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Airduino Guitar

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Abstract

The objective of the AIRduino Guitar project is to imply the theoretical knowledge on a practical device and build a device that translates the numbers into measured or heard such as in this case results. This work is worthy to use in many technical areas and not sounded to the field of interest in any project as there many applications where the same microcontrollers and sensors could be utilized for different purposes. In simple explanation the accelerometer is to detect the motion on the right hand and the ultrasonic is to detect the distance between the two hands to generate a waveform based on the data collected from both the sensors combined with fingers connection in order to imitate to the full operation process of the real guitar using the microcontroller to compute an output sound as close to the real guitar as possible. The project was built using Arduino UNO microcontroller, ADXL345 accelerometer, and a Parallax PING))) ultrasonic distance meter to generate a guitar-like sound which was enriching in both the knowledgeable and the amusement sides.

Keywords: AIRduino, Parallax PING))) Ultrasonic Distance Sensor, UNO Microcontroller

1. Introduction

With the technology revolution in the 2lst century most of the devices are becoming smaller and lighter while still maintain the same functionality or even improving on that area as well and hence the idea of making a virtual guitar was started around 2009 when five students at the Chalmers University in Sweden introduced the idea for the first time and made their prototype of the virtual guitar which worked successfully and imitated the sound generation of the real guitar. The scope of this project is to build a right handed virtually played guitar which will consist of three major parts left hand glove, right hand stick, and a main device where each part of those three parts will have a separate and different task to accomplish and combined all of them will perform the musical guitar task.

Technical Work Preparation

The guitar controller is divided in two parts, left-hand controller and right-hand controller. By left-hand controller the player can bend his fingers and press the glove to change the pitch of the tone. The right-hand controller is represented by a stick which has to be shaken to trigger the sound of the air-guitar. Player can also change the distance between right hand and left hand in order to pitch the tones, simulating the different frets on the guitar neck. To perform such tricks, the main components are an accelerometer to “feel” the stick shake, an ultrasonic sensor to measure the distance between the glove and the stick, and a conductive fabric to construct the glove. The same concept was applied in this project as both the operations are similar and will generate the same musical form of music.

Components List

The component used in this project design is summarized in the Table l.

2.1 Operation Concept

The PING))) sensor detects objects by emitting a short ultrasonic burst and then “listening” for the echo. Under control of a host microcontroller (trigger pulse), the sensor emits a short 40 kHz (ultrasonic) burst. This burst

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travels through the air, hits an object and then bounces back to the sensor. The PING))) sensor provides an output pulse to the host that will terminate when the echo is detected; hence the width of this pulse corresponds to the distance to the target.

Table 1. Full components list

Part	Sub-Part	Model
Main Box	Microcontroller	Arduino UNO
	Rectification & Circuit	20:l transformer
		LM7805
		Red LED
		l0 µF Capacitors
		Terminal Blocks
		l Kfi Resistors
		1 Mfi Potentiometers
		Diode Bridge
		3.5 mm Female Audio Jack
Left Hand Glove	Glove	Leather Glove
		Copper Tape
		8-cores cable
	Ultrasonic	Parallax PING)))™
		AA Battery box
Right Hand Stick	Accelerometer	ADXL345 3-axis

Circuit Design

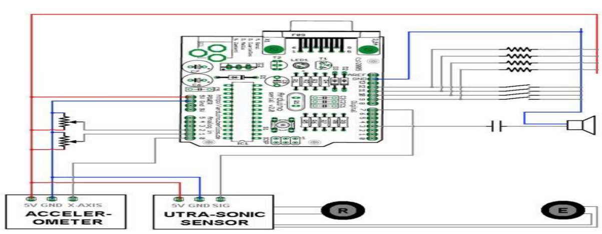

Figure 1. Project schematic.

Deflection of the ADXL345 structure is measured using differential capacitors that consist of independent fixed plates and plates attached to the moving mass. Acceleration deflects the proof mass and unbalances the differential capacitor, resulting in a sensor output whose amplitude is proportional to acceleration. Phase-sensitive demodulation is used to determine the magnitude and polarity of the acceleration.

