oscillatory signal – as implemented in type 1 detectors – and input to the transmitter. Moreover, similar to type 1 detector, the timer reset circuit is also featured to reset the activation signal after 0.5 seconds.

Type 1 motion detectors are used to control tone generation. Conversely, type 2 motion detectors are used to control sound output configuration signals and to activate sound effects.

[3] Power supply: 2 button cell batteries providing $6V_{DC}$.

3.2. Signal Transmission and Encryption

The AMRT4-315 and AMRT4-433 AM transmitter modules from OKW Electronics are used in the motion detectors for signal transmission. The transmitters transmit at frequencies of 315MHz and 433MHz over a distance of up to 100m.

Since the transmitters in the motion detectors must share the 2 transmission channels, an encryption system has been developed to allow the receivers to identify the source transmitter of the signals it receives. The preceding section indicates that an activation signal is combined with an oscillatory signal before it is transmitted. Therefore, by assigning a unique frequency to each oscillator, each detector is thus provided with a unique identification[4]. For convenience with implementation, let all oscillators have 50% duty cycle.

[4] Please refer to section 4.2.1 for details on the receiver data decoding algorithm.

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4. Sound Generator

4.1. Hardware Specifications

Figure 6 shows the system block diagram for the sound generator.

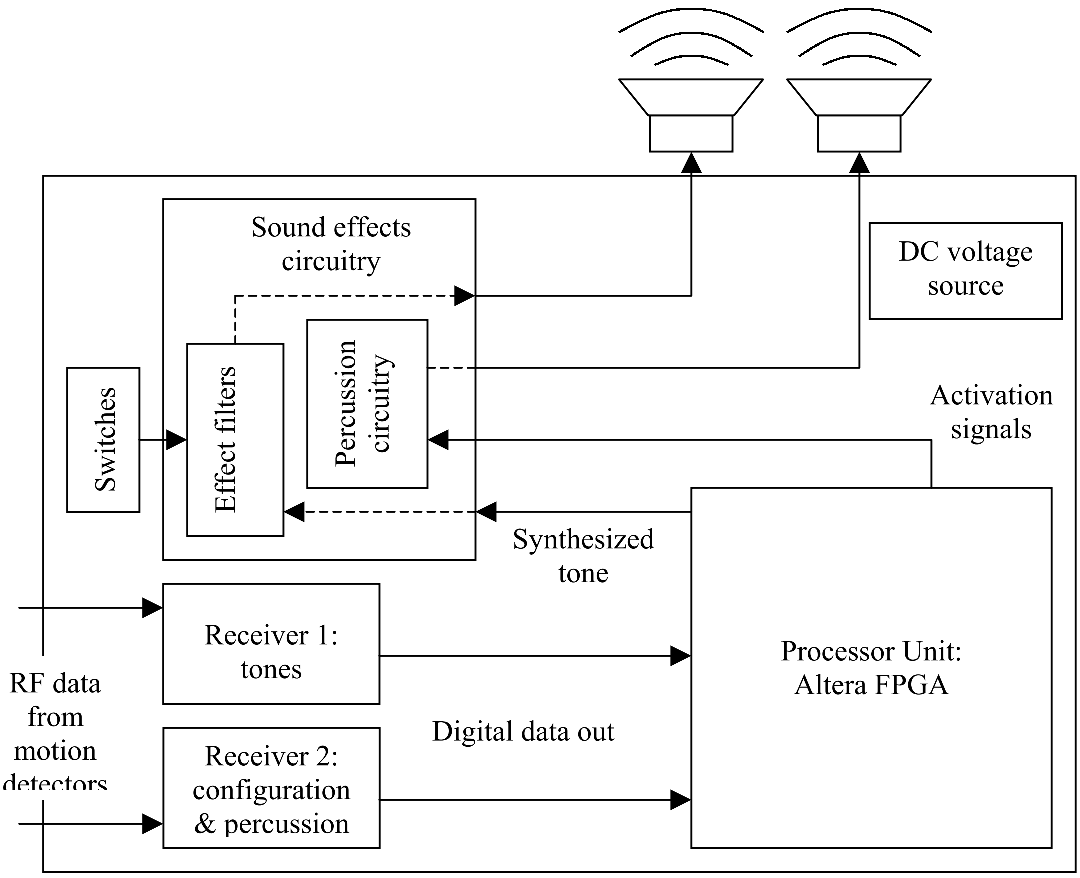

Figure 6: Sound Generator Block Diagram

The sound generator consists of 2 AM receivers, a processor unit, a DC voltage supply[5], and miscellaneous filter circuits for generating sound effects.

