Electric traditional Chinese musical instrument - Xun

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1 Introduction

1.1 Objective

Xun[1], invented 7000 years ago, is one of the oldest musical instruments in China. It used to be made out of clay or bones and now ceramic. However, Xun is now faced with two problems. First, unlike other musical instruments, it lacks an electronic version with which one can practice without making loud sounds and disturbing neighbors. Second, since the population that play Xun is very small, few teachers are available and new players may find it hard to play Xun without an efficient learning method.

To get more people familiar with Xun, we aim to make an electronic instrument by using sensors and a microcontroller. Consisting of pressure sensors and airflow sensors, the sensor system takes inputs from players. Pressure sensors will take the player's gesture as input to determine which note the instrument should play. Airflow sensors will examine the strength of the blow to determine how loud the instrument should play. The microcontroller makes decisions based on inputs and outputs the sounds of Xun in digital forms. The recorded sound of Xun is stored in microcontroller ahead of time and goes to audio jack after passing a DAC module and an amplifier.

One can play the sound of the instrument through headphones, so our instrument will not disturb people by making loud sound. Also, as more people are interested in electronic Xun, it will be easier for people to learn this instrument in general.

1.2 Background

There are already electronic wind instruments on the market that can function as a lot of instruments, such as saxophones and flutes. However, those instruments are very expensive and cannot function as Xun. Our device will be necessary for 3 reasons. First, there are not electronic musical instruments capable of making sound quality of a ceramic or clay wind instrument. Second, the EWI wind controller on the market cannot provide a mode of Xun for its unique shape. Third, our device will be much cheaper than the EWI wind controllers, which cost 700 dollars. Moreover, we may develop an LED system that provides instructional signals to guide players during performance if time allows.

1.3 High-level Requirement List

- Instrument must be able to produce musical sound of typical quality of Xun, with sound matching 50% +/- 5% harmonics. Specifically, the MSE between our sounds and real Xun sounds should be less than 2 when converted to digital signals and normalized under a sampling rate of 16,000Hz.

- Instrument must be able to produce the correct pitch out of 64 based on player’s hand gestures.

- Instrument must be able to change its sound magnitude from -10dB to 4dB based on plays’ strength.

2 Design

Electronic Xun requires four sections for successful operations: a power system, a sensor system, a microcontroller, and an output system. The power section will deliver power at desired voltage levels to the rest of the circuit. The sensor system consists of a pressure sensor and an airflow sensor. They will detect players’ control and provide information to the microcontroller in digital form. Microcontroller then determines the specific sound corresponding to the player’s input and outputs the music signal to the audio output system. Output system takes the digital signal produced by the microcontroller, converts it to analog signals and amplifies it to a desired magnitude.