3. Prototype Building

3.1 Glove

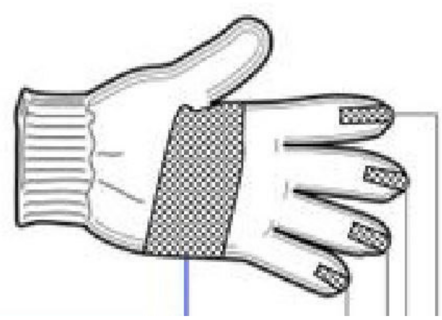

Figure 2. Glove design.

This part is supposed to be a normal glove but with conductive fabric added on its palm and finger tips so it could conduct signals whenever the fingers are pressed upon the palm of the glove. A conductive fabric must be used to achieve this by sewing it to the glove so it does not come off with the glove stretches when the player is wearing it or taking it off.

Finding such a conductive fabric is hard since only a small piece is needed and such materials only comes in huge packages; hence a copper tape was used as an alternative solution to the conductive fabric.

To enhance the glove even more the simplest solution was not to glue the copper tape on the glove directly but separate them with a piece of flat hard material such as plastic or wood. Plastic pieces covered with this copper tape were glued on the palm and the fingertips of the glove to make all the areas needed to be conductive and wires were connected to the copper tape to be connected to the arduino pins.

3.2 Ultrasonic Sensor

Hacking the ultrasonic sensor is a crucial part of this project as it meant unsoldering the transmitter pins from the PING))) board and extending them with wires to separate the board in two parts. The transmitter alone would be moved to the right hand stick while the receiver and the main board would still be on the side of the left hand glove. Doing this process would give a better quality to the distance measuring operation. If the ultrasonic is not hacked and both the transmitter and the receiver are kept soldered on the board the distance measure wouldn't always be accurate as some echo might reflect back to the receiver from hitting the body of the player or the arm instead of the hand. The hacking ensures that the transmitter is facing the receiver directly so the distance measure would become more accurate.

Figure 3. Glove.

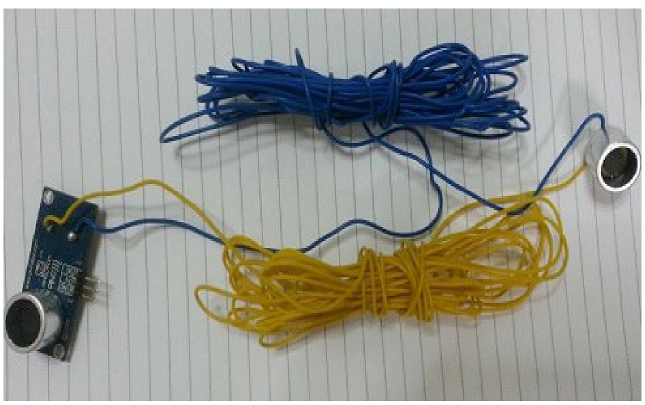

Figure 4. Hacked sensor.

Figure 5: Ultrasonic receiver attached to the glove.

Testing the fingers connectivity is testing how the good the copper tape is conducting signals when any finger is pressed on the palm of the hand. This was accomplished by using four pull up resistors one per each finger. The connection made is also a part of the complete circuit which will be used for this project to be completed. The connection is by connecting the palm of the hand to the ground and the fingertips to the input pins so if no finger is pressed all the LEDs will be on and the input pins will receive a high digital input. If any finger is pressed on the palm "GND" the LED corresponding to that finger will turn off and the input pin will receive a digital zero and that's how the guitar will be working.

The switches in the simulated circuit represents the fingertips if the finger is not pressed the switch is opened and the LED will be on, while a pressed finger is represented by a closed switch resulting in a turned off LED. The VCC in the design is connected to the 5 v pin on the arduino and the GROUND is connected to the GND pin on the arduino.

3.3 Power Circuit

The rectification is needed to power the arduino when it is not connected via the USB cable. All the other components will be powered up from the arduino so it was only a matter of powering the arduino. A simple rectification circuit is built for this project to convert the AC 240 v to a DC 5 v to power the arduino via the pin on the arduino.

The circuit was built to be put inside a box and connected to the network power by a male socket for safety purposes with an ON/OFF switch added for extra protection. Inside the box the transformer steps the voltage down from 240v to l2v. Then the signal is rectified using a bridge rectifier and regulated to 5v using LM7805 voltage regulator. The box was drilled to hold all the components inside it with considering leaving enough space for the arduino and the PCB that will be made later for the complete circuit. The exact voltage driven out from the circuit is 4.98v which is sufficiently enough to power up the arduino.

