Multi-Timbre Harmonica

Mock Design Review

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1.0 Introduction

1.1 State of Purpose

This product is designed for the musicians who would like to play melody using different kinds of musical instruments especially when he or she does not know how to play certain kind of instrument. Besides, it is a much simpler solution for musicians to make changes about the music score for the part of one particular instrument on our harmonica since most musicians would like to play and hear his or her inspirational idea immediately. For now, people are mostly using applications on laptops to play music in different timbres. In comparison, our project will provide a more direct and more convenient solution. Harmonica is chosen as the carrier for this product since it is relevantly easy-to-play and more portable than the other musical instruments.

1.2 Objectives

1.2.1 Goals & Benefits

- Allow users to play the harmonica with original timbre or with different kinds of timbres.
- Allow users to wash and disinfect the harmonica. The mouthpiece will be detachable so that users don’t need to wash the whole harmonica.
- The size of the final product required to be small enough for the user to put into a pocket.
- Allow users to demo music pieces using different timbres in a faster and simpler way.
- Users can easily recharge the device by changing the batteries.

1.2.2 Functions & Features

- There are two modes in the harmonica: original mode and the multi-timbre mode. For original mode, the user can play the harmonica using the original timbre. And for multi-timbre mode, the user can set the timbre they want from the default timbre library.
- Visually display current timbre: Using the LED lights to tell the users the current chosen timbre.
- Changeable air tube valve: The air ought to be redirected from the metal reeds using the changeable air tube valve when the users want different timbres. When it is in the
original mode, the valve should not be activated so that the harmonica will behave like a normal one.

- The air pressure sensor ought to tell the difference between the blowing and drawing of users with different amplitude.

2.0 Design

2.1 Block Diagram

![Block Diagram Image]

2.2 Block Description

2.2.1 Control Block

The control block is going to receive the user’s commands and then figure out which mode the user has chosen. According to the specific mode, the control block will send signals to the accessory block to make the correct action of each part of the harmonica. The control block includes the debounced buttons, several air pressure sensors and a programmable microcontroller which provides multiple functionalities.
2.2.1.1 Debounced Buttons

The buttons are served for the users to choose the timbre they want in the multi-timbre mode. We are using the debounced buttons to get rid of the potential faults in the hardware part. Users are going to push the arrow-shaped buttons until they find the LED light standing for the correct timbre name is on. Besides, the users can choose the mode to be original or multi-timbre using the switch on one side of the harmonica.

2.2.1.2 Air Pressure Sensor (Plan B: Heat sensor)

The air pressure sensor is used to recognize the change of the air pressure in order to recognize the action of the user (blow or draw) since the air pressure will have a sudden drop during the drawing and a sudden raise during the blowing. Besides, the sensors ought to detect the magnitude of the action in several levels based on the accuracy of the sensor. The sensors with the most significant changes will send the signal to the microcontroller to determine which holes the user is currently using. We decide to use the MEMS Gauge Pressure Sensor which can work in the temperature between 0°C and 85°C and in the humidity 95%RH. The pressure range is between -50 to 50kPa. Since the humidity of the breathing is around 95% and the largest air pressure a person can generate is around 2psi (around 7k Pa), the sensor suits our requirement perfectly. Heat sensor can be the plan B if the accuracy of the air pressure sensor does not meet the requirement: resolution to be 0.3psi. The temperature will raise up when the user is blowing and it will come down when the user is drawing.

2.2.1.3 Programmable Microcontroller

The programmable microcontroller is the core of the control block. It takes the signal from the buttons and sensors, gets the pitch and amplitude information and then process them with the signal processing technique to put them into a different timbre. It will also control the corresponding LED light to be turned on and make the stepper motor to turn on or off the air tube valve. Finally, the microcontroller will make the speaker produce the corresponding sound using the specific timbre. We are going to use the ATmega328P microcontroller in our project.
2.2.2 Accessory Block

The accessory block contains all components that work with the order coming from the microcontroller. It includes the displayer (or LED lights), air tube valve and the speaker. They receive signals from the controller block and perform the corresponding functionalities by displaying the timbre information, turning the stepper motor to operate the air tube valve or generating the required sounds with the desired pitch and amplitude.

2.2.2.1 Air Tube Valve

The air tube valve will change the direction of the wind blowing to or drawing from the harmonica. Since the designed harmonica has two modes: original mode and the multi-timbre mode, the harmonica should make the original timbre of the harmonica when it is in the former mode and it must be mechanically silence in the later mode. In that case, the air tube valve holds the functionality that it is able to change the direction of the wind in the multi-timbre mode so that there will be no wind pass the metal reeds which means there will be no original sound any more. In the original mode, the valve should not be activated so that the harmonica will behave like a traditional one. In our project, we will use a bipolar stepper motor to operate the valve since we only need the valve to be either open or close. The working voltage of the motor is around 5V and 0.5A, and it will be fine to apply a smaller voltage and current on the motor since we don’t have the requirement on the speed of the operation and the valve will be light enough for the motor to move in a low-voltage mode.

2.2.2.2 Speaker

The speaker is going to make the specific sound using the timbre which the user wants when the harmonica is in the multi-timbre mode. When it is in the original mode, the speaker should be turned off to get rid of the potential noise and save power. We are using the PCB speaker COM-07950 or COM-11089 which can operates around the audible 2kHz (around C7 pitch) range.

2.2.2.3 Displayer

We are going to use the three LED lights to tell the user which timbre is currently used and another one LED light to show the current mode of the harmonica. There will be the corresponding name of the timbre beside each LED light. When the user press the
arrow-shaped button, the LED light will be turned on circularly. The mode light will be on when the multi-timbre mode is on.