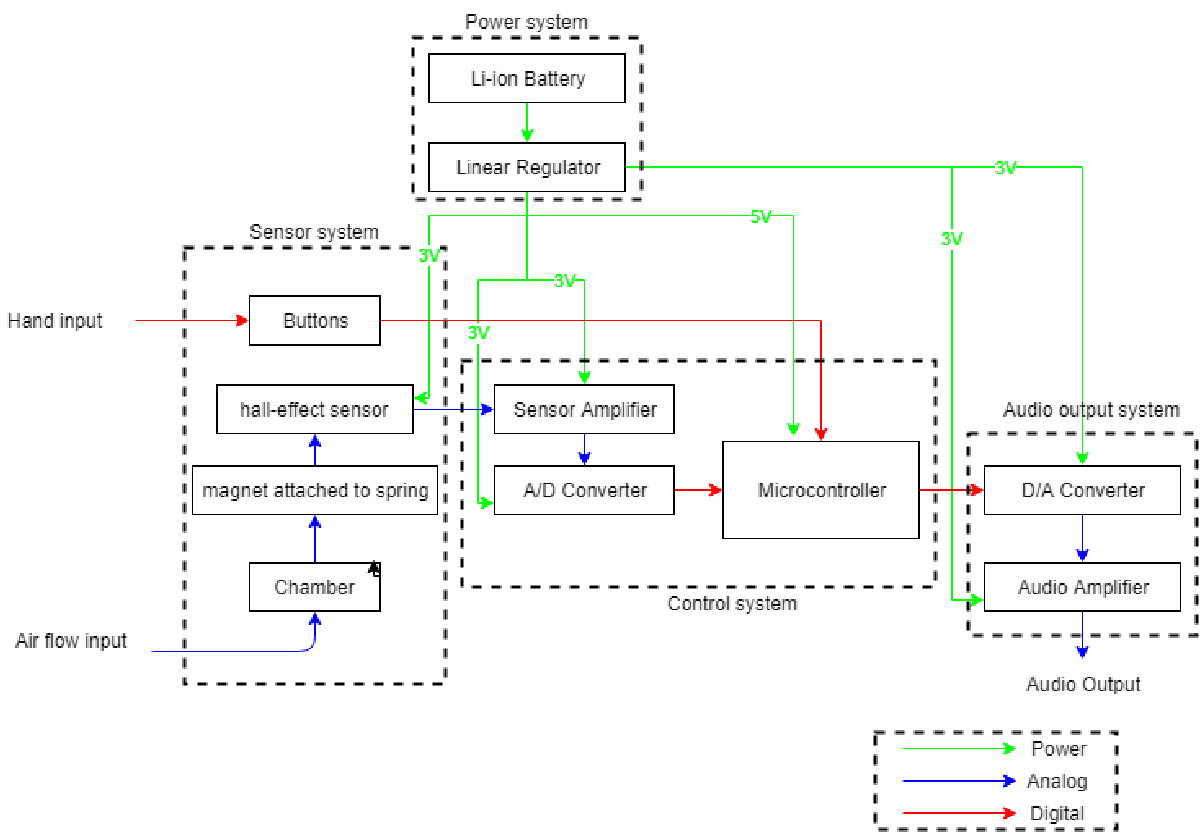

Fig.1 Block Diagram

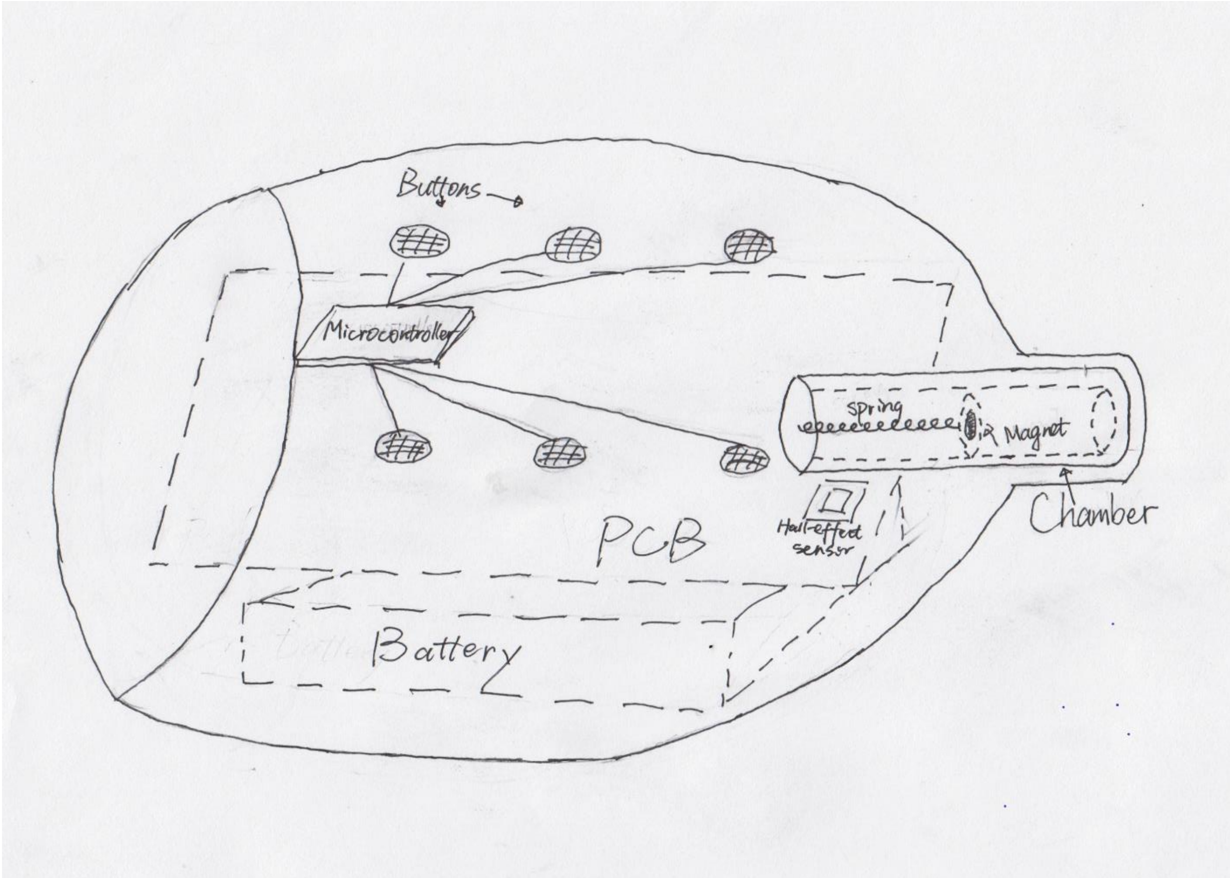

Fig.2 Physical Diagram

2.1 Power Supply

Power supply will deliver power to the rest of the circuit. It consists of a 12V DC lithium-ion battery and a linear regulator.

2.1.1 Li-ion Battery

The lithium-ion battery must be able to provide power steadily to the circuit before it runs out of energy. The linear regulator will be directly connected to this 12V DC power supply.

Requirements	Verification
1. Must be able to hold 1000 mAh in order to power the circuit for at least an hour.	*Procedure:* 1) Connect a 120Ω resistor to the ends of the 12V battery on the breadboard 2) After every one hour, use a voltmeter to ensure the voltage across the resistor is above 11.5V 3) In the first ten hours, the voltage across the resistor should be above 11.5V

2. Must be able to provide at least 35 mA peak current.	*Procedure:* 1) Connect a 240*Ω* resistor to the ends of the 12V battery on the breadboard 2) Add a current meter into the series between the battery and resistor 3) The current meter should show a current about 50 +/- 3 mA

2.1.2 Linear Regulator

Linear regulator is chosen to be AP1150. It takes power from the battery and converts it to 5.0V level output that is required by specific components. Hall-effect sensor, sensor amplifier, A/D converter, audio amplifier, microcontroller and D/A converter are connected directly to this linear regulator.

Requirements	**Verification**
1. Must provide 5.0V +/- 10% from a 11.0-12.5V power source.	*Procedure:* 1) Connect the linear regulator to a 12V Li-ion battery 2) Add a voltage meter to the circuit, with one end attached to the output end of the linear regulator and the other end attached to the ground 3) The voltage meter should display a value of 5.0V +/- 10%
2. Must be able to provide at least 25 mA peak current.	*Procedure:* 1) Finish the verification steps for Requirement 1 and keep the circuit setups 2) Add a 150*Ω* resistor between the regulator output end and the ground 3) Add a current meter in series with the resistor 4) The current meter should show a current magnitude between 25 mA and 30 mA

2.2 Sensor System

The sensor system will get all necessary inputs from the player, namely the tone-hole combinations and the blowing pressure. Buttons, a set of passive sensors, will respond to the player's tone-hole combinations and send input signals to the microcontroller for the purpose of pitch determination. Air flow sensor, an active sensor, will be used to reflect the blowing strength of the player and send voltage signals to ADC module to determine the loudness of audio output.