3.4 Combining the Parts

Seeing this graph provided on the arduino website it became easier to conclude the connection on the arduino board to the Table 2. The next step is to use all the knowledge gained from testing the devices separately to make the complete code of the project. The code could

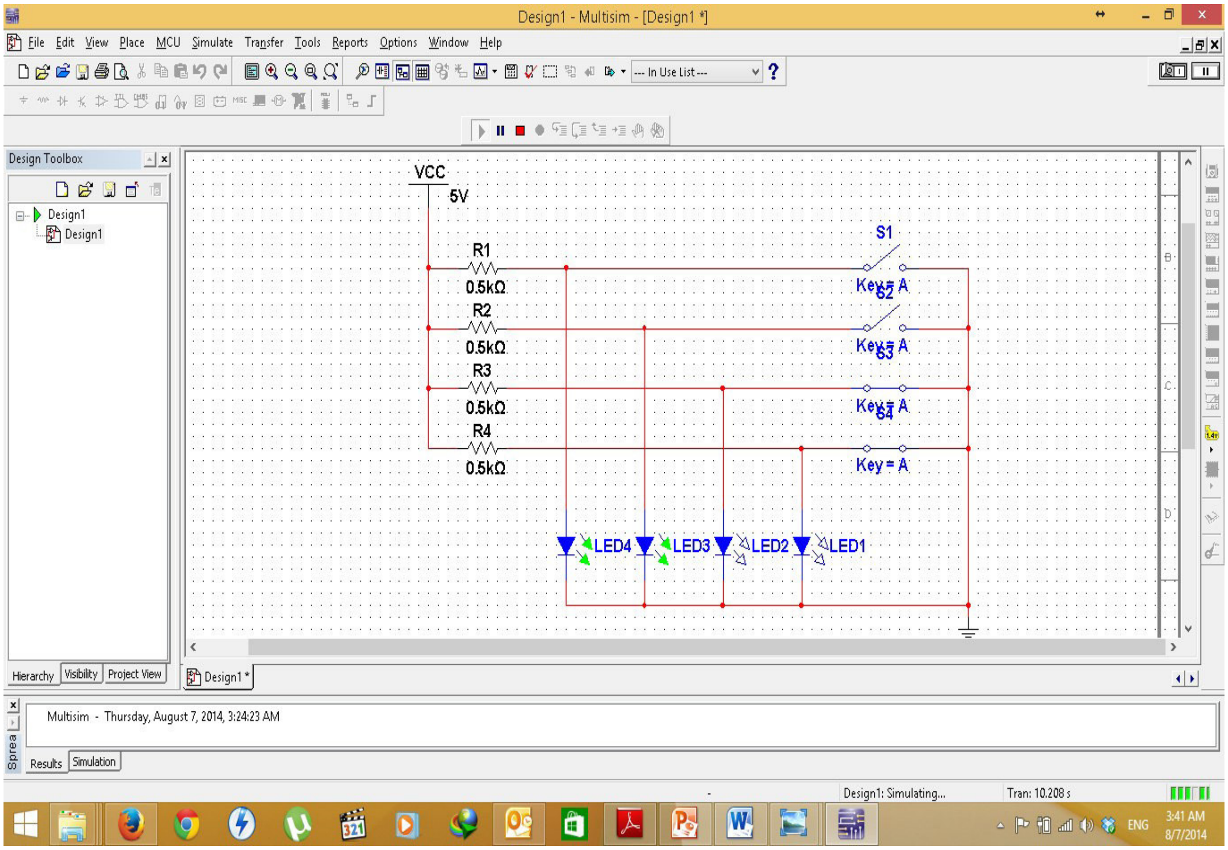

Figure 6. Fingers function simulation.