The AMHRR3-315 and AMHRR3-433 AM receiver modules from OKW Electronics would be used to construct the receiver units, whose transmission frequencies are 315Hz and 433.92Hz, respectively. These modules have transmission ranges of up to 45m at a data rate of 2kHz. Output data is digitalized and thus is compatible with digital logic devices.

[5] Power supply: 9V battery.

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The Altera EPF10K10LC84 FPGA would be used to implement the processor unit of sound generator. The EPF10K10LC84 offers 10,000 gates, 576 logic cells, 6K bits of RAM, and 59 user I/O pins. The large number of available flip-flops in this device – 2 in each logic cell – makes it suitable for the high amount counting operations that are involved in the tone generation process[6]. An external 2.5MHz crystal oscillator would be used as the system and sampling clock of the processor unit.

The sound effect circuitries are mixed signal in nature, having both digital and analog devices. They are divided into two independent categories for generating percussions and for modifying the tones produced by the processor unit. These sound effect systems consist mainly of op-amp filters and RC circuits.

[6] Refer to section 4.2.2 for details on the tone generation algorithm.

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4.2. Processor Unit

4.2.1. Receiver Data Decoding Algorithm

Figure 7 shows the algorithm for decoding data from the receiver.

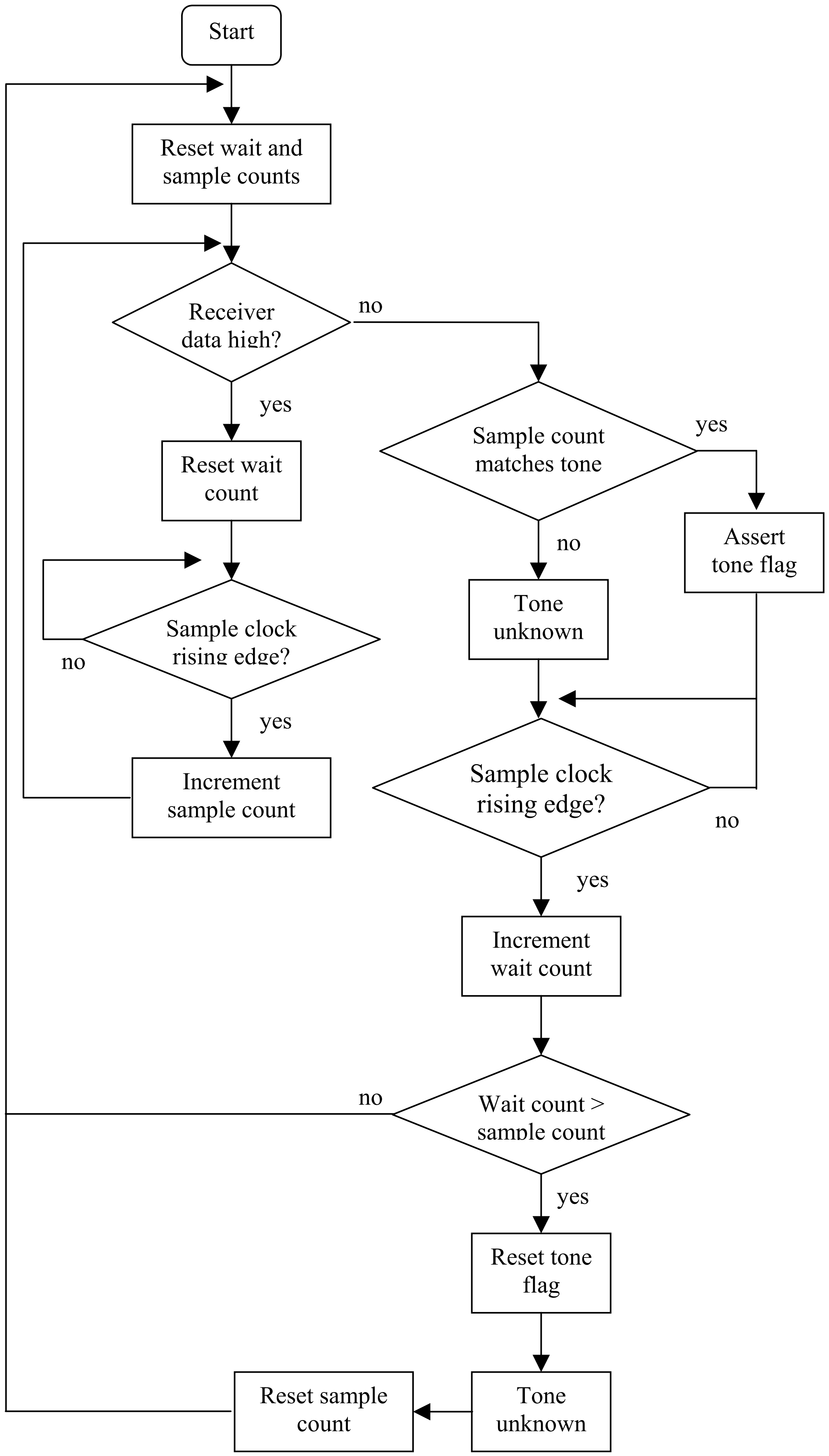

Figure 7: Receiver Data Decoding Algorithm

The processor unit determines which tone to play based on the values of sample and wait counts, which corresponds to the number of system clock cycles observed while data from the receiver is high or low, respectively.

As previously discussed in section 3.2, each motion detector generates a unique 50% duty cycle square-wave. Thus, it is possible to identify the source of the signal by counting the number of sample clock cycles while the receiver data is high or low, and comparing them with known values. In the implementation of the decoding process, the high cycle is chosen to be used to activate tones, whereas the low cycle is used to deactivate the tone after the motion detector has turned off, as shown below in Figure 8.

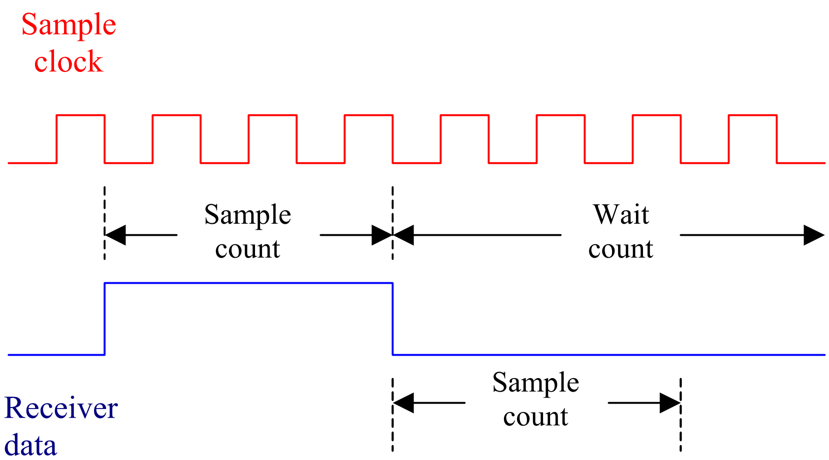

Figure 8: Sample and Wait Counts

In the scenario shown above, it is apparent that wait count exceeds sample count. Since receiver data must have 50% duty cycle, it can be concluded that data transmission from the motion detector has stopped and has therefore turned off.

4.2.2. Tone Generation Algorithm

The sound generator produces tones from octave 1 to 5. The procedure is divided in 2 steps:

1. Synthesize the tones of the highest octave.
2. Divide the frequency of the highest octave tones to produce the lower octaves.

Figure 9 shows the algorithm for digitally synthesizing tones.