2.2.1 Buttons

We will use ALPS Tactile Switches. The buttons, when pressed, will generate an electrical signal that can be detected by the microcontroller. There are 6 buttons in the sensor system, corresponding to the 6 holes on the actual instrument. Users will feel a click when the button is fully pressed. The microcontroller will get the status of the 6 buttons at the same time.

Requirements	Verification
1. Must generate an electric signal of 3.0V +/- 10% when they are effectively pressed.	*Procedure:* 1) Connect buttons to a 5V power source 2) Connect a voltage meter to the output ends of buttons 3) Effectively press the buttons and observe the voltage meter in the meantime 4) Make sure the voltage meter shows a voltage of 3.0V +/- 10%
2. The electric signal will persist until 1ms +/- 10% after the player releases the button.	*Procedure:* 1) Finish verifying Requirement 1 and keep the circuit setup 2) Connect the button output ends and the ground to an oscilloscope 3) Fully press the buttons and keep pressing for 5 seconds 4) Release the buttons and wait for another 5 seconds 5) From the oscilloscope screen, locate the region that corresponds to the first 5 seconds, when the buttons are pressed 6) Use the cursor to make sure that the signal roughly persists the 3V magnitude for another 0.9 - 1.1 ms

	after the first 5 seconds

2.2.2 Hall-effect Sensor

"A Hall effect sensor is a transducer that varies its output voltage in response to a magnetic field [2]." Hall-effect sensor is chosen to be EQ-430L and it will output a voltage according to the magnitude of the nearby magnetic field. It is used to sense the magnetic field given by the magnet attached to the spring. The output voltage goes to the A/D converter. With the spring swinging back and forth, the hall-effect sensor gets magnetic field of different magnitudes, and generates voltages of different magnitudes accordingly.

Requirements	Verification
1. Must be sensible enough to give at least 0.5V voltage when a 150 Gauss magnetic field +/- 5% pointing north is detected at the location of hall-effect sensor.	*Procedure:* 1) Connect the EQ-430L properly to a power supply on breadboard 2) Connect the output of hall-effect sensor and ground to oscilloscope 3) Put a Gauss meter beside the hall-effect sensor 4) Move the magnet to a place so that gauss meter reads 150 Gauss pointing north 5) Record the voltage on the oscilloscope and ensure it to be larger than or equal to 0.5V
2. Must give out at least 1V +/- 5% output difference per 100 Gauss input magnetic field change.	*Procedure:* 1) Connect the EQ-430L properly to power supply on breadboard 2) Connect the output of hall-effect sensor and ground to oscilloscope 3) Put a Gauss meter beside the hall-effect sensor 4) Move the magnet to a place so that gauss meter reads 150 Gauss pointing north 5) Record the voltage on the oscilloscope 6) Move the magnet again to another place so that gauss meter reads 50 Gauss pointing north

	7) Record the voltage on the oscilloscope and ensure it to be larger than or equal to 1V

2.2.3 Magnet attached to spring

Magnet attached to spring is placed near the hall-effect sensor. It will directly receive the air flow from player's breath. The breath will push the spring to a steady location closer to the hall-effect sensor. The harder the player blows, the closer the magnet and sensor are, and the larger magnetic field the sensor feels.

Requirements	Verification
1. Magnet must give at least 150 Gauss at a distance of 8 cm +/- 5%.	*Procedure:* 1) Put the magnet and the gauss meter on the table 2) Use the ruler to measure the distance between magnet and gauss meter 3) Adjust their position so that magnet is 8 cm away from the gauss meter 4) Record the magnetic field strength on the gauss meter and ensure it to be larger than or equal to 150 Gauss
2. Magnet must have a diameter less than 1.2 cm in order to be fit into the chamber.	*Procedure:* 1) Use the ruler to measure the diameter or the longest dimension of the magnet 2) Record the measured length and ensure it to be less than 1.2 cm
3. Spring must be able to contract 2.5 cm +/- 10% at 2.5 m/s +/- 10% air flow.	*Procedure:* 1) Use ruler to measure length of the spring at rest and record it 2) Place the spring inside the self-made chamber 3) Connect one end of chamber to anemometer 4) Blow wind into the other end of chamber and watch for the wind speed on the anemometer 5) Measure the length of ruler when the

	wind speed is 2.5 m/s and record it 6) Calculate the difference of two length and ensure it to be 2.5 cm +/- 10%

2.2.4 Chamber

Chamber is used to contain the air flow from player's breath. Players blow from one end of the chamber, and the other end is covered with the magnet attached to the spring. Using a chamber prevents air leak.

Requirements	Verification
Must be able to prevent air leak so that when an adult man is blowing at full strength from one end of the chamber, the wind speed detected at the other end should be larger than 2.5 m/s.	*Procedure:* 1) Connect an anemometer to one end of the chamber 2) Blow from the other end of the chamber at full strength 3) Record the reading on the anemometer, and ensure that it to be larger than 2.5 m/s

2.3 Control system

The control system takes all input signals from the sensor system. After processing the input signals, it will output digital sound signals stored previously in the microcontroller to the audio output system.

2.3.1 Sensor Amplifier

We will use LM324 amplifier. The sensor amplifier takes voltage signals from the air flow sensor and amplifies the signal to a range of 0 to 5V so that the A/D converter will be able to process the voltage signals.

The output range of the hall-effect sensor we are using is 1.7V to 2.7V. The input voltage range of the ADC module is 1.65V to 1.95V. Therefore, we can calculate the DC closed loop gain of the sensor amplifier as

$$Gain = 20log(V_{out}/V_{in}) = 20log(1.8/2.2) = -4dB \quad \text{Eqn.1}$$

Requirements	Verification

Must be able to generate a closed loop gain of -4dB +/- 10%.	*Procedure:* 1) Assemble the amplifier circuit on a breadboard. Connect the signal input to a function generator. Connect both the circuit input and output to an oscilloscope. 2) Apply the circuit with 3V +/- 5% power source. 3) Use the function generator to generate a sinusoidal wave with peak-to-peak voltage of 1V. Record the output from the oscilloscope. The calculated gain should be -4dB +/- 10%.