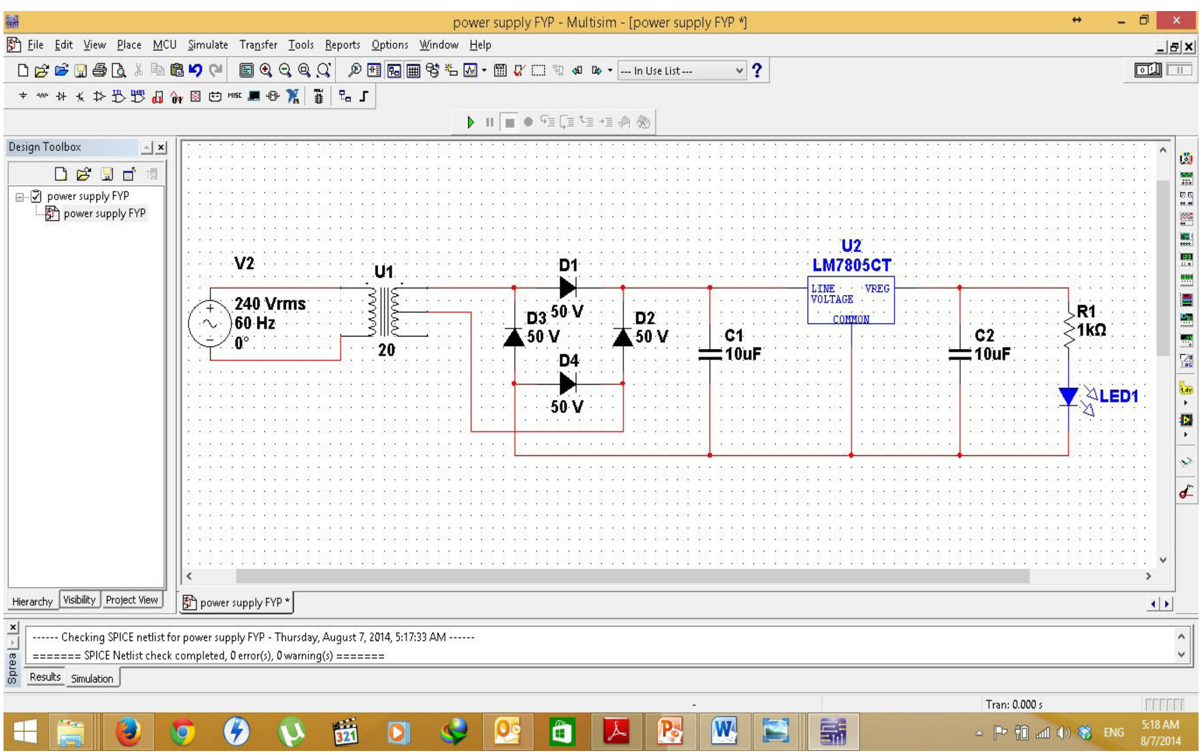

Figure 7. Power circuit.

be planned as the flow chart showed in the next page. The flow graph has two main parts:

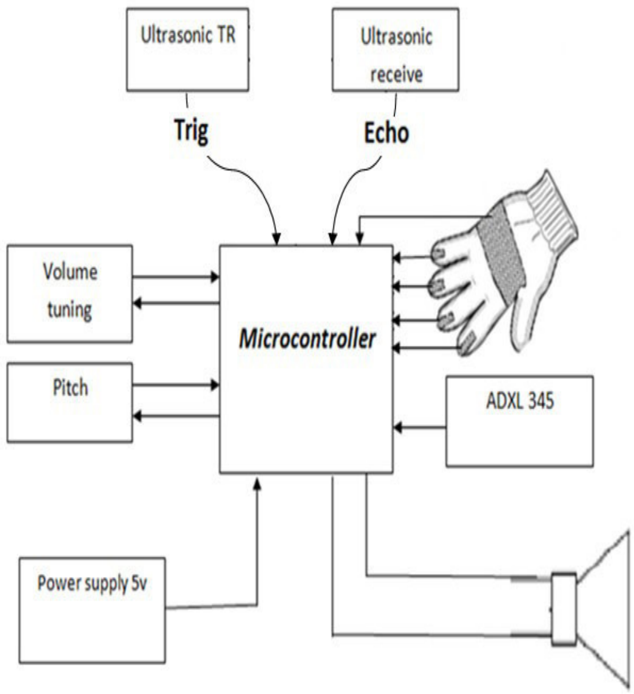

Figure 8. System block diagram.

- The unrepeated part which is the part applied only once when the device is turned on and then is never applied again unless the device is reset or rebooted. This represents the "setup" method in the arduino coding.
- The continuous loop which is the part that will keep repeating as long as the device is running. This represents the "loop" method in the arduino coding.