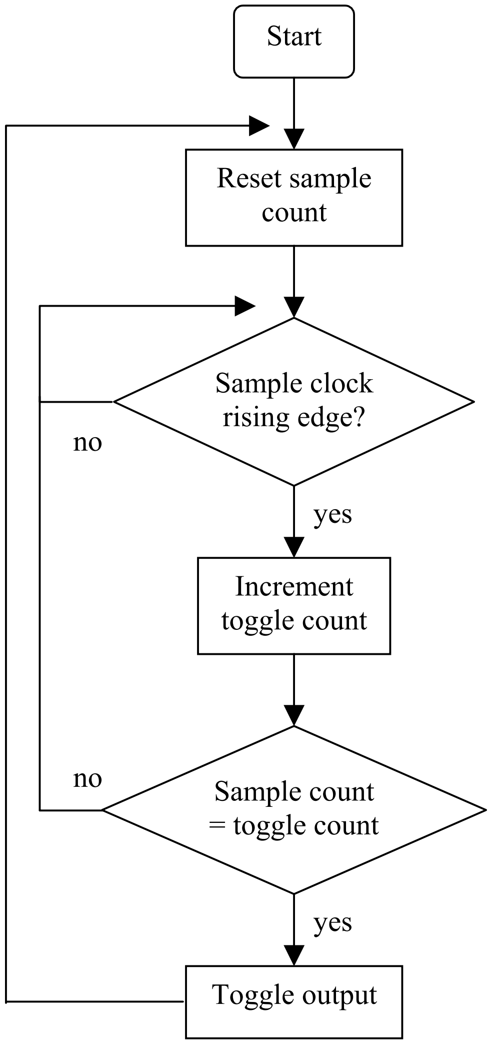

Figure 9: Tone Synthesis Algorithm

Tones are produced from oscillations at the harmonic frequencies. The process of digitally synthesizing tones involves toggling the logic of the output signal once every half the period of the desired tone. The toggle count is set to the number of sample clock counts that mimic the time interval at which the output signal toggles.

The algorithm for changing the pitch of the tones is shown in Figure 10.