2.3.2 A/D Converter

We will use AK5355 for A/D converter. Analog voltage signals generated by the hall-effect sensor and amplified by the sensor amplifier will be converted to digital forms for the use of microcontroller. A resolution of 16 bits will be used to represent the airflow strength.

Requirements	Verification
1. Must be able to function at a sampling frequency of 11.3MHz +/- 20%.	*Procedure:* 1) Assemble an ADC circuit on breadboard. Connect the digital output to an Arduino. Connect the function generator to both the signal input of the circuit and the input channel of an oscilloscope. 2) Apply the circuit with 3V +/- 5% power source. 3) Use the function generator to generate a square wave at 10kHz. The Arduino should record a digital output at a frequency of 11.3MHz +/- 10%. The samples can reconstruct a sinusoidal signal of 1kHz.
2. Must be able to change the digital output by 4 if input is changed by 200mV +/- 5%.	*Procedure:* 1) Assemble an ADC circuit on breadboard. Connect the digital

	output to an Arduino. Connect the function generator to both the signal input of the circuit and the input channel of an oscilloscope. 2) Apply the circuit with 3V +/- 5% power source. 3) Use the function generator to generate a sinusoidal signal at 100 Hz and with peak-to-peak voltage 2.5 V and an offset of 1.5V. 2.5V will provide 100 different values with resolution of 50mV. The arduino should be able to record the digital output with a change of 4 when the input signal is changed by 200mV +/- 5%. In other words, a period of reconstructed signal should have 100 different sample values.

2.3.3 Microcontroller

We will make our own microcontroller using ATmega328 IC chip. It is the processor of Arduino Uno, and if we build it properly, our microcontroller can do anything that an Arduino Uno can do. The buttons and A/D converter will be connected to the input data pins on the chip. Also, an SD card, which stores all the music files of Xun, is connected to the microcontroller. Based on the signal from the buttons, the microcontroller will generate the corresponding sound stored previously in the SD card. Six buttons will generate a total of 64 kinds of pitches. Based on the signal from the A/D converter, microcontroller will output the music signal in desired magnitude/volume. The music signal will then go to the D/A converter.

Requirements	Verification
1. Must be able to give output signal within 40ms +/- 5% after the microcontroller receives the sensor input generated every 0.1ms +/- 5%.	*Procedure:* 1) Connect the microcontroller to power supply and sensor circuit on the breadboard 2) Manipulate the buttons or blow into the chamber 3) Start the timer when microcontroller receives the information from sensor 4) Wait until the microcontroller finishes

	outputting the music signal and stop the time 5) Record the time given by the timer and ensure it to be less than 40 ms
2. Must be able to play the music files stored in the SD card.	*Procedure:* 1) Connect the SD card, audio jack, and power supply to microcontroller 2) Program the microcontroller to play the music files stored inside the SD card 3) Play the music files on a computer, and compare the two sounds. Ensure that two sounds are from the same file sources
3. Must generate the correct note of the Xun corresponding to the hand gesture.	*Procedure:* 1) Connect the SD card, buttons, audio jack, and power supply to microcontroller 2) Program the microcontroller to play the specific music files stored inside the SD card corresponding to the input from buttons 3) Play the desired note on a computer and ensure that the two sounds are from the same file source
4. Must be able to generate music signal at different voltage levels specified in the A/D converter section.	*Procedure:* 1) Connect the SD card, buttons, audio jack, and power supply to the microcontroller 2) Connect the output end of the microcontroller to an oscilloscope and display the signal on the screen 3) Program the microcontroller to play the specific music files stored inside the SD card corresponding to the input from buttons 4) Observe the oscilloscope screen and make sure that the output signals can reach all voltage levels specified in the A/D converter section

2.3.4 SD card

We will use sandisk for our SD card. It will store all recorded sounds of Xun. The recorded sounds will be fetched and played by the microcontroller.

Requirements	Verification
Must be able to store at least 1G data.	*Procedure:* 1) Connect SD card to computer 2) Store 1G amount of music data in SD card 3) Play the music data on another computer and ensure that there is no loss of any form in the music

2.4 Audio Output System

Digital signals from the microcontroller will be processed by a D/A converter and amplified to an audio output jack.

2.4.1 D/A Converter

We will use AK4331, a 32-bit DAC. The digital to analog converter will be used to take the digital signals from the microcontroller and convert the signals to analog signals, which will then be processed by the audio amplifier for the purpose of audio output.

Requirements	Verification
Must be able to function at a sampling frequency of 44.1kHz.	*Procedure:* 1) Assemble a DAC circuit on breadboard. Connect the digital input to a function generator. Connect the analog output to an oscilloscope. 2) Apply the circuit with 3V +/- 5% power source. 3) Use the function generator to generate a sawtooth(ramp) wave of audible frequency 44.1kHz. On the oscilloscope, verify that the DAC interface can serialize and transmit arbitrary 32-bit numbers.

2.4.2 Audio Amplifier

We will use LM324. Analog audio signals sent from the DAC module will be amplified by the audio amplifier to a range of -0.15V to 0.15V so that it can be output to the audio jack.

Requirements	Verification
Must be able to support analog volume gain levels from +4dB to -10 dB, with 2dB step +/- 5%.	*Procedure:* 1) Connect the audio amplifier circuit on a breadboard. 2) Connect a function generator to the input ends of the audio amplifier. Connect the output ends of the audio amplifier to an oscilloscope. 3) Apply a 3V DC power source to the audio amplifier circuit. 4) Generate a sinusoidal wave with peak-peak voltage of 0.3V. Adjust the load resistor of the audio amplifier circuit. Calculate the gain for each step. For all gain levels between +4dB and -10dB, with 2dB step +/-5%, verify the output voltage approximately obtain the formula: *Amplifier Gain* = 20log($\frac{V(out)}{V(in)}$) [dB].