2.2.3 Power Block

The Power Block provides power for all other blocks in the harmonica. It consists of a switch and a battery. The switch is for users to turn on when they want to use the multi-timbre mode since the default original mode of the harmonica can be used without the power block. The battery will be the main power source. And we are going to use two AAA batteries to provide the power with 1.5 Volt each. Besides, we are going to use the voltage regulator to change voltage level while connecting the power with a high-voltage required block such as the stepper motor in the air tube valve.

3.0 Circuit Schematic

MC3x063A 1.5-A Peak Boost/Buck/Inverting Switching Regulators
4.0 Simulation Result
5.0 Calculation
### 6.0 Requirements and Verification

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
<th>Points</th>
</tr>
</thead>
</table>
| **Air Pressure Sensor**            | 1) Sensor is able to produce result if the lowest 0.3 psi is present on blowing. Test this by finding fan that can blow to pressure gauge with 0.3 psi and use the same level of blow strengthen and distance to see if a sensor can register this blow.  
2) With sensors placed in place with 10 mm maximum range, test if the sensors can correctly register air pressure. Test if a blow will cause too many or too few sensors to respond. Ideally, a blow should not activate more than 3 sensors.  
3) Sensor is able to produce stable and accurate result at around 95% humidity environment. Testing sensor in this environment by using humidifier. | 20     |
| **Air Tube Valve**                 | 1) Recording the time it takes to close the valve and the time it takes to open the valve with a timer. The time for both operations should under 2 seconds.  
2) Upon close, the air tube to the normal harmonica should be closed. Test it by put a air pressure sensor behind the valve. While blowing, the increase of the air pressure should be smaller than 0.1 psi. | 20     |
<p>| <strong>Point: 20</strong>                      |                                                                                                 |        |</p>
<table>
<thead>
<tr>
<th>Displayer</th>
<th>Microcontroller</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1)</strong> Button: correctly debounce buttons and the LED light should change correspondingly while pushing the button.</td>
<td><strong>1)</strong> Buttons should be debounced. Test it by pressing buttons after they are connected to microcontroller. The state should change upon button press only once per press. The LED light standing for the correct timbre should be on.</td>
</tr>
<tr>
<td><strong>2)</strong> LED: correctly display corresponding states in microcontroller. Series voltage 2V +/-0.2V.</td>
<td><strong>2)</strong> LED should display the current states. Power LED should be on whenever the system is on. Only one of the state LEDs should be on at a certain time. The LED should be on when microcontroller is in the corresponding state. Use the oscilloscope to check the voltage across to the LED.</td>
</tr>
</tbody>
</table>

<p>| <strong>Microcontroller</strong> | <strong>1)</strong> Power the microcontroller, and verify that it has at least 10 working digital inputs, 4 working analog inputs, 2 working digital outputs and 4 working analog outputs by programming. Check the value with multimeter. | <strong>3)</strong> Using the Matlab to output the synthesized sound by applying the envelope shape of the corresponding musical instrument, the pitch and the magnitude information. There are three default timbres: piano, flute, brass. Matlab outputs the envelope shape of these three timbres. |
|-----------|-----------------|
| <strong>1)</strong> Input output pin: at least 14 inputs (10 pressure sensors, 1 switch, 3 buttons) and 6 outputs (4 LEDs, 1 speaker, 1 valve) | <strong>2)</strong> Use microcontroller send output to speaker and step motor. Adding amplifier if necessary. The signal after amplifier should be checked by multimeter and verified with requirements. |
| <strong>2)</strong> Output voltage and current level: 4 analog outputs and 2 digital outputs (3V ~ 5V and &lt;35mA for speaker, 5V and 0.5A for step motor). | <strong>3)</strong> Using the Matlab to output the synthesized sound by applying the envelope shape of the corresponding musical instrument, the pitch and the magnitude information. There are three default timbres: piano, flute, brass. Matlab outputs the envelope shape of these three timbres. |
| <strong>3)</strong> Digital signal processing: 3 default timbre sound should be stored in the memory. | <strong>10</strong> | <strong>30</strong> |</p>
<table>
<thead>
<tr>
<th>Power</th>
<th>Speaker</th>
</tr>
</thead>
</table>
| 1) Must supply at least 6V DC and at least 0.5A current | 1) Place Digital Multimeter in parallel with the power source. Measure the voltage difference across the power source. The voltage should read 6V.  
2) Place Digital Multimeter in series with the power source and heating elements. Measure the current difference from the power source. The current should read 0.5A | |
|  | 1) Power the speaker and connect it to a microcontroller. The microcontroller outputs a piece of music or a pitch with 260 Hz frequency and sets the intensity to maximum if needed. Measure the sound intensity. The intensity should be above 60 dB. | |
| 10 | 10 |
7.0 Safety Statement

7.1. Electrical Concerns:

The product is powered by standard battery. The battery voltage is 1.5V for one piece of battery if using AAA battery. The design should use no more than three AAA batteries or one 9V battery. This is considerably low voltage. There will not be any power line which will be exposed to air or users. Therefore, users should be protected from contacting directly the power component at any time in usage except for changing battery. Even though the safety the project poses very low risk, do not place the machine in extreme heat conditions or submerge it underwater. Temperature over 70°C is extremely dangerous for microcontrollers and power system.

7.2. Mechanical concerns:

One step motor is used in this product. It possess a potential danger of overheating even though it is only used when multi-timbre mode is turned on or turned off. In particular, power off the device if hear or smell anything weird. Although the surface will be polished and a mouthpiece will be attached to the device. Users should be careful when detaching the mouthpiece in case of unintentional cut from edges. Also, users should clean the mouthpiece regularly to prevent themselves from bacteria infection.

8.0 Citations