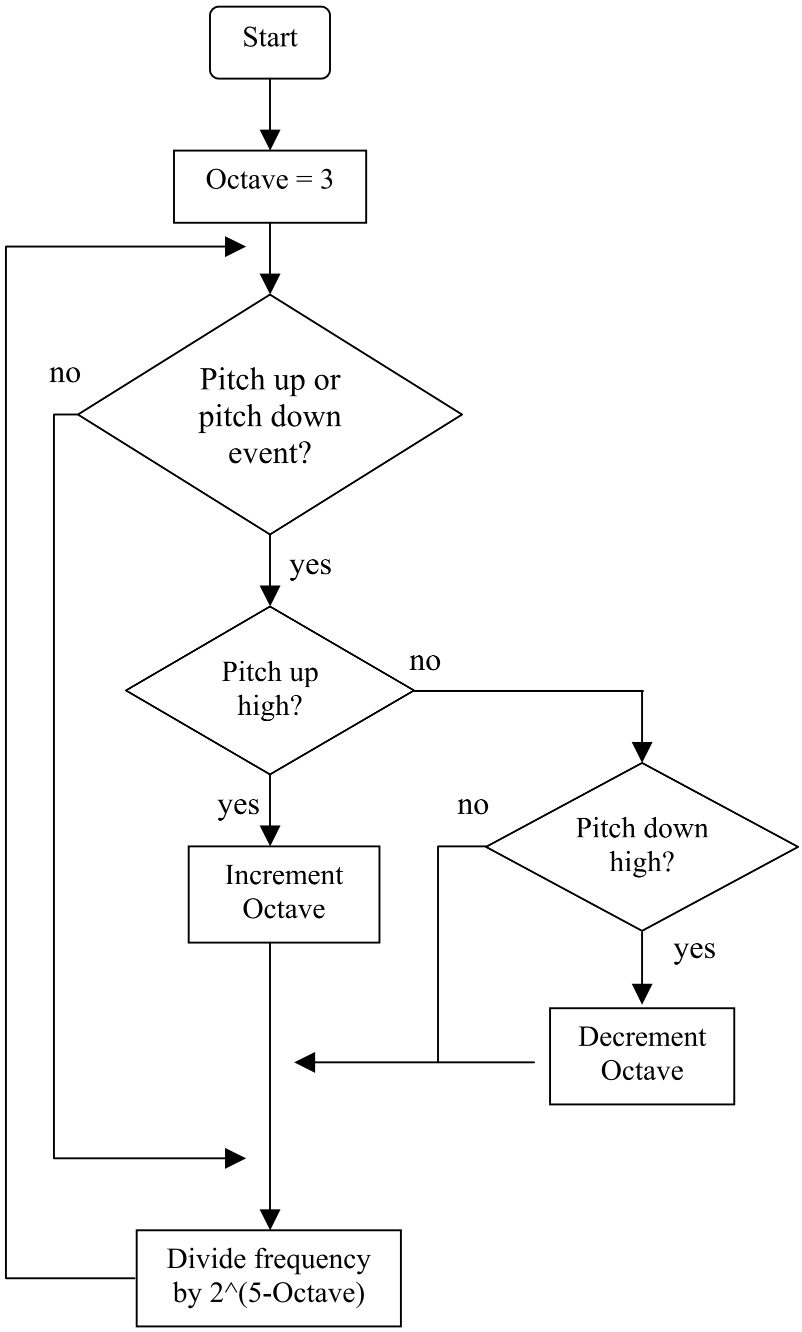

Figure 10: Pitch Changing Algorithm

Tone variations are associated with frequency changes by factors of 2. Raising a tone by each octave multiplies its frequency by 2; conversely, lowing an octave divides the frequency of a tone by 2. Since the highest octave tones have the highest frequencies, dividing them by factors of 2 can be used to generate all the lower octave tones.

As shown in the algorithm in Figure 10, the processor unit is designed to produce tones at the octave 3 – the neutral octave – by default.

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4.3. Sound Effects Circuitry

Sound effects are implemented with analog circuits composed of circuit elements such as transistors, resistors, op-amps, capacitors, and inductors. Specifically the fuzz and wah-wah effect circuits will be built and they will be activated and deactivated with on-board dipswitches. Inputs to the circuits are the note output from the FPGA. Outputs from the circuits are directed to one of the two speakers[7].

[7] Refer to Appendix A for schematics of the sound effect circuits.

5. Testing

5.1. Motion Detectors

Testing is an essential procedure to verify the proper operation of a device. The testing procedures would show that activation signals are generated accordingly and at the correct encryption frequency. In addition, since the motion detectors contain mechanical components, it should also be verified that the design could sustain predictable impacts.