2.5 Risk Analysis

The airflow sensor is of the most significance and the highest risk to the completion of the project. Whether the airflow sensor will be able to successfully detect the airflow from the player's mouth and output a reasonable voltage signal or not is essential. Two major essential components, a spring, and a magnet, must both be embedded inside a chamber to avoid air leak. The third component, the hall-effect sensor, should be placed outside the chamber but close enough to detect the changes in the strength of magnetic field. We will need to determine the threshold of a voltage signal to tell the difference between a state where spring is steady and a state where the spring is actually bent by the airflow generated by a player. Moreover, the spring is supposed to quickly swing back to its original steady position as soon as the air flow is stopped, and it should easily swing so that the player do not have to blow too much air to generate a sound. All the requirements mentioned above are difficult to meet because it requires perfect manufacturing of the device and a large amount of signal testing and parameters adjustments.

Further, the sound qualities of Xun might not be as real as that generated by the actual musical instrument. Due to the quality of recordings and the data transmissions back and forth, the sound quality may need further adjustment after the implementation of the system.

Last but not the least, every module must be real-time for the nature of the project. ADC and DAC module might need some time to process the signals, but we need to process signals of a wide range of frequencies and amplitudes in real time. The microcontroller needs to process the input signals, load the previously stored sounds, and determine which pitch and loudness should be output to the audio system in real time. These requirements can be hard to meet but we can only allow a maximum delay of 0.5 second.