3.3 PCB Design

Building the PCB is essential to this project to save connection wires and make the circuit smaller. The PCB was designed using the Diptrace software which is specialized software for PCB designing. The design steps were:

- Calculating the distance between the arduino pins to make an accurate spacing on the PCB.
- Design the un-existing components on the software such as the terminal blocks and the bridge rectifier.
- Accurate dimensions for the PCB board to fit in the desired place inside the box.
- Place all the components within the PCB border and wire all the pins.

The main problem while designing the PCB was to not cross the connection wires which wasn't possible using only the back side of the PCB. To solve this problem a double sided PCB was used as a solution to the overlapping connections.

Some pins were added in the middle of the PCB to connect the two sides together to solve the overlapping wiring and to keep the soldering on one side only.

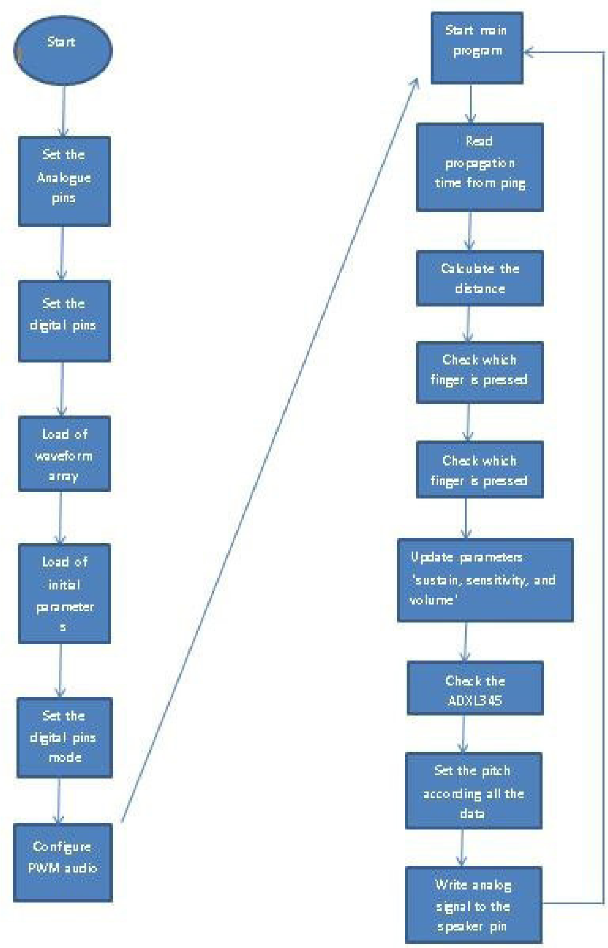

Figure 9. Code flowchart.

4. Results and Discussion

When the project was completed is a musical sound that could be heard using any external speakers plugged in the 3.5 mm female audio jack on the front side of the project box.

Table 2. Project connection mapping

Arduino Pin	Atmega Pin	Atmega Pin Label	Label	From	To
Analog IN (A0)	23	PC0(ADC0)	AD0		
Analog IN (A1)	24	PC1(ADC1)	AD1	1MΩ Pot.	
Analog IN (A2)	25	PC2(ADC2)	AD2	1MΩ Pot.	
Analog IN (A3)	26	PC3(ADC3)	AD3		
Analog IN (A4)	27	PC4(ADC4)	AD4/SDA		
Analog IN (A5)	28	PC5(ADC5)	AD5/SCL		
Digital 0 (RX)	2	PD0(RXD)	IO0		
Digital 1 (TX)	3	PD1(TXD)	IO1		
Digital 2	4	PD2(INT0)	IO2		
Digital 3 (PWM)	5	PD3(INT1)	IO3		10µF Capacitor
Digital 4	6	PD4(T0)	IO4		
Digital 5 (PWM)	11	PD5(T1)	IO5		
Digital 6 (PWM)	12	PD6(AIN0)	IO6		
Digital 7	13	PD7(AIN1)	IO7	SIG on PING)))	SIG on PING)))
Digital 8	14	PB0(ICP)	IO8		
Digital 9 (PWM)	15	PB1(OC1)	IO9	Finger 1	
Digital 10 (PWM)	16	PB2(SS)	SS	Finger 2	
Digital 11 (PWM)	17	PB3(MOSI)	MOSI	Finger 3	
Digital 12	18	PB4(MISO)	MISO	Finger 4	
Digital 13	19	PB5(SCK)	SCK		
SDA	27	PC4(ADC4)	AD4/SDA	ADXL SDA	
SCL	28	PC5(ADC5)	AD5/SCL		ADXL SCL