An effective and simple experiment to verify the generation of the activation signal is to have a user to use the device. The frequency and duty cycle of the transmission signal, subsequently, can be checked using an oscilloscope or a logic analyzer.

The endurance of the devices can be verified by stress testing. By having human test subjects with various body sizes to operate the device to assure that it will not break apart under normal operating conditions.

5.2. Sound Generator

The accuracy of note generation with or without sound effects can be examined with two methods. A direct method is to measure the frequency of each note output with individual sound effect using an oscilloscope or a spectrum analyzer. A less direct approach is to generate notes from the slowest frequency to the highest frequency in the ascending order of octaves. Audience will then judge on the accuracy of the generated octaves. Each note generated can be played until a specific time limit has expired. If signals for generation of more than one tone are detected at the same time, one note will be played until its time limit has passed.

Drum, bells and bongo, the three sound generating effects, are generated with body movements at the designated body joints. Only one generating effect will be played at one time. Outputs for sound generating effects and generated notes are connected to separate speakers. Therefore, a separate test is necessary to ensure that sound generating effects and generated notes can be played at the same time.

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Appendix A

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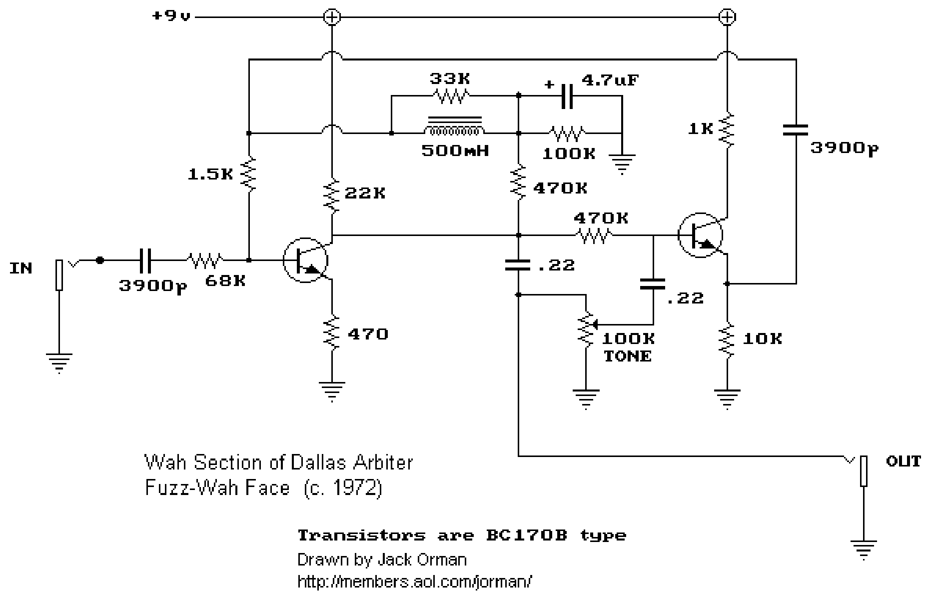