2.6 Supply Material

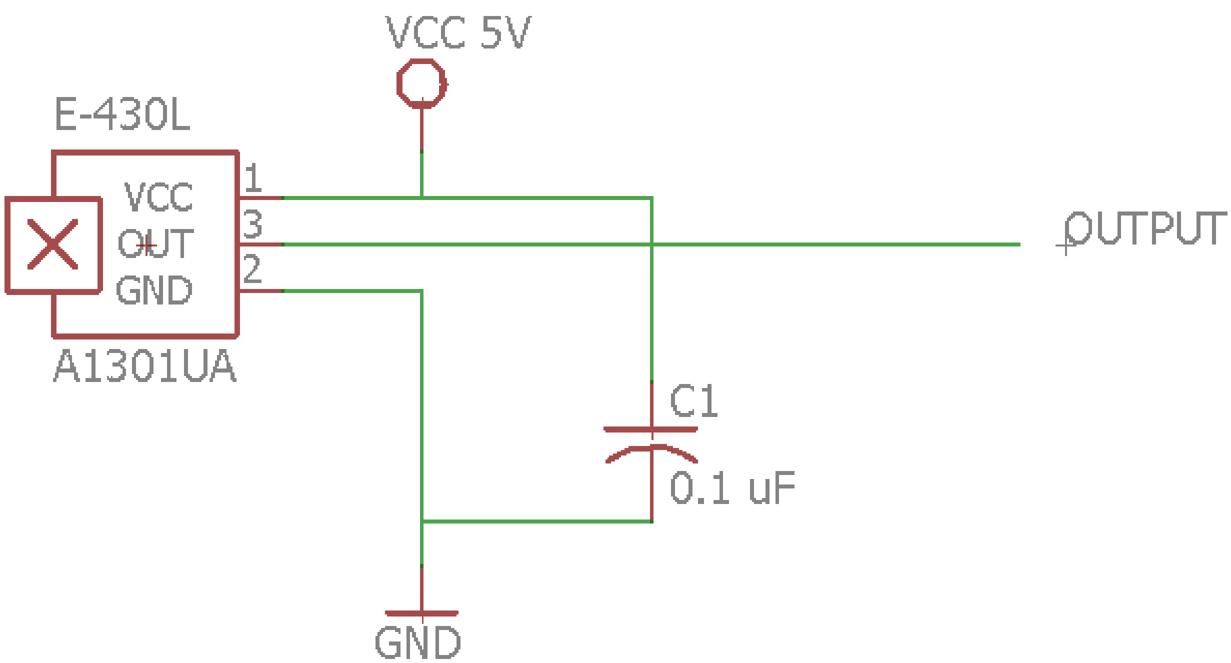

Fig.3 Hall-effect Sensor

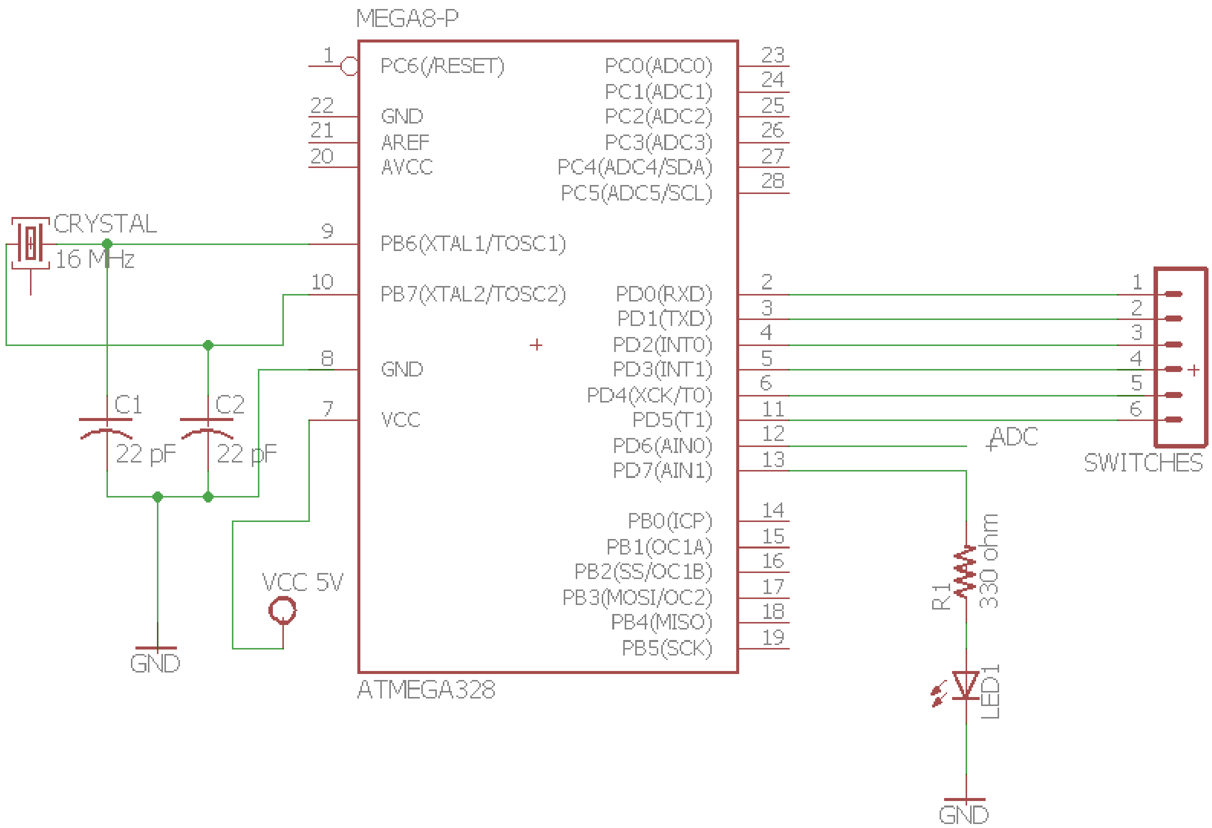

Fig.4 Microcontroller

2.7 Data Processing

The data processing part of our device is relatively simple. The major role of the software is to analyze the digital signal of the sensor input system in the microcontroller and choose the corresponding sound pitch and loudness based on the inputs. The algorithm is shown in the following flow chart.

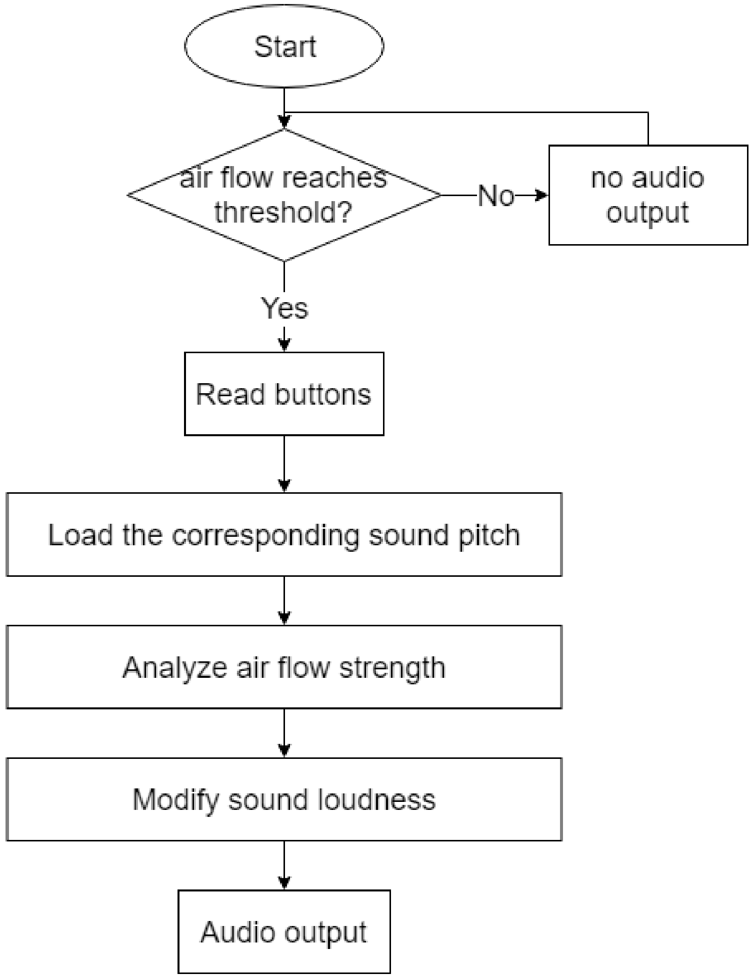

Fig.5 Physical Diagram Data Processing Flow Chart

Specifically for the air flow sensor system, we have a simulated plot as follows.