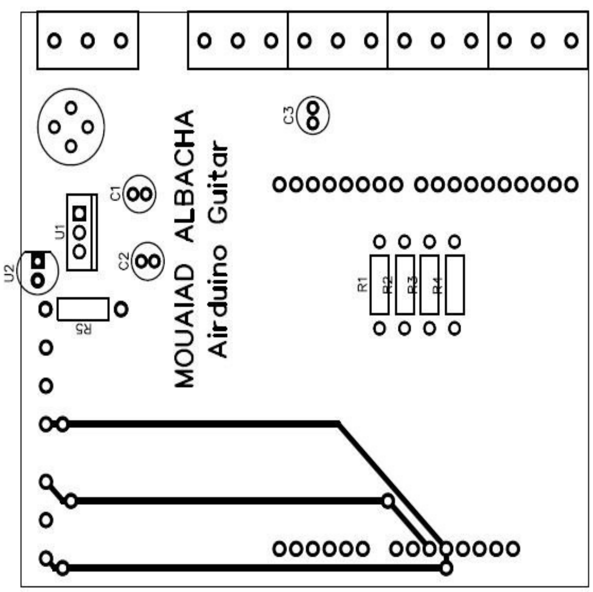

Figure 10. PCB front.

The arduino calculates the distance between the two hands based on the readings from the PING))) ultrasonic sensor. The maximum detectable distance is 70 cm which represents almost the length of the real guitar. The fingers represent the strings on the real guitar and each one of them represents half a tone so the sound would change by pressing different fingers or by not pressing any fingers at all. All this is triggered by the reading of the x-axis on the ADXL345 accelerometer which simulates exactly the process of playing a real guitar.

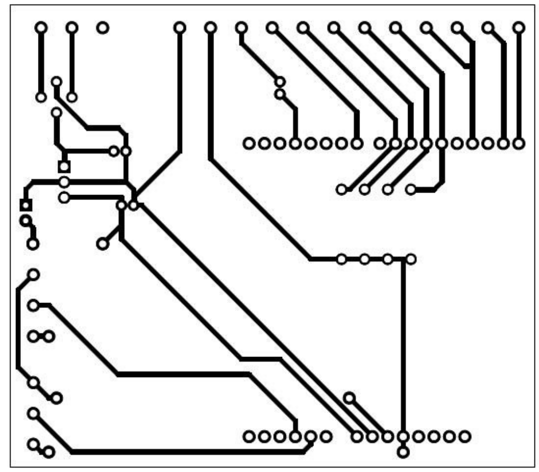

Figure 11. PCB rear.

The circuit was completely build and enclosed inside the box with 2 potentiometers arms coming out of the box to control the sensitivity of the project and the volume. The back side of the box has all the connections ports including the power socket, power switch, USB port and the cables coming from the 2 hands to the box to connect all the component of the prototype together. The aims of this work were:

- To understand the functionality of the micro-controller and program it to perform the needed/specified tasks.
- To understand the concept of the accelerometers and to implement such a device in the project.
- To understand the concept of the ultrasonic distance measuring and to implement a corresponding device for this concept.

The project achieved all its aims successfully by the successful implementation and coding of all the components be it arduino microcontroller, ADXL345 accelerometer and PING))) ultrasonic distance sensor. The combination of all these components generated a new function which simulates the operation of the guitar and generate a musical notes via a virtual guitar.

4.1 Future Recommendation for Applications

This project could be improved in many areas in the future to have more features such as making it work wirelessly by the implementation of various devices such as the XBee wireless network communicator. The XBee would be more than sufficient for this project as some models of it implies 16 channels and I2C protocol to broadcast to various clients since two clients are needed one for each hand and the coordinator would be placed on the box connected directly to the arduino.

The XBee is a family of small, cost-effective wireless communicators that enables low power and low bandwidth simple wireless communication. Using the XBee would enhance the project by bypassing the area limitations coming from the cables lengths. And make it freer to use and lighter to swing as no cables hindrance would exist anymore.

Another improvement could be to imply and green energy generation scheme to allow the usage of the project outdoors where no network electricity is available.