Figure 11: Schematic for Wah-Wah Sound Effect Filter Circuit

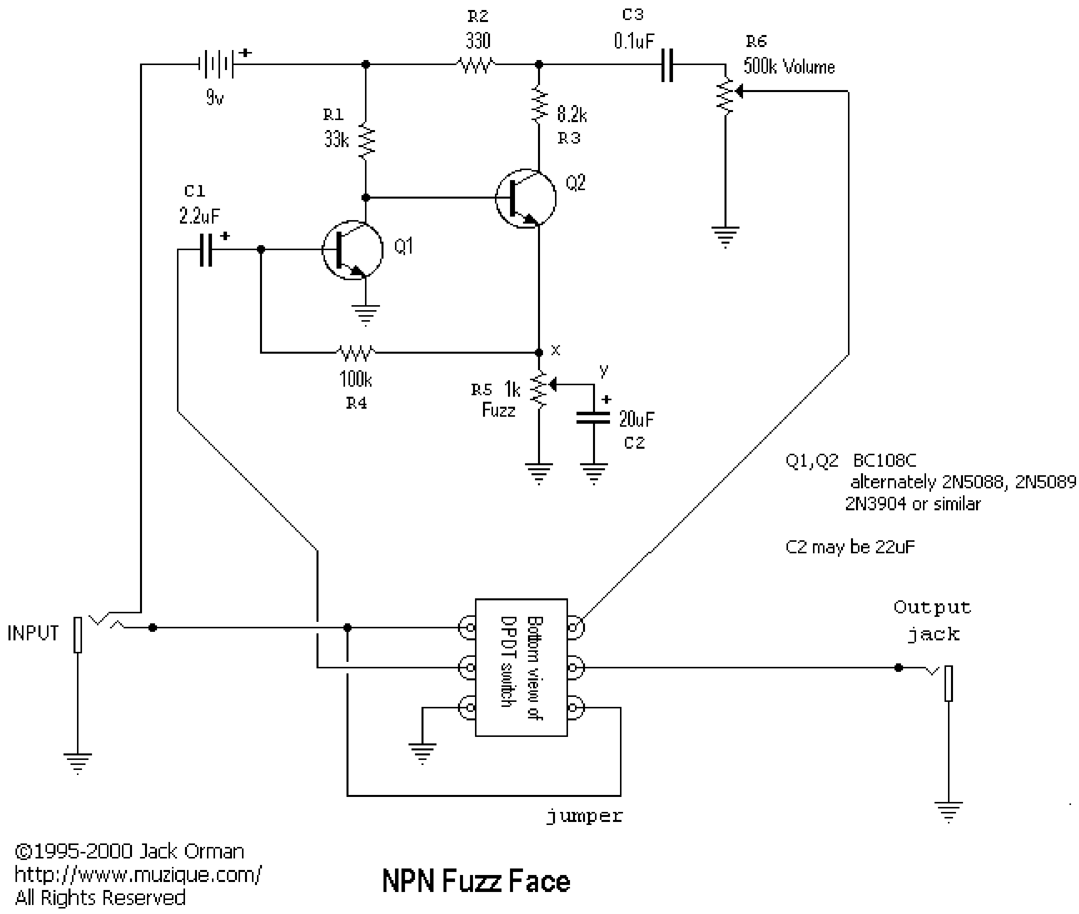

Figure 12: Schematic for Fuzz Sound Effect Filter Circuit