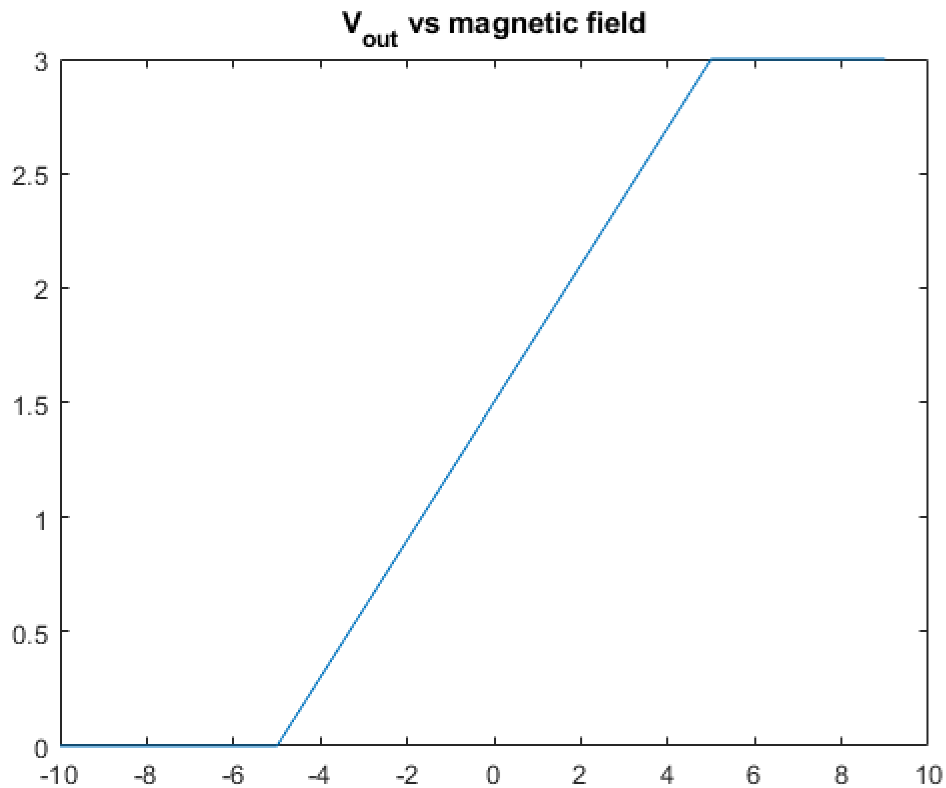

Fig.6 Simulated Hall-effect Sensor Output

The hall-effect sensor will provide an output voltage from 0.3V to 2.7V. We will use the north magnetic field waves, which means the output range we will use for the input of the microcontroller is 1.7V to 2.7V. An estimated threshold of the air flow is 2.1V. Based on the linear variance of the voltage, we will assign loudness from -10dB to 4dB to the audio output.

For the sound pitches, there will be six buttons. So the total number of sound pitches will be:

$$2^6 = 64 \qquad \text{Eqn.2}$$

2.8 Tolerance Analysis

One important tolerance of the device is the adjustment of the air flow sensor system. The relative position of the magnet and the hall-effect sensor is very crucial. Suppose magnetic field inside the magnet is a constant B_0.

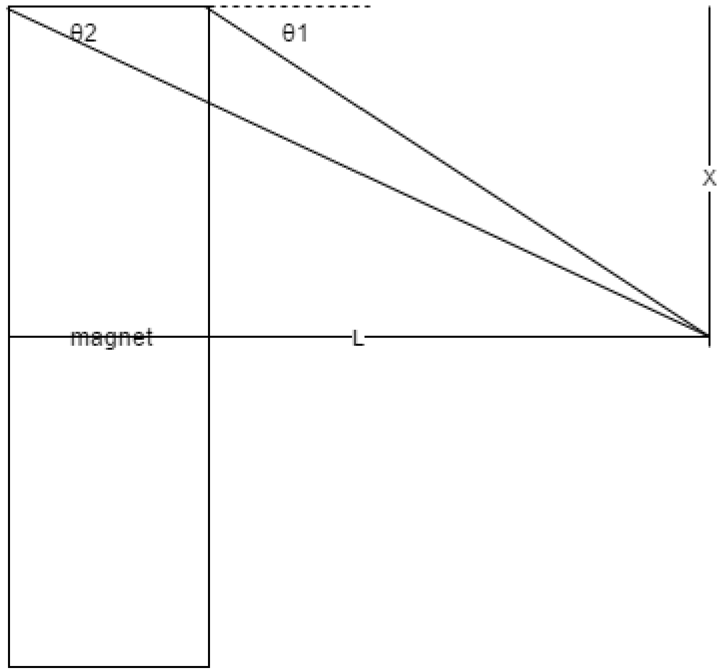

Fig.7 Magnet diagram

After a integration, we can approximate the magnetic field strength of the position outside the magnet as

$$B = B_0/2\ (sin\theta_2 - sin\theta_1) \quad \text{Eqn.3}$$

We can further conclude that the B field is approximately linearly related to the change in the horizontal distance between the point outside the magnet and the magnet itself, using trigonometric properties. However, we will not show the derivation since it is out of the scope of this course. Meanwhile, the air flow strength is proportional to the change in the spring ΔL so it is also linearly related to the magnetic field sensed at the position where the hall-effect sensor is located. The typical sensitivity of the hall-effect sensor will be 100 mV/mT +/- 5%, or 1 V/ 100 Gauss +/- 5% as stated in the requirement. Since the minimum requirement of the magnet we use is to provide a magnetic field heading north of 150 Gauss (15mT) at 8 cm. At 9 cm, the calculated B field is about 120 Gauss using Eqn.3. Thus, the 5% or 5 mV/mT tolerance will provide approximately 3mT*5mV/mT = 15 mV/cm tolerance when the magnet is 8 cm away from the hall-effect sensor. This tolerance of 15 mV/cm will yield an error tolerance of 15mV/200mV = 7.5% for each step of the digital air flow signal.

We can set up a model to calculate the fluctuation of the position of the magnet. Suppose that the friction constant of the chamber is **x**, magnet fluctuation kinetic energy caused by inconsistency of the breath is **E**, spring constant is **k**, and fluctuation distance is **s**. Then because of energy conservation law, we can write:

$$E = s * x + \frac{1}{2} * k * s^2 \qquad \text{Eqn.4}$$

Empirically, we get values: **E** = 1e-4 J, **x** = 0.05 J/m, **k** = 100 N/m, for a 10 gram magnet moving on a glass surface attached to a spring with spring constant 100 N/m. Then we calculate to get **s** = 1 mm.