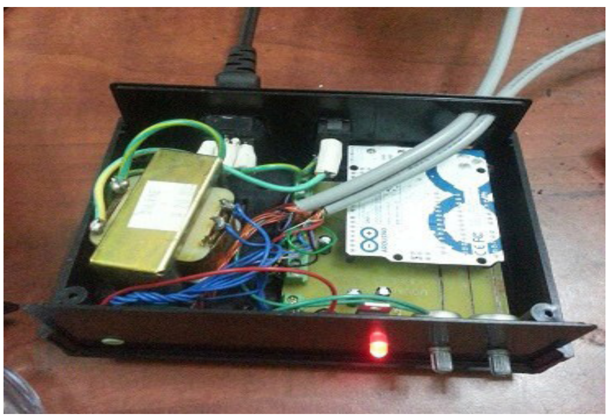

Figure 12. Completed prototype box.

Figure 13. Completed project.

5. Conclusion

The project achieved its aims enlisted in the chapter 1 successfully by the successful implementation and coding of all the components be it arduino microcontroller, ADXL345 accelerometer and PING))) ultrasonic distance sensor. The combination of all these components generated a new function which simulates the operation of the guitar and generate a musical notes via a virtual guitar.

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Appendix

A. Pin configuration ADXL

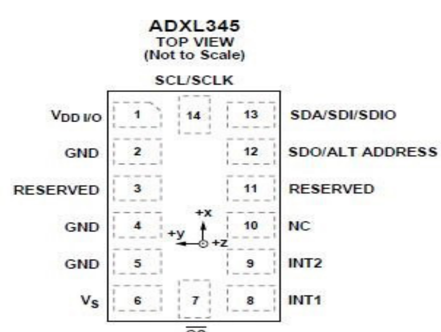

Figure 14. ADXL pins.

Table . ADXL345 Pins Configurations

Pin No.	Mnemonic	Description
1	$V_{DD\,I/O}$	Digital Interface Supply Voltage.
2	GND	This pin must be connected to ground.
3	RESERVED	Reserved. This pin must be connected to V_S or left open.
4	GND	This pin must be connected to ground.
5	GND	This pin must be connected to ground.
6	V_S	Supply Voltage.
7	$\overline{CS}$	Chip Select.
8	INT1	Interrupt 1 Output.
9	INT2	Interrupt 2 Output.
10	NC	Not Internally Connected.
11	RESERVED	Reserved. This pin must be connected to ground or left open.
12	SDO/ALT ADDRESS	Serial Data Output (SPI 4-Wire)/Alternate I^{2}C Address Select (I^{2}C).
13	SDA/SDI/SDIO	Serial Data (I^{2}C)/Serial Data Input (SPI 4-Wire)/Serial Data Input and Output (SPI 3-Wire).
14	SCL/SCLK	Serial Communications Clock. SCL is the clock for I^{2}C, and SCLK is the clock for SPI.

B. Ultrasonic sensor

The Parallax PING))) ultrasonic distance sensor provides precise, non-contact distance measurements from about 2 cm (0.8 inches) to 3 meters (3.3 yards). It is very easy to connect to microcontrollers such as the BASIC Stamp®, SX or Propeller chip, requiring only one I/O pin. The PING))) sensor works by transmitting an ultrasonic (well above human hearing range) burst and providing an output pulse that corresponds to the time required for the burst echo to return to the sensor. By measuring the echo pulse width, the distance to target can easily be calculated.

The PING))) sensor detects objects by emitting a short ultrasonic burst and then "listening" for the echo. Under control of a host microcontroller (trigger pulse), the sensor emits a short 40 kHz (ultrasonic) burst.This burst travels through the air, hits an object and then bounces back to the sensor.

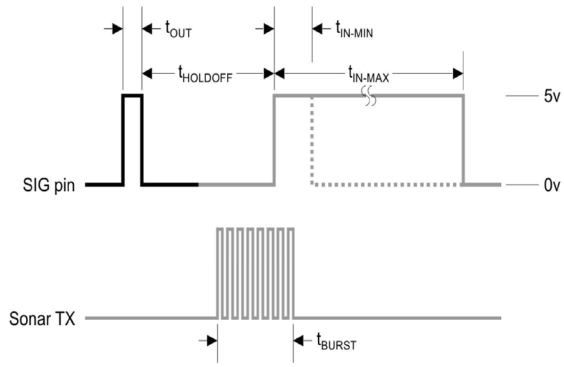

Figure 15. PING))) operation timing.