With s = 1 mm and suppose the magnetic field vary linearly within such a small distance, we can calculate the magnetic difference at a 8-cm distance to hall-effect sensor to be:

$$\Delta B = B(8cm) * \frac{1}{8} \qquad \text{Eqn.5}$$

Plugging in B(8cm) = 150 Gauss, we have delta B = 1.875 Gauss. We choose to use magnetic field at 8 cm away because our magnetic is not capable of moving closer to hall-effect sensor than 8 cm. Magnetic field detected by the hall-effect sensor is at maximum at 8 cm, which would cause the maximum magnetic deviation. It is within the tolerance range calculated above. In the worst case, namely the magnet is fluctuating and giving a maximum magnetic field shift of 1.875 Gauss detected by hall-effect sensor, our circuit can still function properly.

3 Costs

Our fixed development costs are estimated to be \$40/hour and 9 hours/week for three people. As a result, the human resource cost for our project in this semester (16 weeks) is as the following:

$$3\times \frac{\$40}{hr} \times \frac{9\,hr}{wk} \times 16\text{wk} = \$17{,}280 \qquad \text{Eqn.6}$$

The costs for different parts and prototypes of our projects are listed in the following table:

Part	Cost
2400mAh 12V Li-ion Battery×4 (Amazon; AmazonBasics)	$10.97
AP1150 Linear Regulator×2 (Digi-Key; Asahi Kasei Microdevices)	$14.24
ALPS Tactile Buttons ×6 (Mouser; Alps Electric)	$6.42

EQ-430L Hall-effect sensor (GMW Associates; Asahi Kasei Microdevices)	$1.73
Magnet (AMFMagnets; ½”×⅛”×¼”)	$1.55
Chamber (made by Machine Shop)	$6.00
LM324 (Texas Instruments; Texas Instruments)	$0.26
AK5355 A/D Converter (Digi-Key; Asahi Kasei Microdevices)	$4.21
ATmega328 IC Chip (eBay; Microchip Technology)	$3.90
8GB SD Card (Adorama; SanDisk)	$5.99
AK4331 D/A Converter (Digi-Key; Asahi Kasei Microdevices)	$6.52
Instrument case, modeled by a military water bottle (Amazon)	$6.91
PCBs (PCBWay)	$4.00
Total	$72.7

Therefore, the total cost of our project will be $17,280 + $72.7 = $17,352.7. In overall, the total cost is around $17,400.

4 Schedule

Week	Chi	Yujie	Hongyi
09/17/2018	Research on hall-effect sensors that can detect blowing strength.	Search for appropriate buttons, A/D converters and D/A converters.	Search for proper linear regulator, SD card and microcontroller.
09/24/2018	Get the mathematics, physics and magnetics under the hall-effect sensors clear so that we’re ready to place order	Carry out detailed calculations for our sensor system, control system and audio output system, including circuit	Talk to Machine Shop and figure out how to make the instrument case and chamber.

	and assemble the blowing strength detector.	analysis and tolerance analysis.	
10/01/2018	Gather parts for blowing strength detector, including hall-effect sensor, magnets, and springs.	Plot circuit schematics and lead the group to prepare design documents.	Place the order for the water bottle and various electronics. Work with Machine Shop to make the chamber and the instrument case.
10/08/2018	Finish testing and experimental data collection for the blowing strength detector.	Work with Hongyi to make the microcontroller by using the ATmega328 IC chip.	Work with Yujie to make the microcontroller by using the ATmega328 IC chip.
10/15/2018	Finish assembling the hall-effect sensor with magnets and springs and thus building the blowing strength detector.	Make PCBs for the whole system.	Finish assembling and testing the self-made microcontroller.
10/22/2018	Finish testing buttons. Finish building the power system by combining the battery with the linear regulator.	Finish testing the D/A converter and the audio amplifier. Finish the assembly of the audio output system.	Finish testing and constructing the storage system by utilizing the SD card.
10/29/2018	Finish testing for the A/D converter.	Finish the assembly of the audio output system.	Start combing the storage unit with the microcontroller to make a complete control system.
11/05/2018	Finish putting sensors and A/D converters together to make a complete sensor system that can communicate with	Start connecting the control system to the audio output system.	Finish building a complete control system.

	the control system.		
11/12/2018	Finish connecting the sensor and power system to other parts.	Finish connecting the control system to the audio output system.	Work with Yujie and Chi to connect different parts together.
11/19/2018	Start testing the whole system.	Start testing the whole system.	Start testing the whole system.
11/26/2018	Finish building and testing the whole system.	Finish building and testing the whole system.	Finish building and testing the whole system.
12/03/2018	Prepare for the final presentation and start the final report.	Prepare for the final presentation and start the final report.	Prepare for the final presentation and start the final report.
12/10/2018	Finish the demo and report.	Finish the demo and report.	Finish the demo and report.

5 Safety and Ethics

There are several potential safety issues with our project. Li-ion batteries can get very hot when it's overloaded and can even explode under this kind of situations [3]. To handle this, we will make careful choices of batteries and electronics. In addition, we will go through all data sheets and make sure that the overall load of circuits won't exceed the limit of the battery.

Another potential safety hazard comes from players' blowing. As people blow air into the instrument, which has actually a small semi-closed space, it's unavoidable for the moisture in the breath to get liquefied. As a result, there can be some water inside the carrier, which may cause short circuits in our systems. To resolve this issue, we plan to use some packets to seal the electronic systems so that they won't be in direct contact with the moisture.

Now that we're trying to imitate the instrument Xun, it's possible that our sound qualities will have some differences from the original. As a result, when evaluating and making conclusions about our project, we'll obey the IEEE code ethics, #3:"To be honest and realistic in stating claims or estimates based on available data" [4].

We are responsible for the impact of our designs and aim to comply with the IEEE code ethics, #5:"To improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems"

[4]. We hope to bring more people to this amazing historical instrument and facilitate educations in this area.

We'll also stick to the IEEE code ethics, #7:"To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others [4]". On the one hand, we will thoroughly record and report all the external sources we use. On the other hand, we'll also take comments and suggestions from other people, including peers, TAs and professors, seriously to improve our design.

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